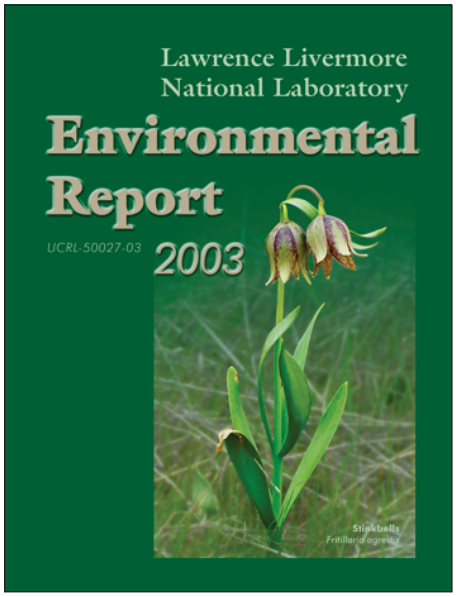
Lawrence Livermore National Laboratory

Environmental Report 2003

UCRL-50027-03

Stinkbells
Fritillaria agrestis



Cover

Although stinkbells (*Fritillaria agrestis*) has beautiful nodding bell-shaped flowers, it is distinguished from similar species by its unpleasant odor, which has been described as "very obnoxious" (Jepson 1957). This species is found only in California, where it occurs in scattered locations throughout the Sierra Nevada foothills, Great Valley, and Coast Ranges. In these areas, it is reported to occur in a variety of different habitats including chaparral, woodlands, coniferous forests, and in clay depressions and other heavy soils within grasslands (Tibor 2001; Ness 1993). Five small populations of stinkbells are found in remote areas of Site 300 in native grasslands. These stinkbells flower early in the spring (mid-March) and quickly wither, leaving only dried seedpods to indicate that their bulbs are waiting beneath the soil for the next spring. Stinkbells is included on the California Native Plant Society's List 4 (Tibor 2001), which includes species that, although not currently considered threatened or endangered, are rare enough to warrant monitoring at this time.

Cover photo: Michael van Hattem, LLNL Wildlife Biologist.

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Distribution:

Subject: 2003 Annual Site Environmental Report (ASER) for the Lawrence Livermore National Laboratory (LLNL)

This report, prepared by LLNL for the Department of Energy, National Nuclear Security Administration (NNSA) Livermore Site Office, provides a comprehensive summary of the environmental program activities at LLNL for calendar year 2003. The ASER is prepared annually for all Department of Energy sites with significant environmental activities, and is distributed to relevant regulatory agencies and other interested organizations or individuals.

The information in this report has been reviewed by NNSA and LLNL personnel for accuracy. The review was based on quality assurance protocols applied to monitoring and data analyses at LLNL. There is continuing progress in the reduction of contaminants on-site and off-site as the cleanup process continues. LLNL's environmental protection and compliance programs have been established and implemented to reinforce our commitment toward the protection of public health and the environment.

A reader survey form is provided with the ASER to provide comments or suggestions for future versions of the report. Your response is appreciated.

Sincerely,

Kevin King
FOR
Daniel Nakahara, Assistant Manager
for Environmental Stewardship Division

Preface

The *Environmental Report 2003* is prepared for the U.S. Department of Energy (DOE) by the Environmental Protection Department at Lawrence Livermore National Laboratory (LLNL). The submittal of the *Environmental Report 2003* satisfies requirements under DOE Order 231.1A, *Environmental Safety and Health Reporting* and DOE Order 5400.5, *Radiation Protection of the Public and Environment*. The purpose of the *Environmental Report 2003* is to present summary environmental data, confirm compliance with environmental standards and requirements, and highlight facility programs and efforts.

The primary methods of distribution of the *Environmental Report 2003* are electronic. The document will by physically distributed by compact disc (CD), and accessible on the Internet at the LLNL Site Annual Environmental Report homepage: http://cmg.llnl.gov/saer/. Both the report and data tables can be viewed in its most up-to-date form. Environmental reports covering calendar years 1994 through 2002, and corrections to them, can be accessed at this same Internet address.

This report contains an Executive Summary and a summary of LLNL's compliance with environmental regulations and environmental programs. The majority of this report then features LLNL's environmental monitoring programs – air; waters including wastewater, surface water, and groundwater; soil and sediment; vegetation and foodstuff; ambient radiation; and wildlife and rare plants – with some discussion on quality assurance activities associated with these monitoring programs. To describe the impact of LLNL operations on the public and environment, the monitoring chapters are followed by a chapter on radiological dose assessment. This report also provides an overview of LLNL's groundwater remediation program. Information on both the Livermore site and Site 300 is presented in each chapter. All environmental monitoring data summarized in this report are provided in files on the report CD.

The *Environmental Report 2003* continues the practice of using *Système International* units. This is consistent with federal law stated in the Metric Conversion Action of 1975 and Presidential Order 12770, Metric Usage in Federal Government Programs (July 25, 1991). For ease of comparison to environmental reports issued prior to 1991, dose values and many radiological measurements are presented in both metric and U.S. customary units. A conversion table is also provided in the Glossary under the heading of "metric units."

This document is the responsibility of LLNL's Operation and Regulatory Affairs Division of the Environmental Protection Department. Monitoring data were obtained through the combined efforts of the Operation and Regulatory Affairs Division, Environmental Restoration Division, Chemistry and Materials Science Environmental Services' Environmental Monitoring Radiation Laboratory, and the Hazards Control Department. Special recognition is deserved for the dedication and professionalism of the technicians who carried out environmental and effluent monitoring – Gary A. Bear, Karl Brunckhorst, David J. Castro, Steven Hall, Renee Needens, Terrance W. Poole,

Donald G. Ramsey, Sterling Sawyer, and Robert Williams –of the data management personnel – Hildy Kiefer, Kimberley A. Swanson, Beth Schad, Suzanne Chamberlain, Della Burruss, and Susan Lambaren – and of the secretarial staff who prepared and distributed the drafts – Celina Chance and Monique de Vasconcelos. Special thanks go to William Hoppes, Art Biermann, and Charlene Grandfield for their strong support of the project and reviews of the drafts.

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EX

Executive Summary

Lawrence Livermore National Laboratory (LLNL) is a U.S. Department of Energy (DOE) national laboratory operated by the University of California. LLNL has two sites—the Livermore site located in Livermore, California, and the Experimental Test Site (Site 300) located approximately 20 km (12 mi) east of Livermore, near Tracy, California.

When it was founded in September 1952, LLNL's purpose was to support the Nation's nuclear weapons program by providing innovative design and engineering. Since that time, LLNL has grown to become one of the world's premier scientific centers, with additional substantial research efforts directed toward laser fusion energy, computation, non-nuclear energy, biomedicine, and environmental science.

Although LLNL's mission has been fundamentally one of scientific research, as an institution it has been ever mindful of its responsibilities for protecting the environment and the health and safety of its employees. As stated in the *Environment, Safety and Health Manual*, "It is the Laboratory's environment, safety, and health (ES&H) policy to perform work in a manner that protects the health and safety of employees and the public, preserves the quality of the environment, and prevents property damage. The environment, safety, and health are to be priority considerations in the planning and execution of all work activities at the Laboratory. Furthermore, it is the policy of LLNL to comply with applicable ES&H laws, regulations, and requirements."

To meet these requirements, LLNL currently monitors the ambient air, water, soil, vegetation and foodstuff, and air and liquid effluents for numerous radiological and nonradiological materials. LLNL complies with all federal, state, and local environmental permitting requirements, including the requirements imposed by listing as a Superfund site on the National Priorities List.

This summary is a brief overview of environmental compliance and monitoring activities undertaken by LLNL in calendar year 2003.

Radiological Monitoring

The emissions most often associated with LLNL, especially the Livermore site, are the emissions of tritium (which is the radioactive isotope of hydrogen) to the atmosphere. Tritium emissions occur in two chemical forms: tritium gas (HT) and tritiated water (HTO). The HT and HTO emissions from the Tritium Facility are monitored continuously. In addition, samples of ambient air, vegetation, sewer effluent, storm water, rainwater, groundwater, sediment, and wine are collected and analyzed for HTO. **Figure EX-1** shows the HTO emissions from LLNL Livermore site operations, including the emissions from Sandia/California, a neighboring Department of Energy laboratory that used tritium in its operations from 1979 to 1995. The figure also shows the measured quantities of HTO in ambient air at two locations (VIS and ZON7 air) and

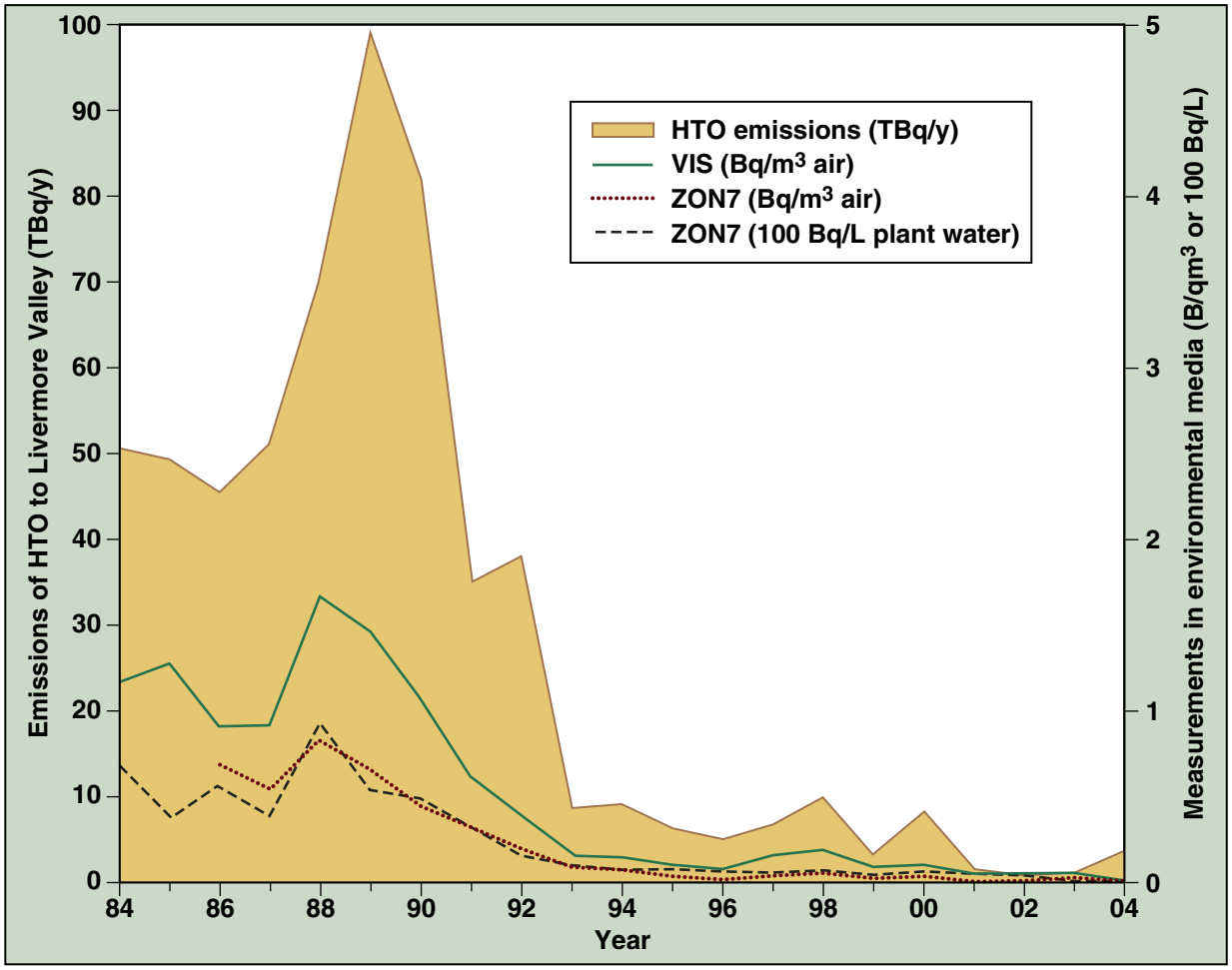


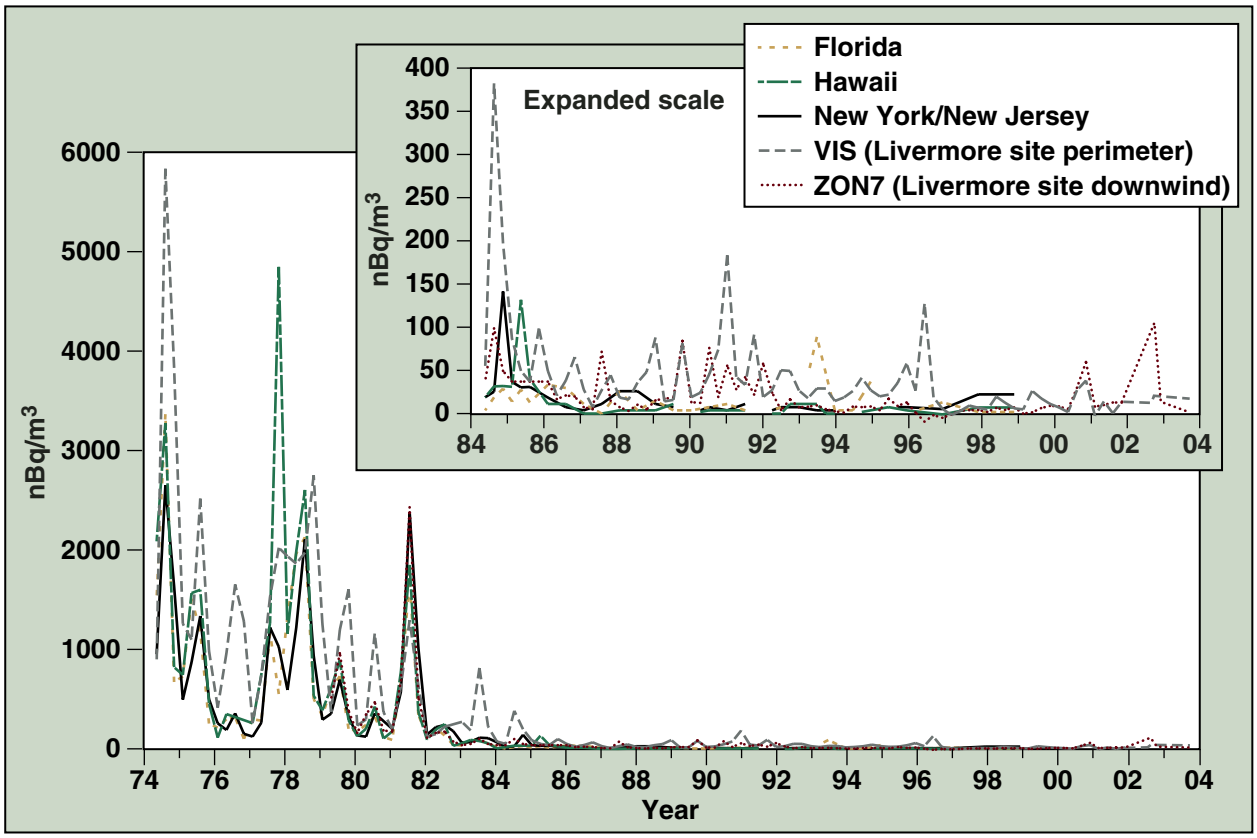
Figure EX-1. Annual median tritium (HTO) concentrations for samples of ambient air and vegetation decline with the declining emissions of HTO

in vegetation from a collocated sampling location (ZON7 plant water). The figure illustrates that ambient environmental measurements decline with the decline in emissions, that the ambient measurement also declines with distance (ZON7 location is farther downwind from the Livermore site than VIS), and that measurements by environmental media are correlated. Although not shown in the figure, measurements of tritium in wine, rainwater, surface water, and sewer effluent show the same trends.

The DOE primary radiation protection standard for protection of the public is 1 mSv/y (100 mrem/y). To enable the determination of whether concentrations of radionuclides in the air or water may cause an exposure greater than the standard, DOE developed Derived Concentration Guides. The Derived Concentration Guides specify the concentrations of radionuclides that an individual could consume, inhale, or be immersed in continuously 365 days a year without receiving a dose greater than 1 mSv/y

(100 mrem/y). The Derived Concentration Guide for HTO in air is 3700 Bq/m^3 (100,000 pCi/m^3). All measurements of HTO in air in 2003 were less than 21 Bq/m^3 (567 pCi/m^3), that is, less than 1% of the Derived Concentration Guide. Although there are no standards for levels of tritium in vegetation or wine, the wine measurements can be compared to the drinking water standard of 740 Bq/L (20,000 pCi/L). The highest measured value for a Livermore Valley wine for the samples collected in calendar year 2003 is 1.7 Bq/L (46 pCi/L), less than 0.2% of the drinking water standard. Tritium concentrations in all wines collected in 2003 are on average approximately 0.1% of the drinking water standard.

Another radioisotope often associated with LLNL operations is plutonium. Current measurements of plutonium at the perimeter of the Livermore site arise from the resuspension of soil contaminated by the operation of solar evaporators of plutonium-containing liquid waste in the early 1970s. **Figure EX-2** shows the measurement of

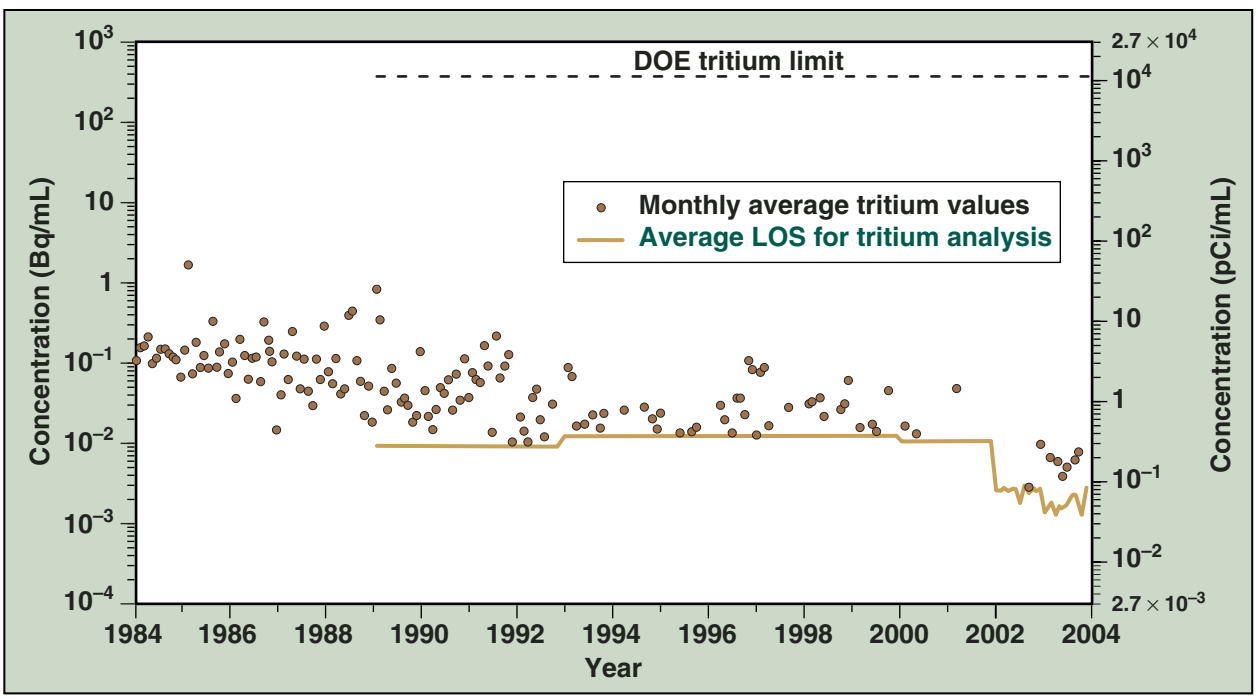


Sources: 1974 to 1985, U.S. Department of Energy Environmental Measurements Laboratory; 1985 to 1999, U.S. Environmental Protection Agency, National Air and Radiation Environmental Laboratory. The samples for Florida were collected in Miami; the samples for Hawaii, in Mauna Loa for 1974 to 1985 and in Honolulu for 1986 to 1999; the samples for New York/New Jersey, in New York City from 1974 to 1990, and in Trenton, New Jersey for 1991 to 1999.

Figure EX-2. Concentrations of plutonium-239+240 in air (nBq/m^3) at three locations throughout the United States, and a perimeter and downwind Livermore site location

plutonium in ambient air from a Livermore site perimeter location (VIS) and a downwind location (ZON7) as well as three other locations from around the United States. The measurements in other parts of the United States result from global fallout from nuclear weapons tests by various nations over the last 50 years. For example, the People's Republic of China conducted eight atmospheric weapons tests of various explosive yields from June 1974 to October 1980. The debris from the tests, including fission products, made a number of passes around the globe before declining to undetectable quantities. The LLNL values at the downwind location (ZON7) are consistent with other measurements of global fallout throughout the United States. The measurements at sampling location VIS show the contributions of resuspension of plutonium-contaminated soil. The Derived Concentration Guide for plutonium in air is 7.4×10^{-4} Bq/m^3 (0.02 pCi/m^3); the highest measured value in 2003 for LLNL sampling locations for plutonium is 6.6×10^{-8} Bq/m^3 (1.8×10^{-6} pCi/m^3), only 0.009% of the Derived Concentration Guide.

Substantial efforts are also undertaken by LLNL to characterize the contribution of operations to the sewer effluent leaving the Livermore site. During 2003, no permitted discharge limit for radioactive materials was exceeded in the sewer effluent. The sewer effluent is monitored continuously for gamma radioactivity, flow rate, pH, and metals. Effluent samples are analyzed daily for gross alpha, gross beta, and tritium radioactivity. Monthly composites of daily sewer samples are analyzed for tritium, plutonium, and cesium radioactivity. **Figure EX-3** shows the monthly average tritium activity in the



Note: Only values above the limit of sensitivity (LOS) of the analytical method used are plotted.

Figure EX-3. Historical tritium concentrations in the Livermore site sanitary sewer effluent

Livermore site sewer effluent since 1984. As can be seen in this figure, the amount of tritium released has declined significantly. During 2003, the monthly tritium activity averages were mostly below the limit of sensitivity of the analytical method used. The maximum monthly tritium release was 0.008 Bq/mL (0.22 pCi/mL), or 0.002% of the Derived Concentration Guide of 370 Bq/mL (10,000 pCi/mL). Similarly, the annual discharges of cesium-137 and plutonium-239 were small percentages, 0.00037% and 0.00004%, respectively, of their Derived Concentrations Guides.

The measurements of radionuclides in soil and the direct measurements of gamma radiation using thermoluminescent dosimeters (TLDs) provide further confirmation of the low level of effects of LLNL's radiological operations on the environment. Most radionuclides in soil were detected at background concentrations. The highest measured value for plutonium-239+240 in soil occurred in a sample from an area of known contamination at the Livermore Water Reclamation Plant. The contamination is the result of an estimated 1.2×10^9 Bq (32 mCi) release of plutonium to the sanitary sewer in 1967 and earlier releases. The maximum measured value for 2003, 14 mBq/dry g (0.38 pCi/dry g), is 3% of the National Council on Radiation Protection (NCRP) recommended screening level of 0.470 Bq/dry g (12.7 pCi) for property used for commercial purposes. The highest measured value for uranium-238 was 110 µg/dry g and was from a sample collected at Site 300, in an area where depleted uranium was used in explosives experiments; the measured value is well below the NCRP screening level of 313 µg/dry g for commercial sites.

TLDs absorb gamma radiation from all sources, including terrestrial sources such as naturally occurring radioactive isotopes of uranium, thorium, radium, and radon present in the soil, cosmic radiation originating from beyond the solar system, as well as any man-made gamma radiation arising from LLNL operations. The TLD measurements for 2003 yielded an annual dose of 0.56 mSv (56 mrem), a value consistent with local measured averages.

Nonradiological Monitoring

Most nonradiological monitoring is performed on samples of groundwater, sanitary sewer water, surface water, and storm water runoff. Although water samples are analyzed for various radioisotopes, their chemical contents are also of concern to regulators, especially where the water is or contributes to a drinking water source or supports aquatic life. Water monitoring at both LLNL sites is conducted to meet general DOE environmental protection requirements, to meet state and federal permit requirements, and to meet Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements. Water monitoring locations include the Livermore site sanitary sewer monitoring station as well as wells, springs, ponds, streams, and drinking water reservoirs. With the exception of a lead and minor pH fluctuations in sanitary sewer effluent, all nonradiological constituents of samples collected in 2003 were within

regulatory or permit limits. Even with the sanitary sewer discharges, no corrective action was required by the regulatory agency and none of the discharges represented a threat to the environment.

Superfund Activities

Two substantial LLNL environmental activities are the investigations and cleanup of groundwater that are being conducted at the Livermore site and at Site 300. The groundwater contaminants at the Livermore site are primarily the volatile organic compounds, trichloroethylene (TCE) and perchloroethylene (PCE). The original source of these contaminants dates from the time that the Livermore site was a Naval Air Station during World War II, when aircraft repair and servicing took place on the site. TCE and PCE were solvents used in cleaning airplane parts.

For the most part, the groundwater contaminants remain within the Livermore site boundary; however, they do extend beyond the boundary to the west and south of the site. Maps showing the extent of PCE contamination in 1988 before cleanup of the PCE plume began, and the current extent of PCE contamination are shown in **Figure EX-4**. These maps show the progress that has been made in the PCE cleanup. Since remediation began in 1989, approximately 8.5 billion liters (2.2 billion gallons) of groundwater and over 1.4 million cubic meters (49 million cubic feet) of vapor have been treated, removing more than 1550 kilograms (3420 pounds) of volatile organic compounds from all remediation sites.

Volatile organic compounds are also the main groundwater contaminants at Site 300. The sites are similar in that the contamination is, for the most part, confined to the site. The sites differ in that Site 300, with an area of 30.3 km^2 (11.8 mi^2), is much larger than the Livermore site, and has been divided into eight operable units based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.28 km^2 (1.3 mi^2) is effectively one operable unit. Site 300 has additional contaminants, including organosilicate oil, nitrate, high explosives, perchlorate, and depleted uranium. Many of these contaminants are present in the groundwater at Site 300 because of the historic practice of burying debris from high-explosives tests.

LLNL has made substantial progress in cleanup at Site 300. For example, before treatment commenced at the General Services Area (GSA) in 1991, the contaminant plume as shown by monitoring of groundwater wells at the eastern GSA operable unit, extended more than a mile down the Corral Hollow Creek channel. Now, TCE concentrations have been decreased to below drinking water standards in groundwater from all off-site wells. The reduction in this plume is illustrated in **Figure EX-5**. Overall, since remediation efforts began at Site 300 in 1990, more than 977 million liters (258 million gallons) of groundwater and approximately 4.3 million cubic meters (152 million cubic feet) of vapor have been treated, yielding about 234 kilograms (516 pounds) of removed volatile organic compounds.

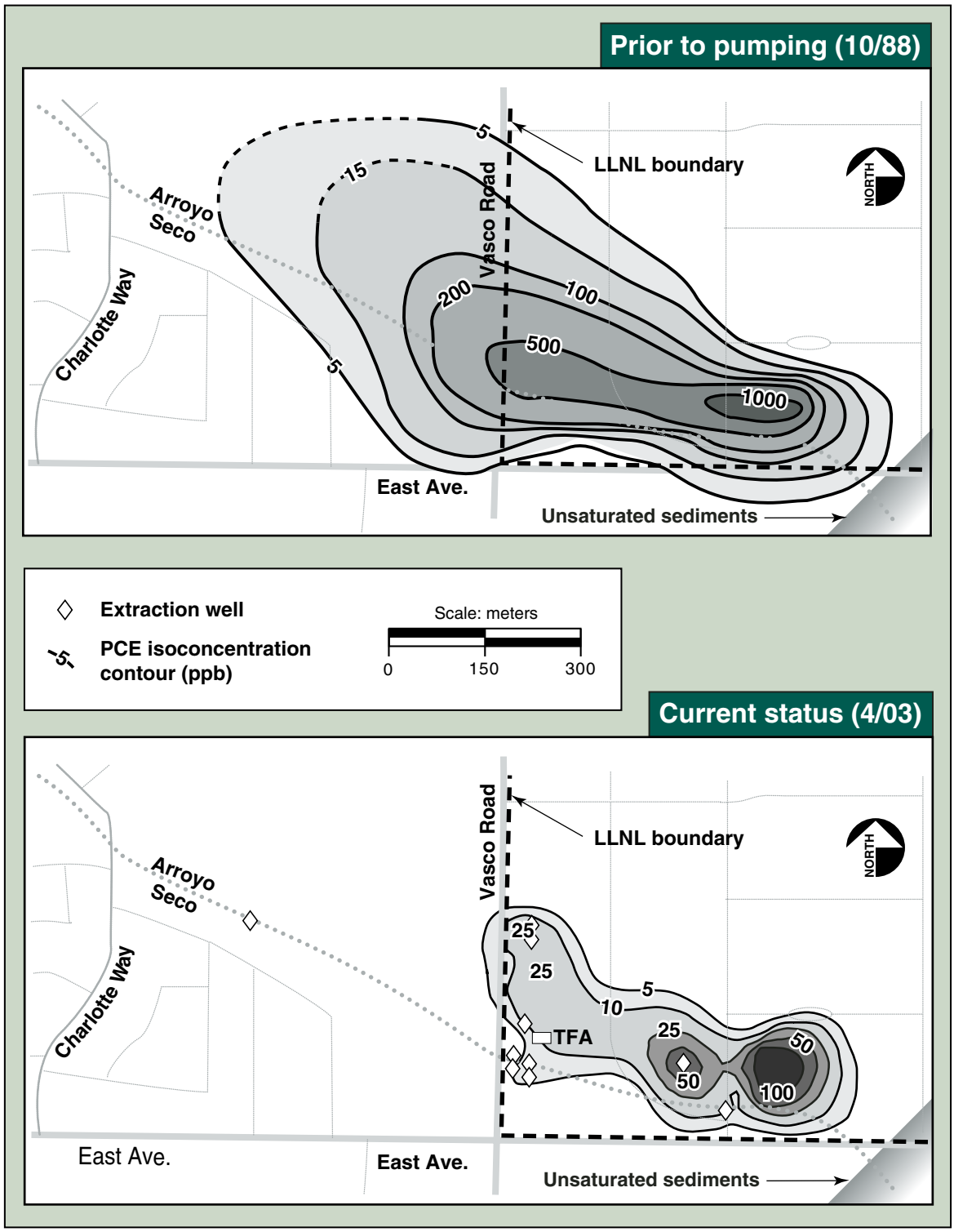


Figure EX-4. Successful reduction of the PCE plume at the western and southern boundaries of the Livermore site

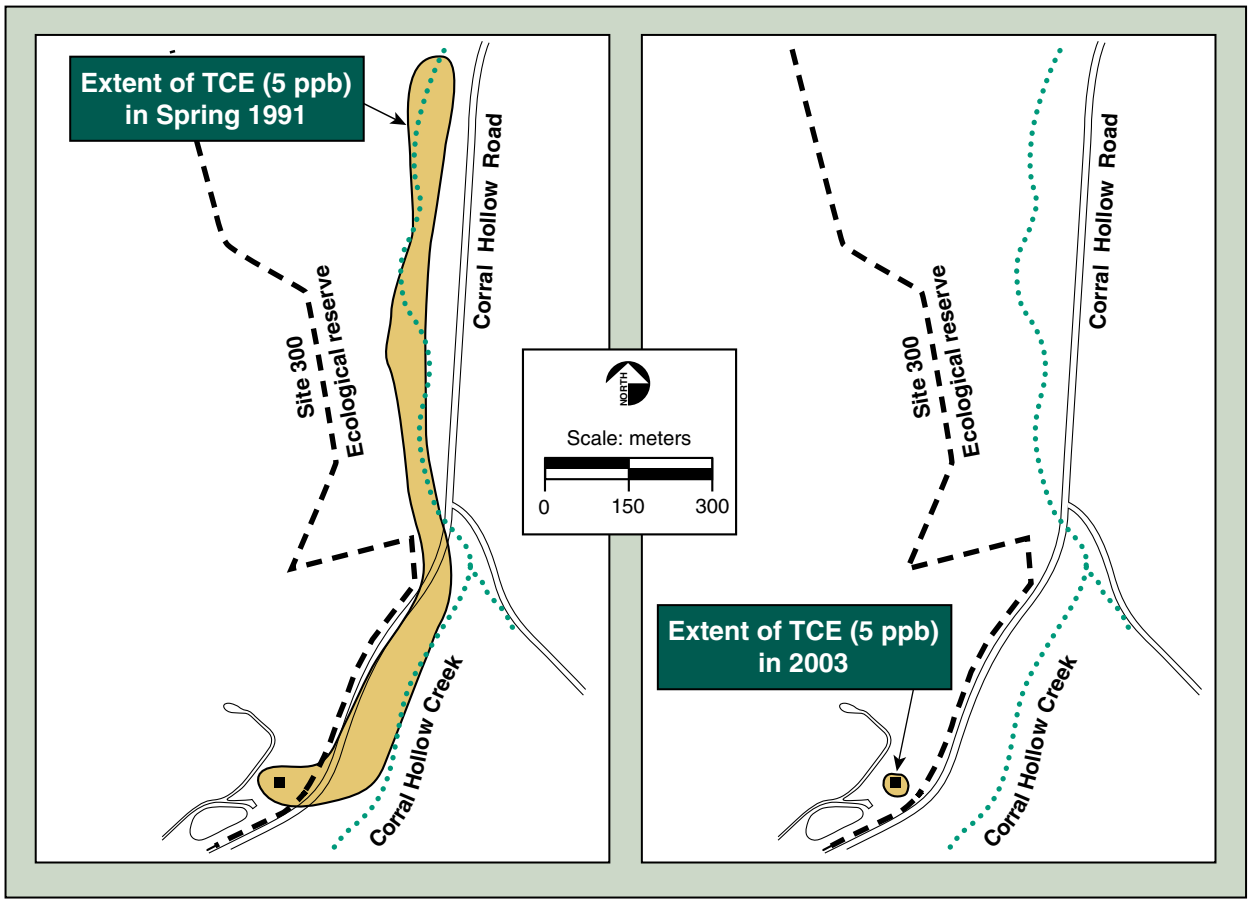


Figure EX-5. Successful reduction of the TCE plume at the southeastern boundary of LLNL's Site 300

Regulatory Permitting and Compliance

LLNL undertakes substantial activities to comply with the many federal, state and local environmental laws. The major permitting and regulatory activities that LLNL conducts are required by the Clean Air Act; the Clean Water Act and related state programs; the Resource Conservation and Recovery Act and state and local hazardous waste regulations; the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA); the Endangered Species Act; the National Historic Preservation Act; the Antiquities Act; and the CERCLA (which is more commonly known as the Superfund Act).

LLNL has numerous environmental permits from a variety of regulatory agencies in all levels of government. Some of these permits cover individual pieces of equipment (for example, air permits for boilers, emergency generators, degreasers, printing presses, or tank permits for product or waste storage). During the years 1990 to 2003, LLNL obtained 150 to 250 air permits each year, depending on operations, while the number of permitted underground tanks steadily declined from 80 to 15 as the tanks were closed or replaced with aboveground tanks. Other permits cover classes of emissions, such as the Regional Water Quality Control Board controls on discharges of industrial or construction-site storm water and treated groundwater to surface water. Similarly, the sewer permits cover all discharges from the Livermore site to the municipal sewage system, setting discharge limits for acidity or alkalinity, metals, organic compounds, and radioactivity. Hazardous waste permits, likewise, cover all operations in which the various physical forms of hazardous, radioactive, mixed, and medical waste are handled or stored.

LLNL had numerous inspections from several local, state, and federal agencies in 2003. All inspections showed LLNL to be in compliance with regulatory requirements except for the following instances. An air inspection at the Livermore site in February 2003 identified a record keeping violation from September 2002 to February 2003, for which LLNL paid a $2650 civil penalty. Hazardous waste facility inspections at the Livermore site in March 2003 identified four potential violations regarding training records; storage time limits of two mixed waste containers; operating record discrepancies; and inadequate aisle spacing between waste containers. For these violations, LLNL provided the regulatory agency with updated training dates; applied to extend the storage time limits on the mixed waste containers; corrected the discrepancies in the operating records; and re-arranged the waste containers to provide adequate aisle spacing, respectively. Another inspection at the Livermore site on waste generator areas in June 2003 identified an unlabeled container in poor condition outside a waste accumulation area; the container, containing sea water which is not a hazardous material, was appropriately disposed. An inspection in October 2003 of hazardous waste facilities at Site 300 identified a training violation; however, LLNL is contesting the violation since LLNL had discussed the training plan with the regulating agency prior to the permit being issued and the agency did not include the training requirement in LLNL's permit. U.S. EPA conducted a multimedia inspection at the Livermore site in November 2003 covering air, water, hazardous waste, tank, and other environmental regulations and permits. A violation regarding incorrect dates on two hazardous waste containers was corrected during the inspection. Two violations regarding LLNL's oil spill prevention program require LLNL to update the Livermore site Spill Prevention Control and Countermeasure Plan and enhances LLNL's current maintenance inspections of aboveground oil containers; these corrections are in process. None of the violations in 2003 resulted in a release or posed a threat to the public or the environment.

Permitting is not the only type of compliance activity. Another significant compliance activity is reporting, and generating data to support the reports. Some reporting can occur as frequently as monthly (such as the sanitary sewer reports), or annually (such as the waste minimization reports); however, reporting may be virtually any period determined by the regulatory agency. Reports cover subjects as varied as hazardous materials

business plans; NEPA and CEQA evaluations of new projects, experiments and construction; waste management reports; storm water pollution prevention plans and reports; antiquities and cultural evaluations; and endangered species surveys.

One report of public interest provides an estimate of the radiological dose to a hypothetical maximally exposed individual member of the public arising from releases of radioactive material to air. This annual report is submitted to the U.S. Environmental Protection Agency (EPA) to demonstrate compliance with the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the federal Clean Air Act. NESHAPs limits the annual dose to members of the public caused by DOE facility operations to 100 µSv (10 mrem). The regulations specify the methods by which airborne emissions and their impacts must be evaluated. The total dose is calculated using the inventories of radionuclides from unmonitored sources as required by the U.S. EPA, as well as stack monitoring and ambient air monitoring, where available. The total dose to the maximally exposed public individual for 2003 was 0.44 µSv (0.044 mrem) for the Livermore site and 0.17 µSv (0.017 mrem) for Site 300. These doses are well below the 100 µSv (10 mrem) standard. LLNL also calculates potential doses to aquatic and terrestrial biota from LLNL operations. These potential doses are found to be well below DOE allowable dose limits. All these dose assessments confirm that the impacts of LLNL operations on the public and the environment are very small.

A final important method by which LLNL complies with environmental regulations is to conduct surveys of and undertake measures to protect endangered and threatened species, as required by the U.S. Endangered Species Act and the California Endangered Species Act. Both the Livermore site and Site 300 have populations of rare or endangered species. Livermore site populations of the California red-legged frog (*Rana aurora draytonii*) were monitored as part of the Arroyo Las Positas maintenance project. Biological assessment surveys were also performed for special-status species at Site 300.

Conclusion

The current techniques LLNL uses for environmental monitoring are very sensitive, allowing detection of extremely low levels of constituents. The combination of surveillance and effluent monitoring, source characterization, and dose assessment shows that the radiological dose to the public caused by LLNL operations is less than 1% of regulatory standards and is about 0.02% of the dose received from natural background radiation. The analytical results and evaluations generally show continuing low contaminant levels, reflecting the commitment of LLNL to control pollutants.

In addition, LLNL's extensive environmental compliance activities related to water, air, endangered species, waste, wastewater, and waste reduction provided further controls on LLNL's effects on the environment.

In summary, the results of the 2003 environmental programs demonstrate that 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. Environmental monitoring of LLNL operations does not indicate an adverse impact to public health or the environment.

1 Introduction

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory. LLNL's primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable, and to prevent the spread and use of nuclear weapons worldwide. This mission enables LLNL programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply LLNL's unique capabilities and to enhance the competencies needed for our national security mission. LLNL serves as a resource to the U.S. government and a partner with industry and academia.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, health and safety, and medical departments—necessary to support its operations and about 9000 personnel.

Meteorology and geography play primary roles in how the environment is affected by human actions. Dispersal of particles in air, for example, is influenced by the wind and rain, which in turn are influenced by geographical characteristics. Similarly, the movement of groundwater is constrained by the particular geology of a site. Thus, knowledge of wind, rainfall, geology, and geographical characteristics is used to understand the effects that operations at LLNL might have on the surrounding environment. Some history and a description of these characteristics help us understand the importance of LLNL's meteorological and geographic setting. An understanding of these characteristics allows LLNL to better monitor LLNL operations effectively and efficiently.

Location

LLNL consists of two sites—the Livermore site located in Livermore, California in Alameda County, and the Experimental Test Site (Site 300) located near Tracy, California, in San Joaquin and Alameda counties (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

LLNL was founded at the Livermore site in 1952 at a former U.S. Navy training base. At that time the location was relatively isolated, being approximately 1.6 km (1 mi) from the Livermore city limits. Over time, Livermore evolved from a small town of fewer than 7000 people when LLNL began to its present population, which is about 78,600 (California Department of Finance 2004). The economy, which had been primarily agricultural, diversified to include light industry and business parks. Within the last few years, single-family residential developments have begun to fill the formerly vacant fields immediately to the west of the Livermore site.

The Livermore site occupies an area of 3.28 km^2 (1.3 mi^2), 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 Lockheed-Martin under U.S. Department of Energy (DOE) contract. Sandia/California engages in research and

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

development associated with nuclear weapons systems engineering as well as related national security tasks. Although components of their missions are similar, LLNL and Sandia/California are separate entities, each with its own management.

To the south of the Livermore site, 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 and ranchettes with some

agricultural use. Single-family dwellings and apartments lie immediately to the west. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills that define the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare (500-acre) parcel of open space to the northeast has been rezoned to allow development of light industry.

Major population centers near Livermore include the nearby communities of Pleasanton and Tracy, and the more distant metropolitan areas of Oakland, San Jose, and San Francisco, as well as Stockton in the San Joaquin Valley. There are over 7.2 million residents within an 80-km (50-mi) radius of the Livermore site (NNSA 2004).

Site 300, LLNL's Experimental Test Site, is located 20 km (12 mi) east of the Livermore site in San Joaquin and Alameda counties in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 km^2 (11.8 mi^2). SRI International operates a testing site located approximately 1 km (0.62 mi) south of Site 300. Property immediately to the east of Site 300 is owned by Fireworks America, which uses it for packaging and storing fireworks displays. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills to the northwest. 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 74,100 (California Department of Finance 2004), located 10 km (6 mi) to the northeast. Within 80 km (50 mi) of Site 300, there are over 6.4 million residents (NNSA 2004), many of whom are located in the metropolitan areas of Oakland, San Jose, and Stockton.

METEOROLOGY

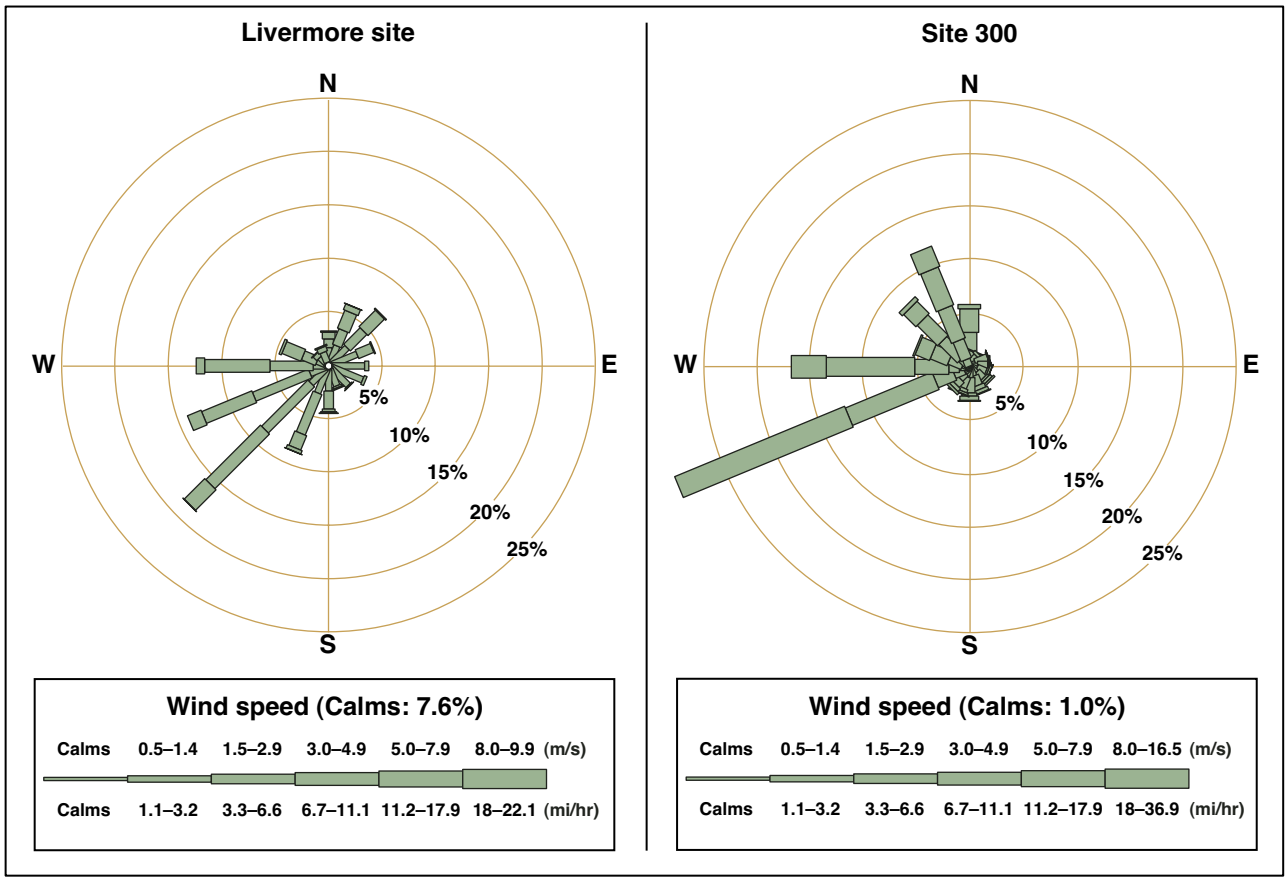
Meteorological data (including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate. A detailed review of the climatology for LLNL can be found in *Climatology of Lawrence Livermore National Laboratory* (Gouveia and Chapman 1989). The mean daily maximum, minimum, and average temperatures for the Livermore site in 2003 were 21.2°C (70.2°F), 9.2°C (48.6°F), and 15.2°C (59.4°F), respectively. The mean daily maximum, minimum, and average temperatures for Site 300 in 2003 were 20.2°C (68.3°F), 13.3°C (55.9°F), and 16.7°C (62.1°F), respectively. The nighttime temperatures are typically higher (and diurnal temperature range smaller) at Site 300 compared to the Livermore site; stronger winds at a higher elevation prevent formation of strong radiational inversions near the ground. Temperatures range from –4°C (25°F) during the coldest winter mornings to 40°C (104°F) during the warmest summer afternoons. While the annual temperature was near-normal during 2003, several individual months experienced large departures from normal. July was the warmest since at least 1990 with the high temperature averaging 32.5°C (90.5°F), or 3.3°C (6.0°F) above normal. Likewise, October was much warmer than normal, with the high temperature reaching 32.5°C

(90°F) on five days, including 33°C (91°F) on October 21. The arrival of Arctic air caused the following month to be the coldest November since 1994. The coldest weather during 2003 occurred during early February when the temperature dipped to –1.5 to –2.5°C (28 to 30°F) on three mornings at LLNL. Temperatures dipped to below freezing a total of five days during the year. The lowest temperature at Site 300 was 1°C (34°F) and occurred on the mornings of January 19 and 20. The warmest day of the year was July 17 when the temperature reached 39°C (102°F) at the Livermore site. The highest temperature at Site 300 was 36.5°C (98°F), occurring on July 28.

Both rainfall and wind exhibit strong seasonal patterns. These wind patterns tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. Most precipitation occurs between October and April, with very little rainfall during the warmer months.

Annual wind data for the Livermore site are included in **Figure 1-2**. These data show that about 54% of the wind comes from the south-southwest through west directions. This prevailing pattern occurs primarily during the summer. During the winter, winds from the northeast are more common. The peak wind gust at the Livermore site of 19 m/s (43 mph) from the south occurred early on April 12 in advance of a storm. Based on a 46-year record, the highest and lowest annual rainfalls were 85.2 and 16.7 cm (33.57 and 6.57 in.), and the normal annual rainfall is 34.6 cm (13.62 in.). In 2003, the Livermore site received 23.9 cm (9.42 in.) of rain, or only 69% of normal. About 45% of the rainfall occurred in November and December. The May total rainfall of 5.6 cm (2.20 in.) was nearly three times the normal and the most for that month since 1983. Thunderstorms in August caused light rain and intense lightning over the area, resulting in forest fires in the hills south of the Livermore site. The 17 days with measurable rain (≥ 0.01 in.) during December was the most since at least 1989. The maximum daily rainfall of 2.1 cm (0.82 in.) fell on November 8.

The meteorological conditions at Site 300, while generally similar to those at the Livermore site, are modified by higher elevation and more pronounced topological relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-2**. The data show that winds are stronger and show less directional distribution than at the Livermore site. Winds from the west-southwest through west occurred 46% of the time during 2003. The peak wind speed at Site 300 of 27 m/s (61 mph) from the west-southwest occurred after a storm had passed. As is the case for the Livermore site, precipitation at Site 300 is seasonal, with most rainfall occurring between October and April. Since Site 300 is situated downwind (north) of more significant terrain (winds are typically southerly during storms) than at the Livermore site, rainfall amounts are typically 20 to 25% lower. Similar to the Livermore site, Site 300 received much (50%) of its rainfall during November and December. The maximum daily rainfall of 1.3 cm (0.50 in.) occurred on December 14. Rainfall for 2003 was only 64% of normal, or 17.0 cm (6.71 in.) at Site 300. The 18 days with measurable rain (≥ 0.01 in.) during December was the most since at least 1989.



Note: The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes. The average wind speed in 2003 at the Livermore site was 2.4 m/s (5.3 mph); at Site 300 it was 5.5 m/s (12.4 mph).

Figure 1-2. Wind rose showing wind direction and speed frequency at the Livermore site and Site 300 during 2003.

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 m (325 ft). The valley is approximately 25-km (16-mi) long and averages 11-km (6.8-mi) in width. The valley floor is at

its highest elevation of 220 m (720 ft) above sea level along the eastern margin and gradually dips to 92 m (300 ft) 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 intermittently. Surface waterways in the vicinity of the Livermore site are the Arroyo Seco (along the southwest corner of the site), the Arroyo Las Positas (along the northern perimeter of the site), and the Arroyo Mocho (southwest of the site). These arroyos are shown in **Figure 4-8**.

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 538 m (1765 ft) above sea level at the northwestern corner of the site to approximately 150 m (490 ft) in the southeast portion.

HYDROGEOLOGY

Livermore Site

The hydrogeology and movement of groundwater in the vicinity of the Livermore site have been the subjects of several investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; Thorpe et al. 1990; Blake et al. 1995). This section is a summary of the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for groundwater management in the Livermore Valley basin (SFBRWQCB 1982a,b).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley groundwater 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 groundwater levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Groundwater flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater 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 water table varies in depth from the surface from about 10 to 40 m (30 to 130 ft). **Figure 1-3** shows a contour map of water table elevations for the Livermore site area. Although water table elevations vary slightly with seasonal and

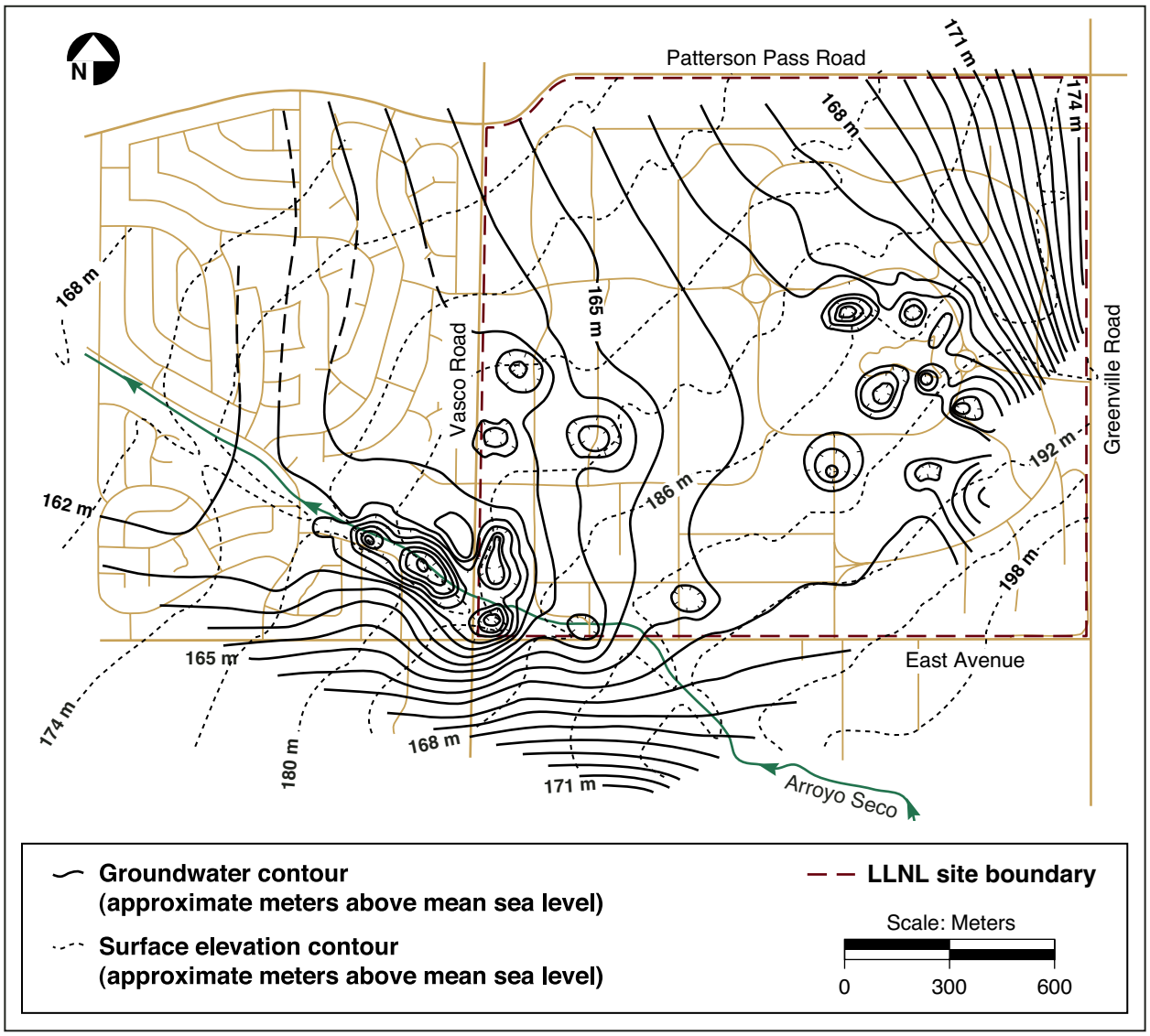


Figure 1-3. Approximate groundwater and surface elevation contours, Livermore site and vicinity

year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-3** are generally maintained. At the eastern edge of the Livermore site, groundwater 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.

Groundwater flow under most of the site is generally westerly. This flow direction diverges from the generally westward regional flow to southwesterly and northwesterly flow patterns. This shift in flow direction is a consequence of groundwater recovery and remediation in the southwest portion of the site since the 1980s and also from

agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity (a measure of the rate of flow) of the permeable sediments ranges from 1 to 16 m/day (3.3 to 52 ft/day) (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an estimated average groundwater velocity of 20 m/y (66 ft/y) (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable alluvial sediments that underlie the area.

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 groundwater occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill. Much less groundwater 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 groundwater and act as aquitards, confining layers, or perching horizons. Groundwater is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Groundwater flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, groundwater 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, groundwater in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly lower blue sandstone, stratigraphically near the base of the formation, generally contains confined water. Wells located in the western part of the General Services Area pump water from this aquifer and are used to supply drinking and process water.

Figure 1-4 shows the elevation contours for groundwater in the regional aquifer at Site 300. This map of the groundwater elevations 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 evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

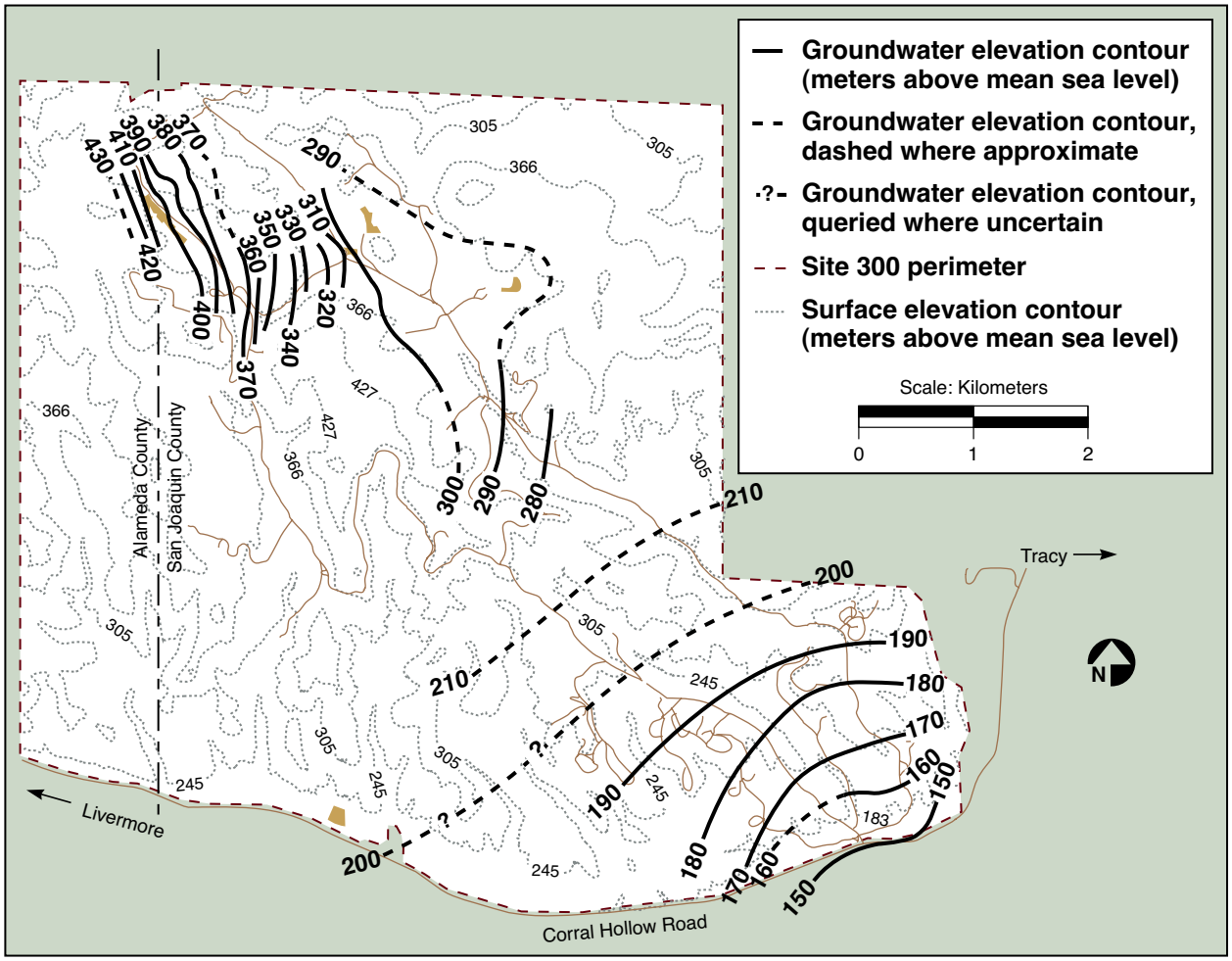


Figure 1-4. Approximate groundwater elevations for the principal continuous water-bearing zone at Site 300

Further information on the hydrology of both the Livermore site and Site 300 can be found in the groundwater monitoring and remediation information in Chapter 7.

SUMMARY

LLNL recognizes the importance of geology, hydrogeology, climate, and geographical relationships with its neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year LLNL gains additional information to better

predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, water, terrestrial, and wildlife—may be affected differently. LLNL takes into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each method used to monitor the environment.

Contributing Authors

We acknowledge the work of Richard Blake, Brent Bowen, Donald MacQueen, Lily Sanchez, and Michael Taffet in preparing this chapter.

2 Environmental Compliance and Program Summaries

Lawrence Livermore National Laboratory is committed to operating in a manner that preserves the quality of the environment. As stated in LLNL's Environmental Policy signed by LLNL's Director in July 2004, LLNL is committed to providing responsible stewardship of the environmental resources in our care. Environmental stewardship is integrated into our strategic planning and decision-making processes and into the management of our work activities through the Integrated Safety Management System.

In support of this policy, LLNL commits to:

- Work to continuously improve the efficient and effective performance of our environmental management system
- Comply with applicable environmental laws and regulations
- Incorporate pollution prevention, waste minimization, and resource conservation into our planning and decision-making processes
- Ensure that interactions with our regulators, DOE, and our community are based upon integrity, openness, and adherence to national security requirements
- Establish appropriate environmental objectives and performance indicators to guide these efforts and measure our progress

This chapter provides a brief summary of LLNL's compliance with environmental regulations and LLNL's environmental management programs.

Compliance Summary

Lawrence Livermore National Laboratory participates in numerous activities to comply with federal, state, and local environmental regulations as well as internal requirements and applicable U.S. Department of Energy (DOE) orders. The following describes regulations and guidance applicable to LLNL during 2003, including a summary of permits active in 2003, and inspections of the Livermore site and Site 300 by external agencies. The following summaries also provide references for more information where available.

Environmental Restoration and Waste Management

Comprehensive Environmental Response, Compensation and Liability Act

Ongoing groundwater investigations and remedial activities at the Livermore site and Site 300 are called the Livermore Site Ground Water Project (GWP) and the Site 300 CERCLA Project, respectively. These activities fall under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Title I of the Superfund Amendments and Reauthorization Act (SARA). As part of work on these projects, DOE and LLNL also continued community relations activities. CERCLA compliance activities are summarized in the following sections; program activities and findings are further described in Chapter 7.

Livermore Site Ground Water Project

The Livermore site became a CERCLA site in 1987 when it was placed on the National Priorities List. The GWP at the Livermore site complies with provisions specified in a Federal Facility Agreement (FFA) entered into by the U.S. 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 (SFBRWQCB). As required by the FFA, the project addresses compliance issues by investigating potential contamination source areas (such as suspected old release sites, solvent-handling areas, and leaking underground tank systems), through continuous monitoring, and by the remediation of groundwater. The groundwater contaminants (constituents of concern) are volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE).

Significant 2003 Livermore site GWP restoration activities include installing 2 groundwater monitor wells, 1 dual (groundwater and soil vapor) extraction well, 21 soil vapor wells, and abandoning 1 borehole; installing 4 new anode wells and abandoning 2 anode wells; conducting 3 hydraulic tests; and conducting 17 soil vapor extraction tests. LLNL met all DOE milestones by starting the Treatment Facility C Northeast (TFC -NE) remediation, Treatment Facility G North (TFG-N), and the soil Vapor Treatment Facility E Eastern Landing Mat (VTFE ELM).

Treatment Facilities: In 2003, LLNL operated groundwater treatment facilities in the following treatment facility (TF) areas: A, B, C, D, E, G, 406, 518, and 5475. A total of 78 groundwater extraction wells supplied water to 26 treatment facilities at a combined average flow rate of about 2020 liters per minute. In 2003, these facilities treated more than 1 billion liters of groundwater and removed about 90 kilograms of VOCs compared to 108 kilograms in 2002. The lower quantity of mass removed in 2003 is partially due to decreasing concentrations in TFD and TFE area groundwater extraction wells. Since remediation began in 1989, approximately 8.5 billion liters of groundwater have been treated, resulting in a mass removal of about 1012 kilograms

of VOCs. In addition, LLNL operated two soil vapor treatment facilities (VTFs): VTF5475 and VTFE ELM. In 2003, these facilities treated about 311 cubic meters of vapor and removed an estimated 84 kilograms of VOCs compared to about 38 kilograms in 2002. The higher quantity of mass removed in 2003 is due to increased flow rates at VTF5475 and activation of VTFE ELM. Since initial operation, the three VTFs (VTF5475, VTFE ELM, and VTF518) have treated more than 1.4 million cubic meters of vapor and removed about 543 kilograms of VOCs. The groundwater and soil vapor treatment systems removed 174 kilograms of VOC in 2003, and have removed about 1555 kilograms of VOCs from the subsurface since remediation began in 1989. See Chapter 7 for further information.

Community Relations: Livermore site community relations activities in 2003 included communications and meetings with neighbors and local, regional, and national interest groups and other community organizations; making public presentations; producing and distributing the Environmental Community Letter; maintaining the Information Repositories; conducting tours of the site environmental activities; and responding to public and news media inquiries. In addition, DOE and LLNL met three times with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and their scientific advisor as part of the activities funded by an EPA Technical Assistance Grant (TAG). Community questions were also addressed via electronic mail, and project documents, letters, and public notices were posted on a public website at www-envirinfo.llnl.gov.

Documentation: In 2003, DOE/LLNL submitted the *LLNL Ground Water Project 2003 Annual Report* (Dibley et al. 2004 [reference included on report CD]) and quarterly self-monitoring reports on schedule. In addition, DOE/LLNL completed all 2003 Remedial Action Implementation Plan milestones ahead of schedule (Dresen et al. 1993).

Site Evaluations Prior to Construction: LLNL was placed on the National Priorities List in 1987 based on historical contamination of soil and groundwater. The *CERCLA Record of Decision for the Lawrence Livermore National Laboratory Livermore Site* (LLNL 1992) identifies selected remedial actions agreed upon by the EPA, SFRWQCB, and DTSC. The Record of Decision requires that before any construction begins, the project site must be evaluated to determine if soil or rubble (concrete and asphalt) is contaminated. Soil is sampled and analyzed for potential radioactive and/or hazardous contamination. Depending on the potential for radioactive contamination, rubble may be either surveyed or analyzed for radioactivity. During 2003, soil and rubble were evaluated at 85 construction sites. Based on the analytical results, the soil was either reused on site or disposed of according to established procedures.

Site 300 CERCLA Project

Investigations and remedial activities are ongoing at Site 300, which became a CERCLA site in 1990, when it was placed on the National Priorities List. Investigations and remedial activities are conducted under the joint oversight of the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), DTSC, and the authority of an FFA for the site. (There are separate FFAs for Site 300 and the Livermore site.) The groundwater contaminants (constituents of concern) for Site 300 vary within the

different environmental restoration operable units at the site. Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994) and *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1999).

LLNL completed all the 2003 FFA milestones for Site 300 on or ahead of schedule. These included construction of the Building 830-SRC groundwater and soil vapor extraction and treatment facility, and construction of the Building 817-SRC groundwater extraction and treatment facility. Installation of monitoring wells and surface soil sampling at Building 812 and remedial investigation field activities at the Pit 7 Complex were also completed on schedule. See Chapter 7 for a further discussion of the treatment areas.

Treatment Facilities: VOCs (primarily TCE) are the main contaminants at Site 300. High explosives, tritium, depleted uranium, organosilicate oil, nitrate, and perchlorate are also found in the groundwater. LLNL operated 11 treatment facilities during 2003. Twenty-three wells extracted groundwater only, 8 wells extracted soil vapor only, and 13 wells extracted both groundwater and soil vapor. About 108.9 million liters of groundwater were extracted and treated. The 13 wells that extract both vapor and groundwater and the 8 wells that extract only vapor together removed 332.3 thousand cubic meters of vapor. In 2003, the Site 300 treatment facilities combined removed approximately 2.87 kilograms of VOCs. Since remediation efforts began in 1990, more than 977.2 million liters of groundwater and approximately 4.3 million cubic meters of vapor have been treated, to yield about 234 kilograms of removed VOCs. See Chapter 7 for further information.

Community Relations: The Site 300 CERCLA project maintains continuing communications with the surrounding communities of Tracy and Livermore. Community relations activities in 2003 included maintenance of the Information Repositories; a public meeting; mailings to stakeholders; and interviews with the news media. LLNL hosted several TAG meetings with Tri-Valley CAREs. These meetings provided a forum for focused discussions on CERCLA activities at the various operable units at Site 300. Tri-Valley CARES receives the annual TAG grant from EPA. The grant also supports an environmental consultant to review Site 300 CERCLA activities.

Documentation: LLNL submitted all required documentation to oversight agencies on time in 2003. The *Final Interim Remedial Design Report for the Building 854 Operable Unit Treatment Facility at Lawrence Livermore National Laboratory Site 300* (Daily et al. 2003), *First Semester 2003 Compliance Report for Lawrence Livermore National Laboratory Site 300* (Carlsen et al. 2003a), quarterly reports, and work plans were among the documents submitted.

Agency for Toxic Substances and Disease Registry Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR), a public health agency of the U.S. Department of Health and Human Services, released for public comment on February 20, 2004, a public health assessment (PHA) addressing potential offsite (community) exposures of radioactive and nonradioactive hazardous substances released from the Livermore site. The ATSDR is required by the U.S. Congress to conduct such PHAs for all CERCLA sites. The PHA evaluates the potential for community exposure to, and potential heath effects from, LLNL-released substances that may be present in off-site groundwater, surface water, soil and sediment, air, and locally grown foodstuffs. The ATSDR assesses the health impacts of these substances singly and in combination, on adults and children. The ATSDR assessment found that LLNL environmental monitoring program and the resulting analytical data provided adequate environmental information to address the public health concerns of the Livermore community. Based on its evaluation and findings, ATSDR states:

> …past and ongoing operations and releases from the LLNL facility, including the Naval Air facility previously on this site, are No Apparent Public Health Hazard. This conclusion means that although community exposures to site-related contaminants may have, or may still be occurring, the resulting doses are unlikely to result in any adverse health effects and are, consequently, below levels of health concern. (ATSDR 2004)

In 2003, ATSDR also addressed community concerns about the health impacts of releases of tritium from LLNL. An ATSDR report, *Health Consultation on Tritium Releases and Potential Offsite Exposures* (ATSDR 2002) was based on the ATSDR's findings and those of a panel of five tritium experts. In the report, the ATSDR concluded that total tritium doses to the communities surrounding LLNL, including potential contributions from organically bound tritium, tritiated water, and tritiated hydrogen gas, are below levels of public health concern and are adequately assessed by current monitoring and modeling.

As part of an effort to address concerns about the 1965 and 1970 releases that account for about 80% of all the tritium released by LLNL, the ATSDR issued a draft report in May 2002, titled *Focused Public Health Assessment of 1965 and 1970 Accidental Tritium Releases at the Lawrence Livermore National Laboratory.* The public comment period was extended to March 31, 2003. In this document, the ATSDR presented doses predicted by modeling both releases based on the best available information, including meteorological conditions. Preliminary conclusions indicate that, though some public exposure to tritium probably did occur as the result of the accidental releases, the maximum exposures predicted were below levels that might cause adverse health effects.

The ATSDR also issued a PHA in early 2003, *Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community* (ATSDR 2003). A release, well within regulatory limits, of about 32 millicuries (1.2×10^{-9} Bq) of plutonium over several weeks in 1967 led to community concerns. The plutonium ended up in sewage sludge that was available to the community and public organizations. Both the California

Department of Health Services (DHS) and the Atomic Energy Commission found no public health concern at the time. Public sludge distribution by the Livermore Water Reclamation Plant (LWRP) ended in the mid-1970s. The ATSDR PHA determined there was no apparent public health hazard from the sludge. ATSDR stated that, while exposure may have occurred or may still be occurring, the resulting doses will not cause sickness or death. The ATSDR determined that any potential radiological doses are below levels of health concern. It stated it had no recommendations concerning additional soil sampling in areas of known or unknown sludge distribution. The agency found that available data and evaluations provide an adequate basis for these public health conclusions. It added that any additional sampling data would be subject to the same types of uncertainties as existing historical data. The agency recommended public outreach on this topic, which it conducted in February 2003. It also recommended that LLNL continue required routine regulatory monitoring.

Both ATSDR PHAs are expected to become final in 2004. Additional information concerning these ATSDR findings may be read in the environmental repositories or at LLNL's environmental information website http://www-envirinfo.llnl.gov/.

Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report

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 handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. Executive Order 13148 directs all federal agencies to comply with the requirements of the EPCRA, including SARA Section 313, "Toxics Release Inventory (TRI) Program."

As a result of greatly reduced TRI reporting thresholds, LLNL submitted to DOE on June 19, 2003, the TRI Form R for lead detailing environmental release estimates for Site 300. A 2.1% reduction in lead releases was achieved as a result of the substitution of nontoxic, nonlead (frangible) ammunition. LLNL's source reduction efforts are further described in the "Source Reduction and Pollution Prevention" section of this chapter.

EPCRA requirements and LLNL compliance are summarized in **Table 2-1**.

Resource Conservation and Recovery Act and Related State Laws

The 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 and the California Code of Regulations (CCR) Title 22 set requirements for managing hazardous wastes in California. RCRA and HWCA also regulate hazardous waste treatment, storage, and disposal facilities, including permit requirements. Because RCRA

Table 2-1. Compliance with EPCRA

EPCRA requirement[a]	Brief description of requirement[a]	LLNL action
302 Planning Notification	Notify SERC of presence of extremely hazardous substances.	Originally submitted May 1987.
303 Planning Notification	Designate a facility representative to serve as emergency response coordinator.	Update submitted May 16, 2003.
304 Release Notification	Report releases of certain hazardous substances to SERC and LEPC.	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2003.
311 MSDS/Chemical Inventory	Submit MSDSs or chemical list to SERC, LEPC, and Fire Department.	Update submitted May 16, 2003.
312 MSDS/Chemical Inventory	Submit hazardous chemical inventory to local administering agency (county).	Business plans and chemical inventory submitted to San Joaquin County (January 15, 2003) and Alameda County (April 4, 2003).
313 Toxics Release Inventory	Submit Form R to U.S. EPA and California EPA for toxic chemicals released above threshold levels.	Form R for lead (Site 300 only) was submitted to DOE June 19, 2003; DOE forwarded it to U.S. EPA and California EPA June 27, 2003.

a See Acronyms and Abbreviations for list of acronyms.

program authorization was delegated to the State of California in 1992, LLNL works with DTSC on compliance with federal and state issues and in obtaining hazardous waste permits.

Hazardous Waste Permits

Livermore Site: The hazardous waste management facilities at the Livermore site consist of permitted units (located in Area 612 and Buildings 693 and 695 of the Decontamination and Waste Treatment Facility [DWTF]) and units that operate under interim status (Area 514 Facility and the Building 233 Container Storage Facility). Permitted and interim status waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). LLNL sent letters to DTSC on April 13, 2001, and November 4, 2003, to request the removal of Building 280 from its permit and to specify plans to use Building 280 for non-DTSC regulated activities. During 2003, LLNL also submitted several Class 1 and Class 2 permit modification requests to DTSC and all the requested Class 1 permit modifications have been implemented. Many of these modification requests are related to as-built changes and consolidation of storage and treatment of hazardous waste at the DWTF complex. See **Table 2-2** for a summary of permits active in 2003. See **Table 2-3** for a summary of inspections and **Table 2-6** for a description of a Summary of Violations (SOVs) received as a result of a DTSC's Compliance Evaluation Inspection (CEI) conducted during March 2003. All four of the violations noted as part of the March 2003 CEI have been resolved as shown in **Table 2-6**. These violations were incorporated into a Consent Order agreed to by LLNL with DTSC and were part of a $15,661 penalty and $15,638 in reimbursement costs paid for violations in 2000, 2001, and 2003.

Table 2-2. Permits active in 2003

Type of permit	Livermore site[a][b]	Site 300 [a][b]
Hazardous waste	EPA ID No. CA2890012584. Hazardous Waste Facility Permit Number 99-NC-006 to operate hazardous waste management facilities including Building 280, Area 612, and DWTF complex. Authorization to mix resin in Unit CE231-1 under a Conditionally Exempt Specified Wastestream permit.	EPA ID No. CA2890090002. Part B Permit—Container Storage Area (Building 883) and Explosives Waste Storage Facility. Part B Permit—Explosives Waste Treatment Facility. Part B Permit—RCRA-Closed Building 829 High Explosives Open Burn Facility, Post-Closure Permit.
Medical waste	One permit for large quantity medical waste generation and treatment covering the Biology and Biotechnology Research Program, Health Services Department, Forensic Science Center, Medical Photonics Lab, Tissue Culture Lab, and Chemistry and Materials Science Department.	Limited Quantity Hauling Exemption for small quantity medical waste generator.
Air	BAAQMD issued 180 permits for operation of various types of equipment, including boilers, emergency generators, cold cleaners, degreasers, printing press operations, manual wipe-cleaning operations, metal machining and finishing operations, silk-screening operations, silk-screen washers, paint spray booths, adhesives operations, optic coating operations, storage tanks containing VOCs in excess of 1.0%, drum crusher, semiconductor operations, diesel air-compressor engines, groundwater air strippers, soil vapor extraction units, material-handling equipment, sewer diversion system, oil and water separator, fire-test cells, gasoline-dispensing operation, paper-pulverizer system, and firing tanks.	SJVUAPCD issued 42 permits for operation of various types of equipment, including boilers, emergency generators, paint spray booth, groundwater air strippers, soil vapor extraction units, woodworking cyclone, gasoline-dispensing operation, explosive waste treatment units, drying ovens, and the Contained Firing Facility.
Water	WDR Order No. 88-075 for discharges of treated groundwater from Treatment Facility A to percolation pits and recharge basin.[c] WDR Order No. 95-174, NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat nonstorm water discharges to surface waters. WDR Order No. 99-08-DWQ, NPDES California General Construction Activity Permit No. CAS000002; Terascale Simulation Facility, Site ID No. 201C317827; Sensitive Compartmented Information Facility, Site ID No. 201C317621; Soil Reuse Project, Site ID No. 201C305529; and National Ignition Facility, Site ID No. 201C306762; East Avenue Security Upgrade Project, Site ID No. 201C320036; 5th Street Project, Site ID No. 201C321420; Central Cafeteria, Site ID No. 201C320518, for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more.	WDR Order No. 93-100 for post-closure monitoring requirements for two Class I landfills. WDR Order No. 96-248 for operation of two Class II surface impoundments, a domestic sewage lagoon, and percolation pits.[c] WDR Order No. 97-03-DWQ, NPDES California General Industrial Activity General Permit No. CAS000001 for discharge of storm water associated with industrial activities. WDR Order No. 97-242, NPDES Permit No. CA0082651 for discharges of treated groundwater from the eastern General Services Area treatment unit. WDR Order No. 5-00-175, NPDES Permit No. CAG995001 for large volume discharges from the drinking water system that reach surface waters. Nationwide Permit 27 for enhancing red-legged frog breeding ponds.

Table 2-2. Permits active in 2003 (continued)

Type of permit	Livermore site[a][b]	Site 300 [a][b]
Water (continued)	WDR Order No. 99-086 for the Arroyo Las Positas Maintenance Project. Nationwide Permit 33 for the Arroyo Las Positas Maintenance Project. FFA for groundwater investigation/remediation.	Water Quality Certification for red-legged frog breeding ponds, WDID # 5B39CR00047. FFA for groundwater investigation/remediation. 34 registered Class V injection wells.
Sanitary sewer	Discharge Permit 1250[d] (2002/2003 and 2003/2004[e]) for discharges of wastewater to the sanitary sewer. Permit 1510G (2002/2004[f]) for discharges of groundwater from CERCLA restoration activities to the sanitary sewer.	
Storage tanks	Seven operating permits covering 10 underground petroleum product and hazardous waste storage tanks: 111-D1U2 Permit No. 6480; 113-D1U2 Permit No. 6482; 152-D1U2 Permit No. 6496; 271-D2U1 Permit No. 6501; 321-D1U2 Permit No. 6491; 365-D1U2 Permit No. 6492; and 611-D1U1, 611-G1U1, 611-G2U1, and 611-O1U1 Permit No. 6505.	One operating permit covering five underground petroleum product tanks assigned individual permit numbers: 871-D1U2 Permit No. 008013; 875-D1U2 Permit No. 006549; 879-D1U1 Permit No. 006785; 879-G3U1 Permit No. 007967; and 882-D1U1 Permit No. 006530

a Numbers of permits are based on actual permitted units or activities maintained and renewed by LLNL during 2003.

b See Acronyms and Abbreviations for list of acronyms.

c Recharge basins referenced in WDR Order No. 88-075 are located south of East Avenue within Sandia National Laboratory boundaries.

d Permit 1250 includes wastewater generated at Site 300 and discharged at the Livermore site.

e The Discharge Permit 1250 period is from May 15 to May 14; therefore, two permits were active during the 2003 calendar year.

f Permit 1510G is a two-year (January to December) permit.

In accordance with the document *Transition Plan: Transfer of Existing Waste Treatment Units to the Decontamination and Waste Treatment Facility* (EPD 1997), operations in the Area 514 Facility will eventually be replaced by those in DWTF, and Area 514 will be closed. The Building 233 Container Storage Facility also will be closed. Final closure plans for the Building 419 Interim Status Facility was submitted to DTSC February 2001 and for Area 514 Facility and the Building 233 Container Storage Facility in May 2000. DTSC is continuing its review of these closure plans and LLNL has provided additional information DTSC requested.

In May 1999, DTSC signed the Hazardous Waste Facility Permit and issued a Notice of Final Permit Decision for DWTF. In July 1999, Tri-Valley CAREs et al. filed a petition for review to appeal the permit decision. The appeal was denied by DTSC in November 1999, and the permit immediately became effective. Tri-Valley CAREs et al. filed a California Environmental Quality Act (CEQA) lawsuit in December 1999 that challenges many of the environmental impact evaluations made in the DTSC initial study, which formed the basis of the CEQA Negative Declaration determination by DTSC. A Settlement Agreement was reached on June 26, 2001, between Tri-Valley CAREs et al.

Table 2-3. Inspections of Livermore site and Site 300 by external agencies in 2003

Medium	Description[a]	Agency[a]	Date	Finding[a]
Livermore Site				
Multimedia	Compliance with air, water, hazardous waste, tanks, and other environmental regulations and permits	U.S. EPA	11/4–11/7	Received an inspection report 5/21/04 with three potential violations.[b]
Waste	Hazardous waste facilities CEI	DTSC	3/17–3/19, 3/21	Received an inspection report and SOV 4/10/03. See **Table 2-6** for description and resolution.
	Waste generator areas and LLNL Business Plan	ACDEH	6/9 8/12	Received Notice to Comply 6/9/03. See **Table 2-6** for description and resolution.
	Medical waste	ACDEH	9/24	No violations
Air	Emission sources	BAAQMD	2/25, 2/28 3/25, 4/9, 4/17, 5/7, 5/21, 6/25 8/6, 9/23 10/22	Received one NOV 4/9/03. See **Table 2-6** for description and resolution.
Sanitary sewer	Annual compliance sampling Categorical sampling Process evaluation	LWRP	10/7–10/8 10/9, 10/29 10/29	No violations No violations Building 231 Plastics Shop will not be regulated as Categorical process
Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	10/23 10/29	No violations
Site 300				
Waste	Permitted hazardous waste operational facilities (EWTF, EWSF, Building 883 CSA), RCRA-closed, post-closure permitted facility Building 829 HE Open Burn Facility, Building 883 WAA, Satellite Accumulation Areas, waste generating areas, and a review of hazardous waste-related documentation.	DTSC	10/28-10/29	Received an inspection report 1/20/04 with a violation.[c]
Air	Emission sources	SJVUAPCD	7/10	No violations
Water	Permitted operations	CVRWQCB	11/18	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	5/14, 5/15 6/9, 6/10, 6/25, 6/26 9/29, 10/23	No violations

a See Acronyms and Abbreviations for list of acronyms.

b Incorrect dates on two hazardous waste containers were corrected during the inspection. Potential SPCC Plan violations are discussed further in the "Tank Management" section.

c LLNL is currently working with DTSC on an alleged personnel training violation issued January 20, 2004, subsequent to the October 2003 inspection. See discussion in the "Hazardous Waste Permits" section for Site 300.

and the Regents of the University of California and DOE. As part of the Settlement Agreement, DTSC, the Regents, and DOE agreed to comply with all of the items listed under Section 6 (Actions by Respondents) of the Settlement Agreement. The Regents are currently in compliance with their responsibilities described in Section 6. The Regents deliver all information requested by DTSC, on an ongoing basis, to support an evaluation to determine the need for additional permit conditions or modifications. DTSC finalized their determination in June 2003.

Site 300: The hazardous waste management facilities at Site 300 consist of three RCRA-permitted facilities. The Explosives Waste Storage Facility and Explosives Waste Treatment Facility are permitted to store and treat explosives waste only. The Building 883 Container Storage Area is permitted to store routine facility-generated waste such as spent acids, bases, contaminated oil, and spent solvents. See **Tables 2-2** and **2-3** respectively for a summary of permits active and inspections at Site 300 in 2003. Though no violations were issued at the conclusion of the inspection, after investigating one potential compliance issue, DTSC issued a violation on January 20, 2004, for noncompliance with the personnel training regulation. However, prior to the permit being issued, LLNL had discussed the training plan with DTSC and DTSC had determined that training was not necessary and did not include a training requirement in the permit. For this reason, LLNL has contested the violation and is awaiting a reponse from DTSC.

Hazardous Waste Reports

LLNL completes two annual hazardous waste reports, one for the Livermore site and the other for Site 300, that address the 2003 transportation, storage, disposal, and recycling of hazardous wastes at the respective sites. The 2003 Hazardous Waste Report-Mainsite and 2003 Hazardous Waste Report-Site 300 were submitted to the DTSC by April 1, 2004.

Hazardous Waste Transport Registration

Transportation of hazardous waste over public roads (e.g., from one LLNL site to another) requires DTSC registration (22 CCR 66263.10). DTSC renewed LLNL's registration in November 2003.

Waste Accumulation Areas

LLNL Programs maintain waste accumulation areas (WAAs) in compliance with waste generator requirements specified in 40 Code of Federal Regulations (CFR) part 262, and 22 CCR part 26262.10, for the temporary storage (less than 90 days) of hazardous waste prior to transfer to a treatment, storage, and disposal facility. In January 2003, there were 23 WAAs at the Livermore site. Three temporary WAAs were put into service, while five temporary WAAs and one permanent WAA were taken out of service. Program representatives conducted inspections at least weekly at all WAAs to ensure that they were operated in compliance with regulatory requirements. Approximately 1175 prescribed WAA inspections were conducted at the Livermore site. One WAA was in operation at Site 300 during 2003. Program representatives conducted 52 prescribed inspections of the WAA at Site 300.

California Medical Waste Management Act

All LLNL medical waste management operations comply with the California Medical Waste Management Act, which establishes a comprehensive program for regulating the management, transport, and treatment of medical wastes that contain substances that may potentially infect humans. The program is administered by California DHS and is enforced by the Alameda County Department of Environmental Health (ACDEH).

LLNL is registered with the ACDEH as a generator of medical waste and has a treatment permit. No violations were issued as a result of the September 2003 ACDEH inspection of buildings at LLNL Health Services, the Biology and Biotechnology Research Program, and the Medical Photonics. (See **Tables 2-2** and **2-3**.)

Radioactive Waste and Mixed Waste Management

LLNL manages radioactive waste and mixed waste in compliance with applicable sections of DOE Order 435.1, as described in LLNL's online *ES&H Manual,* Document 36.1, "Hazardous, Radioactive, and Biological Waste Management Requirements." LLNL has also written the "Radioactive Waste Management Basis," which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities.

Federal Facility Compliance Act

LLNL continues to work with DOE to maintain compliance with the Federal Facilities Compliance Act (FFCA) Site Treatment Plan (STP) for LLNL that was signed in February 1997. All milestones for 2003 were completed on time. Reports and certification letters were submitted to DOE as required. LLNL continued to pursue the use of commercial treatment and disposal facilities that are permitted to accept mixed waste. These facilities provide LLNL greater flexibility in pursuing the goals and milestones set forth in the STP. The FFCA STP provides coverage for all Mixed Waste stored for one year or longer in a Radioactive and Hazardous Waste Management facility.

Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in 40 CFR Part 700-789 govern the uses of newly developed chemical substances and TSCA-governed waste by establishing the following partial list of requirements: recordkeeping, reporting, disposal standards, employee protection, compliance and enforcement, and clean up standards.

In 2003, LLNL generated TSCA-regulated polychlorinated biphenyl (PCB) waste from electrical equipment contaminated with PCBs, liquid PCBs used to calibrate analytical equipment, and asbestos from building demolition or renovation projects.

All TSCA-regulated waste was disposed in accordance with TSCA, state, and local disposal requirements except for radioactively contaminated PCB waste. Radioactive PCB waste is currently stored at one of LLNL's hazardous waste storage facilities until an approved facility accepts this waste for final disposal.

Air Quality and Protection

Clean Air Act

All activities at LLNL are evaluated to determine the need for air permits. 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 (SJVUAPCD) and/or BAAQMD for Site 300.

LLNL operated 180 air emission sources for the Livermore site in 2003. During an inspection in April 2003, the BAAQMD issued a notice of violation (NOV) for a record keeping violation during the time period September 2002 to February 2003 (see **Table 2-3**). LLNL was subsequently assessed a $2650 penalty.

The BAAQMD finalized LLNL's Synthetic Minor Operating Permit in November 2002. The Synthetic Minor Operating Permit conditions require LLNL to ensure that the emissions of regulated air pollutants are below the permitted threshold values. These values limit emissions from combustion sources to less than 50 tons per year for oxides of nitrogen and emissions from solvent evaporating sources to less than 50 tons per year for precursor organic compounds and to less than 23 tons per year for all hazardous air pollutants. In accordance with permit conditions, LLNL submitted to the BAAQMD an annual report summarizing emissions through June 30.

In 2003, the SJVUAPCD issued or renewed air permits for 42 air emission sources for Site 300 (see **Table 2-2**). There were no violations issued from 2003 air inspections of Site 300 facilities (see **Table 2-3**).

National Emission Standards for Hazardous Air Pollutants, Radionuclides

To demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radiological emissions, LLNL is required to monitor certain air release points and evaluate all potential sources of radionuclide air emissions to determine the maximum possible dose to the public. These evaluations include modeling (using EPA-sanctioned computer codes) based on radionuclide inventory data, air effluent (source emission) monitoring, and air surveillance monitoring. The *LLNL NESHAPs 2003 Annual Report* (Harrach et al. 2004), submitted to DOE and EPA, reported that the estimated maximum radiological doses to the public were 0.44 µSv (0.044 mrem) for the Livermore site and 0.17 µSv (0.017 mrem) for Site 300 in 2003.

The reported doses include contributions from both point and diffuse sources. The totals were well below the 100 µSv/y (10 mrem/y) dose limits defned by the NESHAPs regulations. Additional information on the data are described in Chapter 6.

In 2003, LLNL continuously monitored radionuclide emissions from Building 331 (the Tritium Facility), Building 332 (the Plutonium Building), and portions of five other facilities (see Chapter 3). There were no unplanned atmospheric releases at the Livermore site or at Site 300 in 2003. Monitoring activities and results related to air are described further in Chapter 3.

Water Quality and Protection

Clean Water Act and Related State Programs

Preserving clean water is an objective of local, state, and federal regulations. The National Pollutant Discharge Elimination System (NPDES) under the federal Clean Water Act (CWA) establishes permit requirements for discharges into waters of the United States. In addition, the State of California, under the Porter Cologne Water Quality Control Act, requires permits, known as Waste Discharge Requirements (WDRs), for any waste discharges affecting the beneficial uses of waters of the state. These permits, as well as water quality certifications for discharges authorized under Section 401 of the CWA, are issued by local Regional Water Quality Control Boards (RWQCBs) and the State Water Resources Control Board. RWQCBs enforce both the regional and state issued permits. Section 401 state certifications are required when the Army Corps of Engineers issues permits under Section 404 of the CWA.

Several agencies issue other water-related permits. The LWRP requires permits for discharges to the city's sanitary sewer system. The California Department of Fish and Game (CDFG), under the Fish and Game Code, requires streambed alteration agreements (SAAs) for any work that may disturb or impact rivers, streams, or lakes. The Safe Drinking Water Act requires registration with the EPA and management of injection wells to protect underground sources of drinking water.

As required by state and federal regulations, LLNL began complying with the Phase II storm water program in March 2003. These compliance activities included:

- Obtaining coverage under the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ, NPDES Permit No. CAS000002) for projects disturbing 0.4 hectares (1 acre) (previously the size threshold was 2 hectares [5 acres])
- Submitting an NPDES permit application for the operation of a municipal separate storm sewer system for the Livermore site

In 2003, LLNL also updated its inventory of Class V injection wells registered with EPA, reducing the inventory to eliminate redundancies and those subject to CERCLA oversight.

Water-related permits and inspections from outside agencies are summarized in **Tables 2-2** and **2-3**, respectively. LLNL received no NOVs in 2003 from the Livermore site and Site 300's respective RWQCB. However, LLNL identified administrative nonconformances with permit conditions at two construction projects, both of which are permitted by NPDES permit number CAS000002. These instances are discussed in the required annual compliance certification.

During 2003, LLNL received no NOVs from the LWRP. LLNL did receive a Letter of Warning dated March 20, 2003, regarding a finding of lead slightly exceeding the permit limit of 0.20 milligrams per liter (mg/L). Lead was detected at 0.235 mg/L in a sample representing January 15, 2003. This was reported to the LWRP in both the routine Monthly Sewer Monitoring Report and a 5-Day Report. The Letter of Warning stated that adequate measures had been taken and no further action was necessary. The LWRP also determined no further action was necessary for a low pH excursion on May 4, 2003. See **Table 2-4** for a summary of nonconformance with water related permits. Monitoring activities and results related to water permits are described in Chapter 4.

Table 2-4. Water-related permit nonconformance

Permit No[a]	Nonconformance[a]	Date(s) of nonconformance	Description–solution[a]
1250, LWRP sanitary sewer permit	24-hour composite sample exceeded the 0.20 mg/L permit limit for lead.	1/16/03[b]	Daily effluent samples collected January 17 through February 14 demonstrated a return to compliance.
	Excursion below pH permit limit of 5; approximately 200 gallons of effluent within pH range 5.2 to 4.8 released to LWRP.	5/4/03	Remainder of effluent captured and contained on-site by Sewer Diversion Facility.
CAS000002, discharge to ALP	Central Cafeteria—Began construction prior to approval and certification of SWPPP. Failure to inspect after three significant storm events	3/10/03 – 5/8/03[c]	Immediately halted subcontractor work and required installation of sediment control measures. SWPPP was approved and certified. Incident was reported to the SFBRWQCB.
CAS000002, discharge to ALP	National Ignition Facility—Failure to inspect project during and following certain significant storm events.	12/28/02–12/29/02 2/12/03, 2/16/03 4/4/03, 4/21/03, 4/28/03, 5/2/03[c]	Incidents were identified to project management and noted in compliance certification.

a See Acronyms and Abbreviations for list of acronyms.

b Analytical sample collected and dated January 16, 2003, represented effluent from January 15, 2003.

c These dates reflect the construction reporting period of June 2002 through May 2003.

Tank Management

The CWA and California Aboveground Petroleum Storage Act require facilities meeting specific storage requirements to have and implement Spill Prevention Control and Countermeasure plans for aboveground, oil-containing containers, including equipment and tanks. ACDEH and San Joaquin County Environmental Health Department (SJCEHD) also issue permits for operating underground storage tanks containing hazardous materials or hazardous waste as required under the California Health and Safety Code.

LLNL manages its underground and aboveground storage tanks through the use of underground tank permits, monitoring programs, operational plans, closure plans and reports, leak reports and follow-up activities, and inspections. At LLNL, permitted underground storage tanks contain diesel fuel, gasoline, and used oil; aboveground storage tanks contain fuel, insulating oil, and process wastewater. Some non-permitted wastewater tank systems are a combination of underground storage tanks and aboveground storage tanks. **Table 2-5** shows the status of in-service tanks at the Livermore site and Site 300 as of December 31, 2003. All permitted underground storage tanks were inspected by the regulating agencies in 2003. See **Table 2-3** for summary of inspections. During the November 2003 multimedia inspection, U.S. EPA identified potential SPCC Plan violations that require LLNL to update the SPCC Plan in accordance with 40 CFR, Part 112 and enchance LLNL's current maintenance inspections of aboveground oil containers. These corrections are in process.

Table 2-5. In-service tanks in 2003

Tank type	Livermore site		Site 300	
	Permitted	Permits not required	Permitted	Permits not required
Underground storage tanks				
Diesel fuel	7	0	4	0
Gasoline	2	0	1	0
Used oil	1	0	0	0
Process wastewater	0	45	0	11
Subtotal	10	45	5	11
Aboveground storage tanks				
Diesel fuel	0	24	0	7
Insulating oil	0	1	0	4
Process wastewater	19[a]	58	0	16
Miscellaneous non-waste tanks	0	11	0	0
Subtotal	19	94	0	27
Total	29	139	5	38

a Nine tanks are located at Building 695, the Decontamination and Waste Treatment Facility. Ten tanks are located at the Building 514 Treatment and Storage Facility.

Other Environmental Statutes

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes federal policy for protecting environmental quality. The major method for achieving established NEPA goals is the requirement to prepare an environmental impact statement (EIS) for any major federal or federally funded project that may have signicant 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 an 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 a more in-depth NEPA review (i.e., from the preparation of either an EA or EIS). DOE NEPA implementing procedures identify those categorical exclusions and the eligibility criteria for their application. If a proposed project does not clearly fit one of the exclusion categories, DOE determines which type of assessment document may be needed.

There were no LLNL projects in 2003 that required DOE EAs. Thirty-three categorical exclusion applications were approved by DOE, and there were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10 CFR 1022.

In 2003, DOE prepared the draft *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement (LLNL SW/SPEIS)*. The new *LLNL SW/SPEIS* will replace the *1992 Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore (1992 EIS/EIR)* (U.S. DOE and UC 1992a,b) and its March 1999 Supplement Analysis.

The draft *LLNL SW/SPEIS* was issued for a 90-day public comment period (February 27 to May 27, 2004). Three public hearings were scheduled in 2004: April 27 in Livermore, April 28 in Tracy, and April 30 in Washington, D.C. The final *LLNL SW/SPEIS* is scheduled to be complete in fall 2004 with a Record of Decision in January 2005.

Since November 1992, the University of California (UC) and LLNL have implemented 67 mitigation measures identified by the *1992 EIS/EIR*. An addendum to the *1992 EIS/EIR* was prepared in 1997. The measures are being implemented in accordance with the approved 1992 Mitigation Monitoring and Reporting Program associated with the *1992 EIS/EIR*. The 2000 mitigation monitoring reports was published in 2003. The 2001, 2002, and 2003 mitigation monitoring reports will be published in 2004.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) applies to historically important places and things affected by the federal government. LLNL contains resources subject to NHPA consideration. These range from prehistoric archeological sites to remnants of LLNL's own history of scientic and technological endeavor. The responsibility to comply with the provisions of NHPA rests solely with DOE as a federal agency. LLNL and UC as its contractor operator support DOE NHPA responsibilities. LLNL does so in a limited manner with direction from DOE.

The two primary NHPA sections that apply to LLNL are Sections 106 and 110. Section 106 requires federal agencies to take into account the effects their projects may have on historic properties. The agencies must allow and consider comments of the federal Advisory Council on Historic Preservation. The Section 106 rules outline a five-step review process that is conducted on a project-by-project basis. Section 110 sets forth broad affirmative responsibilities to balance agency missions with cultural values. Its purpose is to ensure full integration of historic preservation into federal agency programs.

LLNL has taken two approaches to streamline historic preservation efforts and focus on important historic properties in its holdings. First, DOE, UC, and the State Historic Preservation Office reached an agreement in July 2003 that governs all historic preservation program activities until inventory and assessment activities specified in the agreement are complete. The goal is to reduce the amount of paperwork necessary to ensure protection of important historic properties by reaching a consensus on where and how to effectively focus LLNL's efforts. Second, which is specified in the agreement, is to complete within a reasonable timeframe an inventory of places (prehistoric and historic, archeological, and architectural) that meets a statutory threshold of historic importance. LLNL is on schedule with this inventory and assessment effort. During 2003, LLNL completed a baseline inventory of archeological sites as well as finishing all of the fieldwork necessary to complete an historic context. LLNL also completed fieldwork necessary to support future National Register of Historic Places determinations for buildings, structures, and objects at the Livermore site and Site 300. National Register determinations will be made in 2004.

Antiquities Act

Provisions of the Antiquities Act provide for recovery of paleontological remains. After the discovery of mammoth remains in conjunction with the National Ignition Facility construction in 1997, LLNL has remained vigilant for other fossil finds. No remains subject to the provisions of the Antiquities Act were identified in 2003.

Endangered Species Act and Sensitive Natural Resources

Requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and the California Native Plant Protection Act are met as they pertain to endangered or threatened species and other special-status species, their habitats, and designated critical habitats that exist at the LLNL sites. For example, DOE consults with the U.S. Fish and Wildlife Service (USFWS) when activities will result in an impact to federally endangered or threatened species, surveys for the presence of species of special concern, and follows mitigation requirements in WDRs and biological opinions. A biological assessment (BA) for the implementation of the Arroyo Seco Management Plan was prepared and submitted to USFWS on August 14, 2003. USFWS is currently reviewing the BA. A BA for the implementation of the Arroyo Mocho Road Improvement and Anadromous Fish Passage Project was prepared and submitted to USFWS on November 6, 2003. USFWS responded with their biological opinion for the Arroyo Mocho project on February 10, 2004. A BA for the Livermore site and Site 300 regarding the *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory* and *Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* was prepared and submitted to USFWS on April 9, 2004. USFWS is currently reviewing the BA. Biological surveys for special-status species and monitoring results are described in Chapter 5.

Environmental Occurrences

In 2003, notification of environmental occurrences was required under a number of environmental laws and regulations as well as DOE Order 232.1A, which was replaced by DOE Order 231.1A, "Environmental, Safety and Health Reporting." LLNL's Implementing Procedures for DOE Order 231.1A and DOE Manual 231.1-2 was susequently revised and became effective December 1, 2003. These orders provide guidelines to contractor facilities regarding categorization and reporting of environmental occurrences to DOE and divides occurrences into categories.

LLNL's response to environmental occurrences is part of the larger on-site emergency response organization that includes representatives from Hazards Control (including the LLNL Fire Department), Health Services, Plant Engineering, Public Affairs, Safeguards and Security, and Environmental Protection. In 2003, three environmental incidents, summarized in **Table 2-6**, were reportable under DOE Order 232.1A (because they occurred before Order 231.1A became effective on August 19, 2003) and were categorized as off-normal occurrences according to DOE Order 232.1A. DOE was notified of these incidents. Other regulatory agencies involved are described in **Table 2-6** for each of the incidents.

Table 2-6. Environmental Occurrences reported under the OR System in 2003

Date[a]	Occurrence category	Description[b]
April 9	Off-Normal	LLNL received an NOV from BAAQMD on alleged record keeping violations as a result of the BAAQMD's record review of permitted on-site portable internal combustion (IC) engines. Seven of the permitted on-site portable IC engines were found to be out of compliance with weekly usage record keeping requirements identified in their associated permit conditions. The alleged violation was for September 2, 2002, through February 14, 2003. No corrective action was required since weekly usage records existed for the seven IC engines after February 14, 2003. LLNL paid a civil penalty of $2,650. The seven IC engines were physically inspected by the BAAQMD during their inspections on February 28, March 25, April 9, and April 17, 2003, and found to be in compliance with all applicable regulations and other permit conditions. Receiving an NOV meets the definition of an Off-Normal Occurrence. OR 2003-0014
April 10	Off-Normal	LLNL received an SOV from DTSC for four alleged violations observed during the 2003 CEI of permitted hazardous waste handling operations. The alleged violations and resolutions were as follows: • Training records for six individuals indicated that multiple courses had not been completed in the specified frequencies. The most recent course completion dates were not provided to the inspectors. The inspector was later provided the corrected dates, and the corrections were noted in the exit meeting. • Storage of two mixed waste containers for greater than one year in the Building 612 Facility. A storage extension request letter was submitted to the DTSC. • Operating record discrepancies. Information on Container Content Reports (CCRs) was either not complete or did not reflect accurate information on the status of the container location and storage, treatment and disposal facility start date. The information on the CCRs was corrected and submitted to the inspector. • According to the inspector, inadequate aisle spacing was observed in the Building 614 west cell. Waste containers were rearranged to provide adequate aisle spacing. Receiving an SOV meets the requirements of an Off-Normal Occurrence. OR 2003-0015.
June 9	Off-Normal	LLNL received a Notice to Comply from the ACDEH following the March waste generation area inspection. During the inspection, a 15-gallon, unlabeled container containing liquid was found in poor condition outside a WAA. It was later determined that the liquid was sea water, which is a nonhazardous material. The sea water and container were appropriately disposed. Receiving a Notice to Comply meets the requirements of an Off-Normal Occurrence. OR 2003-0022.

a The date indicated is the date when the occurrence was categorized, not the date of its discovery.

b See Acronyms and Abbreviations for list of acronyms.

Program Summary

Integrated Safety Management System

LLNL implements an Integrated Safety Management System (ISMS) designed to ensure the systematic integration of environment, safety, and health (ES&H) considerations into management and work practices so that missions are accomplished safely. "Safety," used in this context, is synonymous with environment, safety, and health to encompass protection of the public, workers, and the environment, including pollution prevention and waste minimization. LLNL regards protection of the environment an essential component in its overall safety management system.

The core requirements of ISMS are based on DOE's Seven Guiding Principles summarized as: (1) line management is responsible for ensuring the protection of employees, the public, and the environment; (2) clear roles and responsibilities for ES&H are established and maintained; (3) personnel competence is commensurate with their responsibilities; (4) resources are effectively allocated to address ES&H, programmatic, and operational considerations with balanced priorities; (5) ES&H standards and requirements are established that ensure adequate protection of the employees, the public, and the environment; (6) administrative and engineering controls to prevent and mitigate ES&H hazards are tailored to the work being performed; and (7) operations are authorized. How LLNL manages and performs work can be described by the Five Core Functions: (1) define the scope of work; (2) identify and analyze the hazards and environmental aspects associated with the work; (3) develop and implement hazard and aspect controls; (4) perform work within the controls; and (5) provide feedback on the adequacy of the controls for continuous improvement.

The implementation of a management system based on these principles and functions results in accountability at all levels of the organization, project planning with protection in mind, and excellence in program execution. The ISMS Program at LLNL employs a process of assessing hazards and the environmental implications of work; designing and implementing standards-based methods intended to control risks; and complying with applicable ES&H requirements. LLNL's ISMS is detailed in *Integrated Safety Management System Description* (LLNL 2003) which can be found at the following website: http://www.llnl.gov/es_and_h/ism/ism-descriptionv6.pdf

Work Smart Standards

Work Smart Standards (WSS) are an integral part of an ISMS, whereby ES&H professionals identify hazards and environmental aspects, and establish standards of operation appropriate for a particular work environment. WSS are approved at the management level closest to and with the most expertise in the work. Since August 1999, the existing WSS set describes LLNL's ES&H requirements. These standards are continually

reviewed and revised through the change control process as either new DOE orders are issued or regulations are adopted. The Change Control Board (CCB), with representatives from DOE, UC, and LLNL, manages the change control process. In addition, LLNL undertakes periodic review of all the requirements to ensure that the WSS set is current and complete.

The WSS set currently identified to satisfy the ES&H needs of the LLNL work environment are in Appendix G of the UC contract, and can be viewed at: http://labs.ucop.edu/internet/wss/wss.html.

Environmental Management System

On January 15, 2003, the DOE issued Order 450.1, "Environmental Protection Program," which requires DOE sites to implement an Environment Management System (EMS) integrated into their ISMS. The purpose of Order 450.1 is to align the DOE's system for environmental protection with the requirements of Executive Order 13148, "Greening the Government Through Leadership in Environmental Management." In February 2003, LLNL constituted a Standards Identification Team for the purpose of considering the adoption of, in whole or part, the Contractor Requirements Document of Order 450.1. This process considered all or parts of Order 450.1 for incorporation into the contract as necessary and sufficient under LLNL's current integrated ES&H management system. As a result of this process, LLNL has agreed to incorporate ISO 14001 as a WSS. To better understand the status of LLNL's ISMS, LLNL conducted a gap analysis in early 2004 to compare the LLNL program with ISO 14001 and DOE Order 450.1. The gap analysis compares the LLNL program and ISO 14001 EMS, using a tailored ISO 14001 Checklist, along the five key EMS elements:

- Policy and Commitment
- Planning
- Implementation
- Measurement and Evaluation
- Review and Improvement

The analysis evaluated the LLNL *ES&H Manual*, related ISMS documentation, and organizational implementation against 36 detailed elements of ISO 14001. Based on the findings of the gap analysis, LLNL is developing a strategy to enhance LLNL's ISMS in order to self declare compliance with the requirements of Executive Order 13148 by December 2005.

Environmental Protection Department

As the lead organization at LLNL for providing environmental expertise and guidance on operations at LLNL, the Environmental Protection Department (EPD) is responsible for environmental monitoring, environmental regulatory interpretation and implementation guidance, environmental restoration, environmental community relations, and waste management in support of LLNL's programs. EPD prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the ES&H Manual; informs management about pending changes in environmental regulations pertinent to LLNL; represents LLNL in day-to-day interactions with regulatory agencies and the public; and assesses the effectiveness of pollution control programs. EPD has also taken a leadership role in the decommissioning and decontamination (D&D) of DOE facilities as a result of the end of the Cold War. EPD's Space Action Team tactically implements LLNL's institutional D&D activities. Since 1998, more than 51 D&D projects have been completed at LLNL.

EPD monitors air, sewerable water, groundwater, surface water, soil, sediment, vegetation, and foodstuff, as well as direct radiation; evaluates possible contaminant sources; and models the impact of LLNL operations on humans and the environment. These monitoring activities in 2003 are presented in the remaining chapters of this report.

A principal part of EPD's mission is to work with LLNL programs to ensure that operations are conducted in a manner that limits environmental impacts and is in compliance with regulatory requirements. EPD helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes, as well as identify opportunities for pollution prevention, including minimization of nonhazardous waste; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; responds to emergencies in order to minimize and assess any impact on the environment and the public; and provides training programs to improve the ability of LLNL employees to comply with environmental regulations. These functions are organized into three divisions within the department: Operations and Regulatory Affairs (ORAD), Radioactive and Hazardous Waste Management (RHWM), and Environmental Restoration (ERD).

Operations and Regulatory Affairs Division

ORAD consists of six groups that specialize in environmental compliance and monitoring and provide LLNL programs with a wide range of information, data, and guidance to make more informed environmental decisions. ORAD prepares the environmental permit applications and related documents for submittal to federal, state, and local agencies; provides the liaison between LLNL and regulatory agencies conducting environmental inspections; tracks chemical inventories; prepares NEPA documents and conducts related field studies; oversees wetland protection and floodplain management requirements; coordinates cultural and wildlife resource protection and management; facilitates and provides support for the pollution prevention and recycling programs; teaches environmental training courses; coordinates the tank environmental

compliance program; conducts compliance and surveillance monitoring; provides environmental impact modeling and analysis, risk assessment, and reporting; and develops new methods and innovative applications of existing technologies to improve environmental practices and assist LLNL in achieving its mission. ORAD also actively assists in responding to environmental emergencies such as spills. During normal working hours, an environmental analyst from the ORAD Environmental Operations Group (EOG) responds to environmental emergencies and notifies a specially trained Environmental Duty Officer (EDO). EDOs are on duty 24 hours a day, 7 days a week, and coordinate emergency response with other first responders and environmental specialists.

Radioactive and Hazardous Waste Management Division

RHWM manages all hazardous, radioactive, medical, and mixed wastes generated at LLNL facilities in accordance with local, state and federal requirements. RHWM processes, stores, packages, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer. As part of its waste management activities, RHWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas, which are typically 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 and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. RHWM prepares numerous reports, including the annual and biennial hazardous waste reports required by the state and federal environmental protection agencies. RHWM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans.

RHWM meets regulations requiring the treatment and disposal of LLNL's mixed waste in accordance with the requirements of the FFCA. The schedule for this treatment is negotiated with the State of California and involves developing new on-site treatment options as well as finding off-site alternatives. RHWM is also responsible for implementing a program directed at eliminating the backlog of legacy waste (waste that is not at present certified for disposal). This effort includes a large characterization effort to identify all components of the waste and a certification effort that will provide appropriate documentation for the disposal site.

Environmental Restoration Division

ERD was established to evaluate and remediate soil and groundwater contaminated by past hazardous materials handling and disposal processes and from leaks and spills that have occurred at the Livermore site and Site 300, both prior to and during LLNL operations. ERD conducts field investigations at both the Livermore site and Site 300 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 groundwater and soil vapor extraction and treatment, and for assisting in closing inactive facilities in a manner designed to prevent environmental contamination. As part of its responsibility for CERCLA compliance issues, ERD plans, directs, and conducts assessments to determine both the impact of past releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment. ERD interacts with the community on these issues through Environmental Community Relations. Public workshops are held regularly and information is provided to the public as required in the ERD CERCLA Community Relations Plans. These CERCLA activities in 2003 are summarized in the "Environmental Restoration and Waste Management" section earlier in this chapter. ERD's groundwater remediation activities in 2003 are further described in Chapter 7 of this report.

Response to Spills and Other Environmental Emergencies

All spills and leaks (releases) at LLNL that are potentially hazardous to the environment are investigated and evaluated. The release response process includes identifying the release, shutting off the source (if it is safe to do so), eliminating ignition sources, contacting appropriate emergency personnel, cordoning off the area containing the released material, absorbing and neutralizing the released material, assisting in cleanup, determining if a release must be reported to regulatory agencies, and verifying that cleanup (including decontaminating and replenishing spill equipment) is complete. ORAD staff also provide guidance to the programs on preventing spill recurrence.

As previously described, the EDO is available 24 hours a day, 7 days a week to maximize efficient and effective emergency environmental response. Specialized EDO training includes simulated incidents to provide the response personnel with the experience of working together to mitigate an environmental emergency, determine any reporting requirements to regulatory agencies and DOE, and resolve environmental and regulatory issues within the LLNL emergency response organization. The on-duty EDO can be reached by pager or cellular phone at any time.

During normal work hours, LLNL employees report all environmental incidents to an EOG environmental analyst assigned to support their program area. The EOG environmental analyst then notifies the on-duty EDO of the incident, and together with other ORAD staff, the team determines applicable reporting requirements to local, state, and federal regulatory agencies and to DOE. The EDO and the EOG environmental analyst also notify and consult with program management and have 7-day-a-week, 24-hour-a-day access to the office of Laboratory Counsel for questions concerning regulatory reporting requirements.

During off hours, LLNL employees report all environmental incidents to the Fire Dispatcher, who, in turn, notifies the EDO and the Fire Department, if required. The EDO then calls out additional EPD support to the incident scene as necessary, and follows the same procedures as outlined above for normal work hours.

Pollution Prevention

LLNL has a Pollution Prevention (P2) team whose role it is to help facilitate LLNL's P2 program in accordance with applicable laws, regulations and DOE orders as required within the UC Contract. Responsibilities include P2 program stewardship and maintenance, waste generation and P2 analysis and reporting, P2 opportunity assessment and high return-on-investment follow through, implementation of recycling, reuse and waste minimization programs for hazardous as well as non hazardous waste, and coordination of P2 programs and activities with other energy efficiency and resource conservation efforts at the Lab. The P2 team works within the structure of the LLNL ISMS to support P2 efforts and activities through environmental teams. In addition, the P2 team undertakes coordination of the affirmative procurement program and provides awareness presentations, articles, events, and other materials.

DOE Pollution Prevention Goals

In a memo dated November 12, 1999, the Secretary of Energy issued a new and challenging set of pollution prevention goals for the DOE Complex in response to the President's Executive Orders for Greening the Federal Government that require reduction of waste in **Table 2-7**. The goals have expanded the scope of pollution prevention goals by including building and facility energy efficiency; reduction in releases of toxic chemicals, ozone depleting substances, and green house gases; increased fleet efficiency; use of alternative fuels; and the required purchase of environmentally preferable products.

The routine waste generation for the 1993 baseline year, the routine waste generation for 2003, and the percent reductions in routine waste generation since 1993 are presented in **Table 2-8**. Routine waste described in this table includes waste from ongoing operations produced by any type of production, analytical, and/or research and development laboratory operations. Periodic laboratory or facility clean-outs and spill cleanups which occur as a result of these processes are also considered normal operations.

Since 2001, LLNL revised the method by which it calculates waste to better identify future P2 opportunities and to eliminate categories of wastes that would otherwise be counted twice under the new tracking system. The reported waste quantities for hazardous waste, low-level radioactive waste, and mixed low-level waste now include all wastes generated under requisition and tracked in the RHWM Division's Total Waste Management System (TWMS) database, which was replaced in FY 2004 with a new database called HazTrack. Not reported are secondary waste generated as a result of waste treatment activities at RHWM and recycled small batteries and automotive motor oil.

Table 2-7. Pollution prevention and energy efficiency leadership goals at DOE facilities

Goal[a]	Detail
Reduce Waste and Recycling	Reduce waste from routine operations by 2005, using a 1993 baseline, for these waste types: hazardous by 90%, low level radioactive by 80%, low level-mixed radioactive by 80%, and transuranic (TRU) by 80%
	Reduce releases of toxic chemicals subject to Toxic Chemical Release Inventory reporting by 90% by 2005, using a 1993 baseline.
	Reduce sanitary waste from routine operations by 75% by 2005 and 80% by 2010, using a 1993 baseline.
	Recycle 45% of sanitary wastes from all operations by 2005 and 50% by 2010.
	Reduce waste resulting from cleanup, stabilization, and decommissioning activities by 10% on an annual basis.
Buy Items with Recycled Content	Increase purchases of EPA-designated items with recycled content to 100%, except when not available competitively at a reasonable price or that do not meet performance standards.
Improve Energy Usage	Reduce energy consumption through life-cycle cost effective measures by 40% by 2005 and 45% by 2010 per gross square foot for buildings, using a 1985 baseline and 20% by 2005 and 30% by 2010 per gross square foot, or per other unit as applicable, for LLNL and industrial facilities, using a 1990 baseline.
	Increase the purchase of electricity from clean energy sources: (a) Increase purchase of electricity from renewable energy sources by including provisions for such purchase as a component of our requests for bids in 100% of all future DOE competitive solicitations for electricity. (b) Increase the purchase of electricity from less greenhouse gas-intensive sources including, but not limited to, new advanced technology fossil energy systems, hydroelectric, and other highly efficient generating technologies.
Reduce Ozone Depleting Substances and Greenhouse Gases	Retrofit or replace 100% of chillers greater than 150 tons of cooling capacity and manufactured before 1984 that use class I refrigerants by 2005.
	Eliminate use of class I ozone depleting substances by 2010, to the extent economically practicable, and to the extent that safe alternative chemicals are available for DOE class I applications.
	Reduce greenhouse gas emissions attributed to facility energy use through life-cycle cost-effective measures by 25% by 2005 and 30% by 2010, using 1990 as a baseline.
Increase Vehicle Fleet Efciency and Use of Alternative Fuels	Reduce entire fleet's annual petroleum consumption by at least 20% by 2005 in comparison to 1999, including improving the fuel economy of new light duty vehicle acquisitions and by other means.
	Each year, acquire at least 75% of light duty vehicles as alternative fuel vehicles, in accordance with the requirements of the Energy Policy Act of 1992.
	Increase usage rate of alternative fuel in departmental alternative fuel vehicles to 75% by 2005 and 90% by 2010 in areas where alternative fuel infrastructure is available.

Waste Minimization/Pollution Prevention

The P2 Program at LLNL strives to systematically reduce solid, hazardous, radioactive, and mixed-waste generation, and eliminate or minimize pollutant releases to all environmental media from all aspects of the site's operations. These efforts help protect public

Table 2-8. Routine waste reduction in FY 2003

Waste category	1993 (baseline)	FY 2003	Reduction 2003 since 1993 (%)
Low-level radioactive	346 m^3	85 m^3	75
Mixed low-level	26 m^3	18 m^3	31
Hazardous	1054 MT[a]	179 MT	83
Sanitary (nonhazardous solid waste)	5873 MT	4727 MT	20

a MT = metric tons

health and the environment by reducing or eliminating waste, improving resource usage, and reducing inventories and releases of hazardous chemicals. These efforts also benefit LLNL by reducing compliance costs and minimizing potential civil and criminal liabilities under environmental laws. In accordance with EPA guidelines and DOE policy, the P2 Program uses a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal) applied, where feasible, to all types of waste. The P2 team tracks waste generation using the TWMS database. By reviewing this database, program managers and P2 staff can monitor and analyze waste streams to find cost effective improvements to business and mission though pollution prevention.

In August 2003, LLNL submitted the 2002 Hazardous Waste Source Reduction and Management (SB-14) Review Report to the DOE/National Nuclear Security Administration (NNSA) Livermore Site Office in accordance with California Code of Regulation (CCR) Title 26, Section 22-67100.1 *et seq*. The DOE/NNSA Livermore Site Office in turn submitted the LLNL SB-14 Review Report, along with similar reports from Lawrence Berkeley National Laboratory (LBNL), Stanford Linear Accelerator Center (SLAC), and Sandia National Laboratories/California (Sandia/California), to the California DTSC. This report, which is completed every four years, includes 1) a plan that evaluates major LLNL waste streams and a review of possible source reduction measures four years into the future and 2) a performance report that describes LLNL's hazardous waste management practices and accomplishments since the previous SB-14 report and compares them to the baseline year.

LLNL successfully reduced or eliminated a significant portion of the California waste code wastes identified in the 1998 SB-14 Plan. Category B wastes were reduced by approximately 150,000 pounds and extremely hazardous wastes cut to roughly a quarter of what they were in 1998.

LLNL also has two institutional nonhazardous waste minimization projects. One is operated through the Donation, Utilization & Sales Area by selling excess equipment that still has a usable life span rather than disposing of it. In addition all four LLNL cafeterias have their cooking grease picked up by a vendor; it is then recycled into other products, such as soap.

Diverted Waste

Together, the Livermore site and Site 300 generated 4727 metric tons of routine nonhazardous solid waste in 2003. This volume includes diverted waste (for example, material diverted through recycling and reuse programs) and landfill wastes. LLNL generated 24,912 metric tons of nonroutine nonhazardous solid waste in FY 2003. This includes waste that is reused as cover soil at Class II landfills and through the non-routine metals recycling programs. Nonroutine nonhazardous solid wastes include wastes from construction, and decontamination and demolition activities. In FY 2003, the portion of nonhazardous waste (routine and nonroutine) sent to landfill was 3137 metric tons. The routine portion was 1546 metric tons and the nonroutine portion was 1591 metric tons. The breakdown for routine and nonroutine nonhazardous waste that was sent to landfills in FY 2003 is shown in **Table 2-9**.

Together the Livermore Site and Site 300 diverted 3181 metric tons of routine nonhazardous waste in 2003. This represents a diversion rate of 67% from the 1993 baseline. This diversion rate includes waste recycled by RHWM and waste diverted through the surplus sales and pipette box recycling programs. The total routine and nonroutine waste diverted from landfills in FY 2003 was 26,502 metric tons as shown in **Table 2-10**, which illustrates LLNL's comprehensive waste diversion program.

Source Reduction and Pollution Prevention

LLNL reported lead for the first time in 2003 as part of its TRI reporting for Site 300 (see "Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report" section of this chapter). As a result, LLNL has reviewed potential source reduction opportunities for lead. One opportunity consists of using frangible bullets at the Site 300 firing range which reduces the quantity of discharged lead ammunition. During this time of heightened security, the firing range plays a critical role in the training of LLNL security personnel, such that decreasing range use is not an option. The Greenshield™ ammunition in use is a lead-free polymer compound that disintegrates to dust upon impact with a hard surface. Its use eliminates the contamination and health and safety issues associated with lead.

In a separate firing range source reduction effort, LLNL has partnered with Alameda County Sheriff's Department to recycle brass shell casings from spent ammunition. Casings collected at the LLNL firing range are transported to a sheriff's department facility to be recycled.

A second lead-reduction activity involves LLNL's wildlife biologists, who are tasked with the protection of California red-legged frog and their habitat (see Chapter 5). In 2003, LLNL wildlife biologists converted to the use of non-lead air rifle ammunition (pellets) during their exotic species eradication efforts. Such a conversion is particularly beneficial as the eradication efforts often are focused on areas where lead pellets could enter a water body.

A water conservation pilot project was also implemented at the EPD T5475 facility. The EPD Facility Manager and P2 staff teamed with the Site Energy Management Program to replace all 10 urinals in the building with waterless urinals. The project was funded through FY 2003 DOE Federal Energy Management Program Retrofit Funding. Water

Table 2-9. Total nonhazardous waste sent to landfills in FY 2003

Nonhazardous waste	2003 total (metric tons)
Routine	
Compacted	1546
Nonroutine	
Construction demolition (noncompacted)	1533
Industrial	58
Nonroutine subtotal	1591
LLNL total	3137

Table 2-10. Diverted waste in FY 2003

Waste description	Cumulative 2003 total (metric tons)
Asphalt/concrete	21,495
Batteries	27
Beverage and food containers	4.2
Cardboard	155
Compost	721
Cooking grease/food	1.8
Diverted soil (includes Class II Cover)	1,259
Magazines, newspapers, and phone books	45
Metals	970
Miscellaneous	22
Nonroutine metals	610
Paper	278
Pipette box recycling	1.1
RHWM recycled	88
Surplus sales	260
Tires and scrap	15
Toner cartridges	4.9
Wood	545
LLNL diversion total	26,502

savings is estimated to be up to 20,000 gallons per urinal per year. Two other directorates have funded retrofit projects based on the success of the EPD pilot project. Substituting conventional flush-valve urinals with waterless urinals is also being reviewed for new building construction.

LLNL plans for the removal of chillers and halon fire suppression systems that contain class I ozone depleting substances are on track, as described in the *LLNL Report on Pollution Prevention and Energy Efficiency Leadership Goals* (2001). LLNL will complete removal of 4 of 7 chillers that have greater than 150 tons of cooling capacity by 2005. Three other chillers with 150 ton cooling capacities are scheduled for removal by 2007, and 8 other smaller chillers will be replaced as they achieve the end of their useful lives between 2010 and 2015. To date, 92% of the halon-containing fire suppression systems that were in place in 1995 have been replaced, leaving only 5 active systems on site.

In October 2003, EPD began participation in the Federal Electronics Challenge (FEC). The FEC is an EPA-coordinated, voluntary pilot program that is designed for federal agencies and facilities to collaborate with each other regarding the three life cycle phases of electronic equipment: acquisition and procurement, operations and maintenance, and end-of-life management. The specific goals of the FEC are to encourage participating partners to purchase greener electronic products, reduce impacts of electronic products during use, and manage obsolete electronics in an environmentally friendly way. EPD's participation in the FEC complimented efforts already underway to assess LLNL's management practices for electronic waste (e-waste), including preparation for reporting of the recycle/disposal of cathode ray tubes under SB 20 (Electronic Waste Recycling Act) in 2004.

Current ROI

DOE has traditionally funded P2 projects through the High-Return-on-Investment (ROI) P2 Program. In FY 2003, however, there was no new ROI funding available. One new ROI project, a mercury thermometer exchange, was paid for with carryover funds from FY 2002 (see **Table 2-11**). Other ROI work occurring in 2003 was associated with ongoing projects funded in previous years (also described in **Table 2-11**). Two ROI projects were recipients of EPA Champions of Green Government Awards: the Water Recovery/Drain Down System project and the Photovoltaic Demonstration project.

Review of New Processes, Programs, or Experiments

LLNL recently started two affirmative procurement programs. One targets recycled printer toner cartridges where LLNL's vendor automatically provides reconditioned cartridges when available. The second affirmative procurement program encourages the use of 30% post-consumer paper. Before virgin paper can be ordered, the Recycling Coordinator works with the requestor to verify that virgin paper is required. To date, only one brand of color copier is unable to utilize 30% post-consumer paper.

On an ongoing basis, the P2 team promotes a "front-end" review process of new programs, projects, or experiments that could have a significant impact on the environment. For small-scale activities such a review includes an assessment of the hazardous

Table 2-11. High ROI projects in FY 2003

Operation	Project
Mercury Thermometer Exchange Pilot	This pilot project was started in 2003 within the Chemistry & Chemical Engineering Division of the Chemistry & Material Science Directorate. The goal of the pilot is to reduce environmental, health, and safety risk by removing mercury-containing thermometers from use in specified LLNL laboratories. An associated goal is to evaluate how the alternative non-mercury thermometers are received by chemists with specialized temperature measurement needs.
Global Electric Motorcars (GEM) Pilot study	This project funded the purchase of a limited number of Daimler-Chrysler GEMs for a pilot study by the Fleet Management Group. The study, carried out in 2003, evaluated the integration of electric vehicles into the LLNL fleet. Deemed a success, Directorates can now work with Fleet Management to purchase the GEM cars for continued on-site use.
Water Recovery/Drain Down System (completed in FY 2002)	This project funded the purchase and conversion of a water-tank trailer to facilitate removal, storage and replacement of chiller water during maintenance operations. This project, previously a winner of two federal water conservation awards, received an EPA 2003 Champions of Green Government Award.
Photovoltaic (PV) Demonstration Project	This demonstration project installed three types of photovoltaic arrays at the LLNL Discovery Center to demonstrate different PV technologies and deployment scenarios. This project received an EPA 2003 Champions of Green Government Award.

materials to be used and an estimate of the associated wastes. This type of review can also be applied to existing operations. For large processes or new programs, a more extensive review using a tool such as Design for Environment may be applied.

Green building, an integrative, "front-end" concept currently making inroads into new construction at LLNL, emphasizes the design of buildings that are efficient in their use of materials, energy, and other natural resources throughout their life cycle. Significant efforts to incorporate green building into LLNL design practices occurred in 2002 when EPD and Plant Engineering jointly sponsored a Leadership in Energy and Environmental Design (LEED) training session for specific LLNL, Sandia/California, and LBNL personnel.

Promotion of green building at LLNL continued during 2003. In June, the P2 Team sponsored the visit of the Dean and Assistant Dean of the University of California Santa Barbara Donald Bren School of Environmental Science and Management to discuss the green building achievements at their new Donald Bren Hall, which garnered a Platinum rating from the U.S. Green Building Counsel for its design, construction and performance. Attending an executive briefing were representatives from the UC Office of the President, the DOE /NNSA Livermore Site Office, and senior LLNL management from Plant Engineering, the Institutional Manager's Office and the EPD. LLNL staff responsible for the design, project management, construction, and operations of LLNL buildings attended a second session. Guests from Stanford University, SLAC, LBNL and Sandia/California also attended.

A second green building event was held in August when the P2 team sponsored a design charrette for an LLNL generic office building using the LEED building rating system. Green building expert Bill Reed conducted the charrette, which was tailored to the project team for the series of generic office buildings and open to all in Plant Engineering. Training events such as these continue to familiarize LLNL architects, engineers, planners and other professionals with the knowledge and tools to increase the "green" properties of future LLNL buildings.

Pollution Prevention Employee Training and Awareness Programs

In 2003, LLNL conducted a number of activities to promote employee awareness of Pollution Prevention. A key event, the annual Earth Expo, was held in April to coincide with Earth Day. It featured representatives from LLNL environmental activities, businesses with environmentally friendly products, environmental conservation organizations, utilities, environmental agencies, and other organizations with environmental charters. During the course of the year, Pollution Prevention articles appeared in the LLNL newspaper, *Newsline*, and electronic newsletter, *NewsOnLine*. The P2 team conduced training for purchasing staff on EPA requirements for affirmative procurement. The P2 team also placed banners at entry gates for America Recycles Day and National Pollution Prevention Week.

In spring 2003 the P2 team brought a new internal P2 web site online for LLNL employees. The web page is a resource for employees regarding pollution prevention, energy efficiency, the reuse and recycling of materials, green building, and other environmental topics. Employees can also use the site to suggest P2 ideas, ask questions about P2 planning and implementation, and find out about P2 "current events." The P2 team also operates the Earth Hotline. LLNL employees can call with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors.

Contributing Authors

Many authors significantly contributed to this large and diverse chapter. We acknowledge here the work of Mohammad Abri, Art Biermann, Richard Blake, Shari Brigdon, Richard Brown, Bruce Campbell, John Collins, Barbara Fields, Katharine Gabor, Allen Grayson, Robert Harrach, Steve Harris, Bert Heffner, Rod Hollister, William Hoppes, Thom Kato, Danny Laycak, Sandra Mathews, Paul McGuff, Jennifer Nelson-Lee, Barbara Nisbet, Victoria Salvo, Lily Sanchez, Bill Schwartz, Judy Steenhoven, Michael Taffet, Paula Tate, Stan Terusaki, Earl Thomas, Kent Wilson, Joseph Woods, and Peter Yimbo.

3

Air Monitoring Programs

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Lawrence Livermore National Laboratory performs continuous air sampling to evaluate its compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected from hazardous and radioactive air emissions. Federal environmental air quality laws and U.S. Department of Energy (DOE) regulations include Title 40 of the Code of Federal Regulations (CFR) Part 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act, and applicable portions of DOE Order 5400.5, Radiation Protection of the Public and the Environment, and American National Standards Institute (ANSI) standards. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) provides the guidance for implementing DOE Order 5400.5.

The U.S. Environmental Protection Agency (EPA) Region IX has oversight responsibility for LLNL compliance with radiological air emissions regulations. Enforcement authority for the Clean Air Act regulations pertaining to nonradiological air emissions belongs to two local air districts, the Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD).

Whereas LLNL conducts air effluent monitoring of atmospheric discharge points to determine the actual radionuclide releases from individual facilities and processes during routine and nonroutine operations, ambient air monitoring at LLNL-site and off-site locations determines if airborne radionuclides or hazardous materials are being released by LLNL operations to its environs. Ambient air monitoring also serves to verify the air concentrations predicted by air dispersion modeling and to determine compliance with the NESHAPs regulation. (See *LLNL NESHAPs 2003 Annual Report* [Harrach et al. 2004] and Chapter 6.)

Air Effluent Monitoring

LLNL uses a variety of radioisotopes including uranium, transuranics, biomedical tracers, tritium, and mixed-fission products for research purposes. The major radionuclide released to the atmosphere from the Livermore site is tritium. In addition to effluent sampling for tritium, a number of facilities at the Livermore site have air effluent samplers to detect the release of uranium and transuranic aerosols. The air effluent sampling systems described in this section apply to stationary point source discharges.

Air effluent monitoring of atmospheric discharge points is used to determine the actual radionuclide releases from individual facilities and processes during routine and nonroutine operations, to confirm the operation of facility emission control systems, and to corroborate and aid in the resolution of ambient air measurement results for the site. (The relationship can work the other way as well—air surveillance measurements can corroborate effluent monitoring.) It involves the extraction of a measured volume of air from the exhaust of a facility or process and subsequent collection of particles by filters or

of vapors by a collection medium. After collection, the various radionuclides in the sample are measured by appropriate analytical methods. Currently, the air effluent sampling program measures only radiological emissions. LLNL has operations with nonradiological discharges; however, permits for these operations are obtained through local agencies, BAAQMD and SJVUAPCD, and monitoring of the effluent is not required. The California Air Toxics "Hot Spots" legislation requires facilities to prepare an air toxics emissions inventory and risk assessment, which LLNL has completed. Based on the assessment, BAAQMD and SJVUAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

Methods

LLNL evaluates all discharge points with the potential to release radionuclides to the air according to 40 CFR 61, Subpart H, of the NESHAPs regulations. The NESHAPs 40 CFR 61, Subpart H, regulations require that facility radiological air effluents must be continuously monitored if the potential off-site dose equivalent is greater than 1 µSv/y (0.1 mrem/y), as calculated using the EPA-mandated air dispersion dose model and assuming that there are no emission control devices. The results from monitoring the air discharge points provide the actual emission source information for modeling, which is used to ensure that the NESHAPs standard, 100 µSv/y (10 mrem/y) total site effective dose equivalent, is not exceeded. LLNL uses radionuclide usage inventories and/or 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. Monitoring of radionuclide air effluents at LLNL has been implemented according to the DOE as low as reasonably achievable (ALARA) policy. This policy is meant to ensure that DOE facilities are capable of monitoring routine and nonroutine radiological releases so that the dose to members of the public can be assessed, and so that doses are ALARA.

In 2003, LLNL operated 72 sampling systems for radioactivity from air exhausts at 8 facilities at the Livermore site (see **Figure 3-1**) and 1 sampling system at Site 300 (see **Figure 3-2**). These systems are listed in **Table 3-1** along with the analytes of interest, the type of sampler, and the number of samplers. LLNL periodically reassesses the need for continuous monitoring and assesses new operations or changes in operations. From NESHAPs assessments of operations during 2003, one additional discharge point, a new operation in Building 695, was found to require continuous sampling.

LLNL also operates a low-volume radiological air particulate network that consists of two samplers located at HOSP and FCC. The results from these samplers are used to establish background levels of gross alpha and beta activity for direct comparison to emissions from the air effluent samplers. These low-volume samplers collect particulate at a continuous rate of 0.03 m^3/min using membrane filters.

In the past, sampling operations performed in Buildings 175, 177, 490, and 491 have supported research and development for the separation of uranium isotopes under the Advanced Vapor Laser Isotope Separation (AVLIS) Program. In 1999, the AVLIS

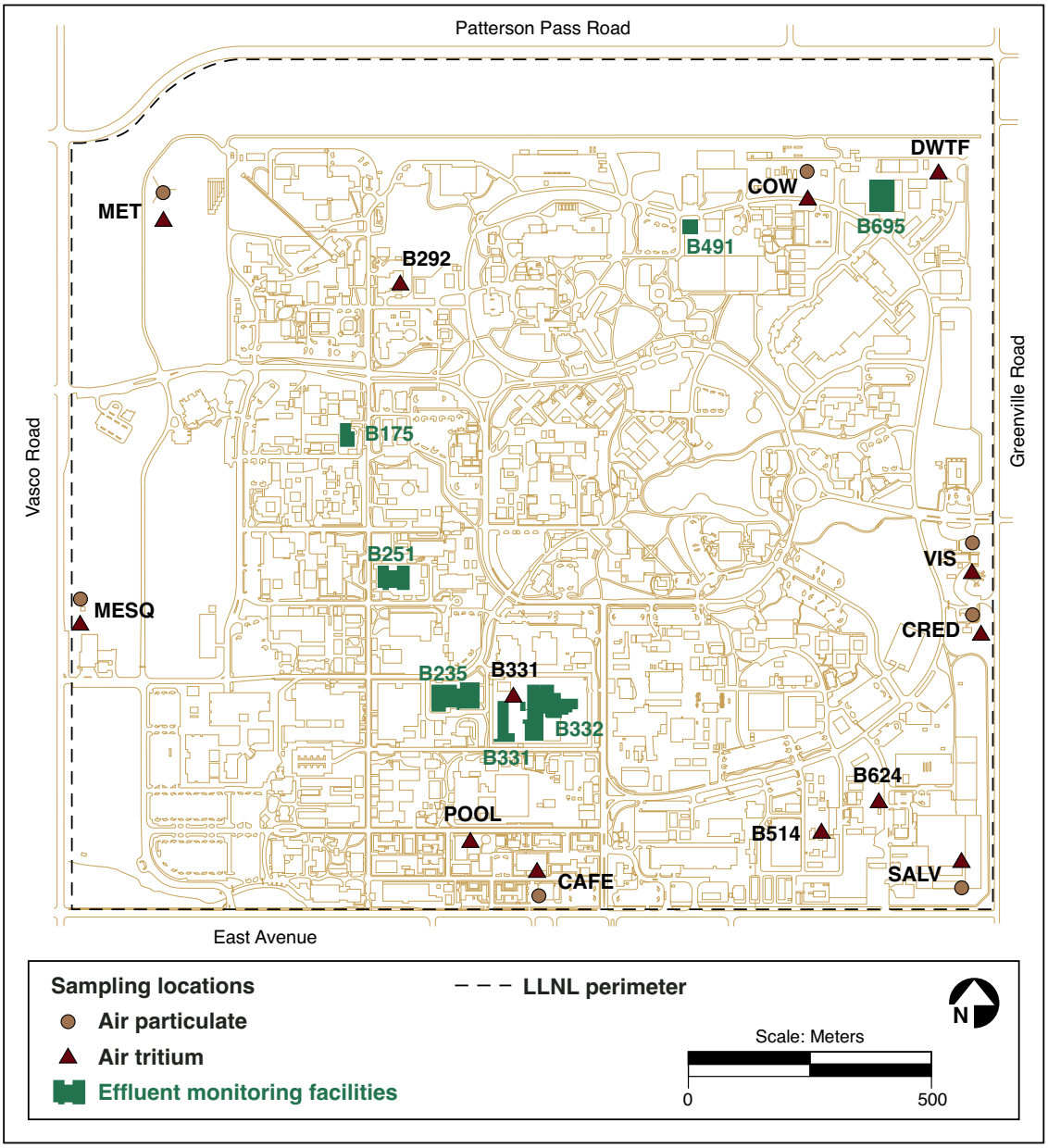

Figure 3-1. Livermore site air monitoring locations, 2003

Program was terminated, and samplers on a Building 490 exhaust system were deactivated because the operation of the ventilation system was stopped. In February 2002, decontamination activities at Building 177 were completed and the sampling system was deactivated. In May 2003, sampling at Building 175 was discontinued because the facility no longer possessed a radionuclide inventory or plans to conduct activities with

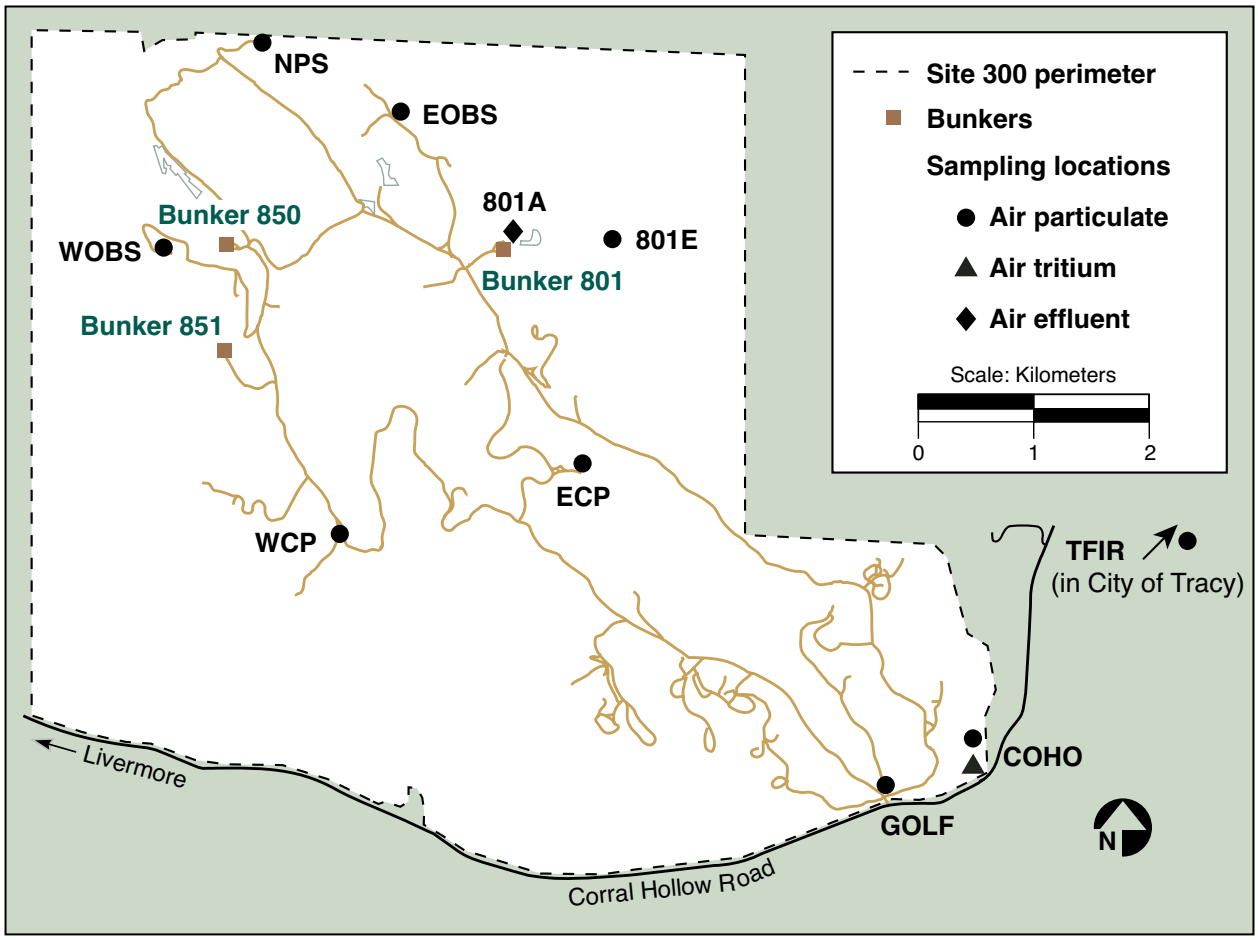

Figure 3-2. Site 300 air monitoring locations, 2003

radionuclides in the forseeable future. The air effluent sampling system at Building 491 continues to operate as part of the maintenance and surveillance shutdown plan for AVLIS facilities.

Sampling for particles containing radioactivity was conducted in seven of the facilities and sampling for tritium was conducted in the Tritium Facility (Building 331). All sampling systems operated continuously. Samples were collected weekly or biweekly, depending on the facility. Most air samples for particulate emissions were extracted downstream of high-efficiency particulate air (HEPA) filters and before the emissions were discharged to the atmosphere. Particles in the extracted air were collected on sample filters and analyzed for gross alpha and beta activity. Tritium was collected using molecular sieves.

In addition to sample collection for environmental reporting, some facilities used real-time alarm monitors (listed in **Table 3-1**) at discharge points to provide faster notification in the event of a release of radioactivity.

Table 3-1. Air effluent sampling locations and sampling systems

Building	Facility	Analytes	Sampler type	Number of samplers
175	Mars[a]	Gross α, β on particles	Filter	6
235	Chemistry and Materials Science	Gross α, β on particles	Filter	1
251	Heavy Element	Gross α, β on particles	Filter	27
331	Tritium	Tritium	Stack ionization chamber[b]	4
		Gaseous tritium and tritiated water vapor	Molecular sieves	4
332	Plutonium	Gross α, β on particles	Stack CAM[b,c]	12
		Gross α, β on particles	Filter	15
491	Laser isotope separation	Gross α, β on particles	Filter	1
695	Decontamination and Waste Treatment Facility	Gross α, β on particles	Filter	1
801A	Contained Firing Facility	Gross α, β on particles	Filter	1

a Operations discontinued; however, air effluent sampling systems at this building continued to operate as part of the maintenance and surveillance shutdown plan for the facilities. The sampling system in Building 175 was removed from service in May 2003; the building no longer contained an inventory of radioactive materials.

b Alarmed systems

c CAM = Eberline continuous air monitors

Analytical results from the continuous samplers are reported as a measured concentration per volume of air or as less than the minimum detectable concentration (MDC) when no activity is detected. In all cases, the MDC is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that are present or may be present in the sampled air. Air effluent samples were obtained in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002).

The following sections discuss the radiological air emissions from facilities that have continuously monitored discharge points. All effluent air analytical results are summarized in the file "Ch3 Air Effluent" included on the report CD.

Air Effluent Radiological Monitoring Results

In 2003, a total of 4.1 TBq (110 Ci) of tritium was released from the Tritium Facility (Building 331). Of this, approximately 3.8 TBq (104 Ci) were released as tritiated water vapor (HTO). The remaining tritium released, 0.22 TBq (6.0 Ci), was elemental tritium gas (HT). The median emissions from the facility were 6.0×10^3 Bq/m^3 (1.6×10^{-7} Ci/m^3) for HTO, and 5.1×10^2 Bq/m^3 (1.4×10^{-8} Ci/m^3) for HT. The

highest single weekly stack emission from the facility was 0.38 TBq (10.2 Ci), of which 0.37 TBq (10.05 Ci) was HTO. Emissions from Building 331 for 2003 continued to remain considerably lower than those during the 1980s. **Figure 3-3** illustrates the combined HTO and HT emissions from the facility since 1981.

Most sample results from the continuously sampled discharge points that have the potential for releasing particulate radionuclides were below the MDC of the analysis. Sometimes a sample will exhibit concentrations greater than the MDC. Generally, these samples are only marginally above the MDC. Due to the way some of the exhaust systems are configured, the monitoring systems sometimes sample air from the atmosphere in addition to HEPA-filtered air from facility operations, thereby collecting background atmospheric radioactivity. If gross alpha is detected, a check is performed to determine if the ventilation blowers were operational at the time of the detection and the results are compared to the low-volume sampling results. If the blowers were operational, the sample result is considered a valid detection; otherwise the result is considered to be background atmospheric radioactivity. None of the facilities monitored for gross alpha and beta at the Livermore site had emissions in 2003.

Building 801A has a continuously monitored air effluent sampling system because depleted uranium is used during facility operations. Building 801 facility activities involving radionuclides are performed in the area of the building where the air is exhausted through HEPA filtration. Operations conducted in the building high bay do

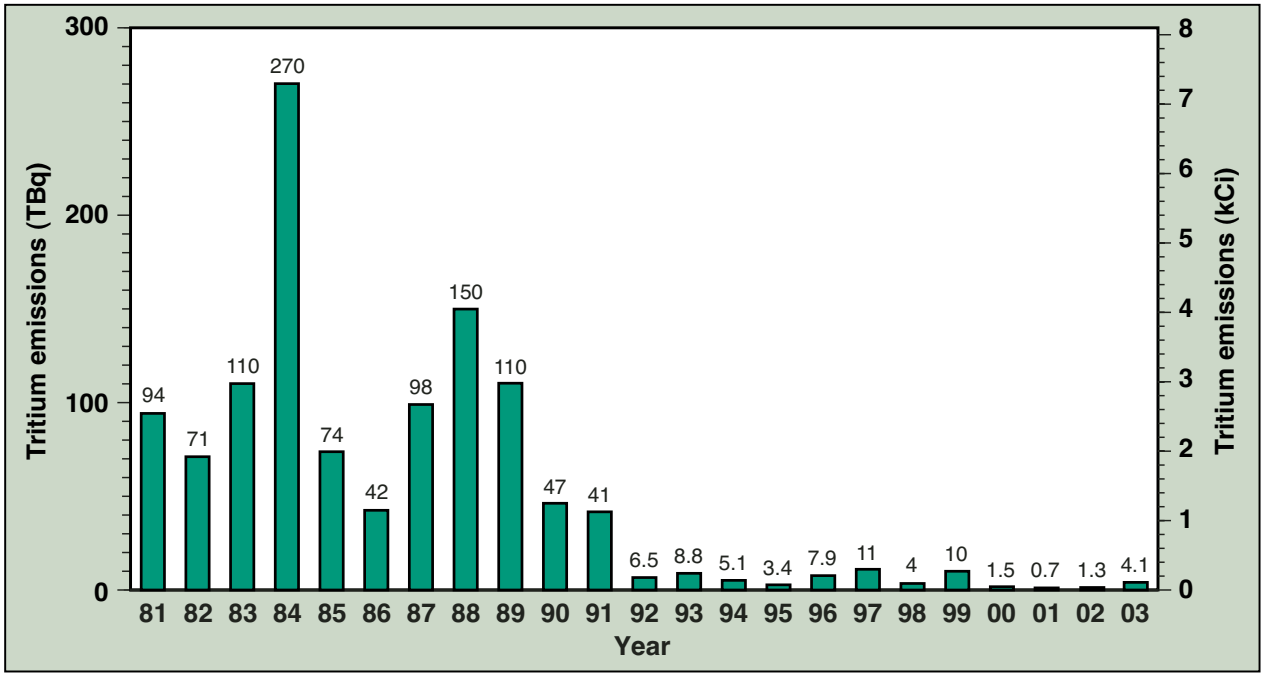

Figure 3-3. Tritium Facility combined HTO and HT emissions from 1981 through 2003

not use radionuclides and exhaust to the stack without HEPA filtration. Consequently, some of the air sampled by the effluent sampling system is unfiltered. In order to determine if any emissions occurred from this facility, the sampling results must be compared to results from the ambient air samplers. In 2003, ten samples out of 48 had concentrations greater than the MDC. The median concentration of the Building 801A alpha detections was 2.4×10^{-4} Bq/m^3 (6.6×10^{-15} Ci/m^3), which is approximately three times higher than the median concentration of the off-site sampling locations. The conservative approach is being taken by reporting this as actual emissions.

The gross alpha emissions for Building 801A was 1.9×10^4 Bq/y (5.1×10^{-7} Ci/y). **Table 3-2** summarizes total radiological emissions as determined from the continuous sampling of facility exhausts for 2003.

Nonradiological Results

The Livermore site currently emits approximately 101 kg/day of regulated air pollutants as defined by the Clean Air Act (e.g., nitrogen oxides, sulfur oxides, particulate matter [PM-10], carbon monoxide, and lead). The largest sources of criteria pollutants from the Livermore site are surface-coating operations, internal combustion engines, solvent operations, and, when grouped together, boilers (oil and natural gas fired). **Table 3-3** lists the estimated Livermore site 2003 total airborne releases for criteria pollutants.

When comparing the estimated releases from exempt and permitted sources of air pollutants at the Livermore site with daily releases of air pollutants for the entire Bay Area, LLNL emissions are very low. For example, the total emissions of nitrogen oxides released in the Bay Area for 2003 were approximately 7.1×10^4 kg/day, compared with an estimate for LLNL releases of 63 kg/day for the Livermore site (0.09% of total Bay Area emissions from stationary sources). The BAAQMD estimate for reactive organic emissions was 9.4×10^4 kg/day for 2003, versus the Livermore site's estimated releases of 14 kg/day (0.01% of total Bay Area emissions from stationary sources) in 2003.

Certain operations at Site 300 require permits from SJVUAPCD. The total estimated air emissions during 2003 from operations (permitted and exempt air sources) at Site 300 are given in **Table 3-3.** The largest sources of criteria pollutants at Site 300 include internal combustion engines, boilers, a gasoline-dispensing operation, open burning, paint spray booths, drying ovens, and soil vapor extraction operations.

Table 3-2. Measured radiological air effluent emissions above the detection limit for Livermore site and Site 300, 2003

Building (Facility)	HT (Bq)	HTO (Bq)	Gross alpha (Bq)	Gross beta (Bq)
331 (Tritium Facility)	2.2×10^{11}	3.8×10^{12}	—	—
801A (Contained Firing Facility)	—	—	1.9×10^4	9.7×10^4 [a]

a Value is consistent with background

Table 3-3. Nonradioactive air emissions, Livermore site and Site 300, 2003

Pollutant	Estimated releases (kg/day)	
	Livermore site	Site 300
Organics/volatile organics	14	0.57
Nitrogen oxides	63	0.97
Carbon monoxide	16	0.22
Particulates (PM-10)	5.8	0.31
Sulfur oxides	1.7	0.98

Environmental Impact on Air Effluent

Measured radiological air emissions from the Livermore site operations for 2003 are well below levels that would cause concern for public health and are well below existing regulatory standards for radioactive dose. The site-wide dose to the hypothetical maximum exposed individual of the public from Building 801A is 1.3×10^{-5} µSv/y (1.3×10^{-6} mrem/y). The dose to the hypothetical maximally exposed member of the public caused by the measured air emissions from the Tritium Facility (modeling HT emissions as HTO as required by EPA) is 0.22 µSv/y (0.022 mrem/y). Thus, the estimated radiological dose caused by measured air emissions from LLNL operations is minimal. See Chapter 6 for a discussion of doses.

Estimated nonradioactive air emissions, which are also very small compared with emissions in surrounding areas, are well below standards and pose no threat to the environment or public health.

Ambient Air Monitoring

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 the ambient air monitoring program, LLNL collects particles on filters and physically traps vapors on a collection medium. Concentrations of various airborne radionuclides (including particles and tritiated water vapor) and beryllium metals are measured at the Livermore site, Site 300, and at off-site locations throughout the Livermore Valley and in the City of Tracy. In addition, some point sources and diffuse, or nonpoint sources, are monitored to fulfill NESHAPs requirements. In 2003, the EPA approved use of the air surveillance monitoring data from the location of the site-wide maximally exposed individual (SW-MEI) to demonstrate compliance with NESHAPs for minor emission point sources (Harrach et al.

2003). In addition, the Derived Concentration Guides (DCGs) found in DOE Order 5400.5 specify the concentrations of radionuclides that can 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. (Chapter 6 provides an explanation of this and other units of dose.) Data tables in this chapter present the DCG and the percent of the DCG for the given isotope. For beryllium metals, an ambient air concentration limit of 10,000 pgm/m^3 is established by the BAAQMD under Regulation 11 for the Hazardous Air Polltants.

Methods

Monitoring networks are established for surveillance of air particulates and tritium in the environs of the Livermore site and Site 300, as well as in the surrounding Livermore Valley and in the City of Tracy. All monitoring networks use continuously operating samplers.

The sampling locations for each monitoring network are listed in **Table 3-4** and shown on **Figures 3-1**, **3-2** and **3-4**. Several locations target specific areas of known contamination while other locations are considered perimeter or background locations. Duplicate quality control samplers operate in parallel with the permanent sampler at a given site, and these samples are analyzed to confirm results. Trip blanks are also taken on the air sampling routes to help identify any contaminate introduction during the sampling process.

In 2003, an LLNL state-certified analytical laboratory performed all sample analyses. Samples were analyzed for gross alpha and beta activity, gamma-emitting radionuclides, plutonium, uranium, tritium and beryllium metals. **Table 3-4** provides the requested analysis for each ambient air sampling station. Ambient air samples were obtained in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002).

Sample Collection

The air particulate networks use high-volume air sampling units, which collect airborne particulate at a continuous rate of 0.42 m^3/min using Whatman 41 cellulose filters. The tritium samplers, operating at a flow rate of 500 cm^3/min, use a continuous vacuum pump to capture air moisture on silica gel contained in sampling flasks. These flasks are changed every two weeks.

Table 3-4. Sampling locations and type and frequency of analyses for ambient air

Livermore site						
	Target location	Weekly gross alpha & beta (high volume)	Monthly $^{239+240}Pu$	Monthly Gamma & $^{235, 238}U$[a]	Monthly beryllium	Biweekly tritium
Network	Air particulate					Air vapor
Collection Media	Cellulose					Silica gel
SALV, MET MESQ, COW CAFE, VIS[b]	Perimeter	X	X	X	X	X
DWTF	Perimeter					X
B331, B514, B624 POOL, B292[c]	Diffuse					X
ZON7	Downwind	X	X			X
PATT	Downwind	X	X			X
AMON	Downwind	X	X			
CHUR	Upwind	X	X			X
FCC[d], VET, FIRE, CRED[b]	Upwind	X	X			X
HOSP[d], TANK	Upwind	X	X			
LWRP	Special Interest	X	X			
Site 300						
		Weekly gross alpha & beta (high volume)	Monthly Gamma & $^{239+240}Pu$[a]	Monthly $^{235, 238}U$	Monthly beryllium	Biweekly tritium
Network		Air particulate				Air vapor
Collection Media		Cellulose				Silica gel
EOBS, GOLF, WOBS	Onsite[b]	X	X	X	X	
ECP, WCP, NPS, 801E	Onsite[b]	X	X	X		
COHO	Onsite[b]	X		X		X
TFIR	Offsite[b]	X		X	X	

a Perimeter composite samples include portions of weekly filters from the specified locations.

b SW-MEI

c Removed from Air Tritium Network in July 2003

d Low-volume sampler also operated at this location, the collection media is millipore filters. These samplers are operated to provide background values for the air effluent monitoring program.

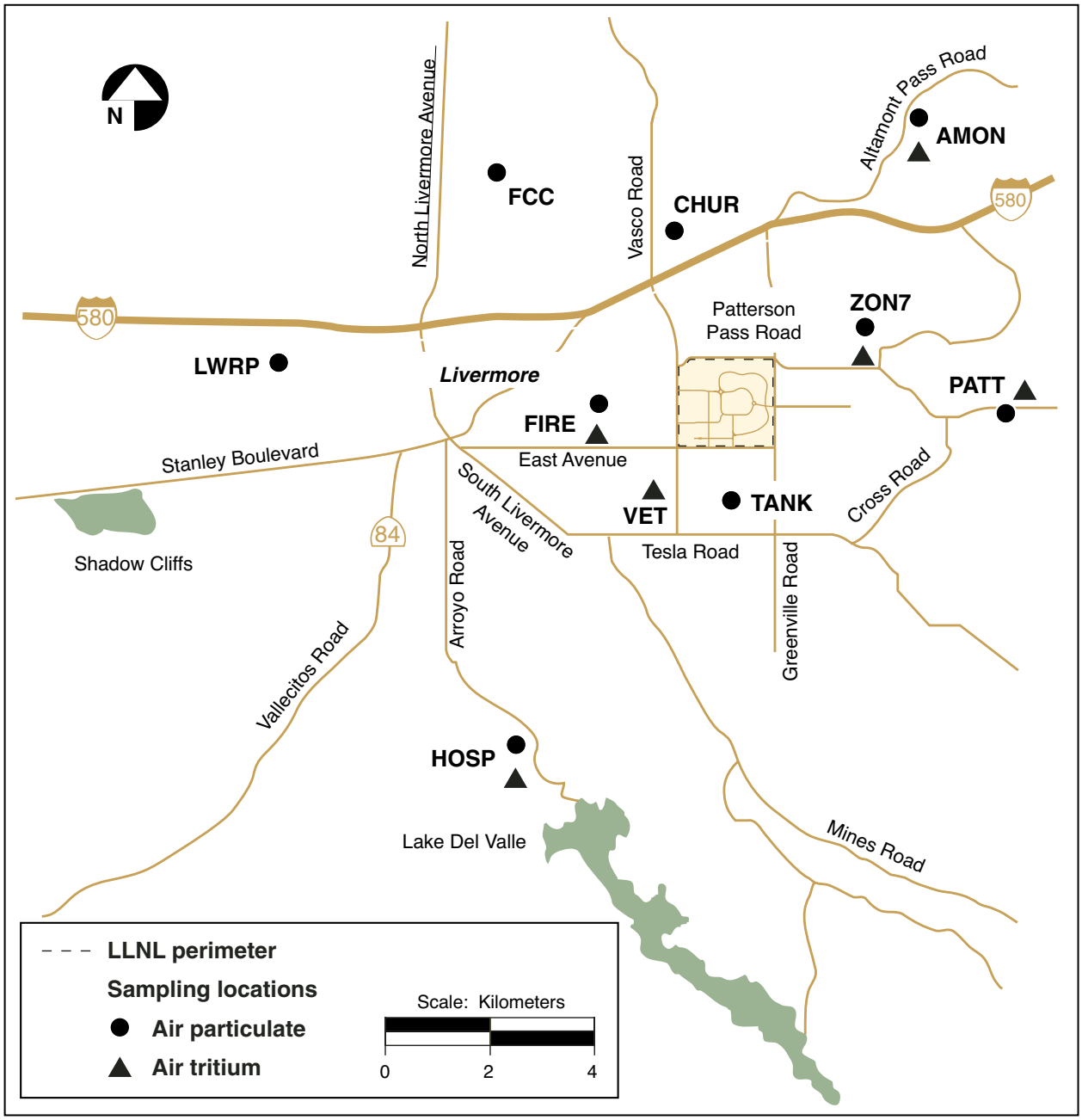

Figure 3-4. Air particulate and tritium sampling locations in the Livermore Valley, 2003

Sampling Locations

Using the historical meteorological data to determine prevailing wind direction, LLNL staff has positioned all ambient air samplers to provide reasonable probability that any significant concentration of radioactive or beryllium effluents from LLNL operations will be detected. LLNL activities are routinely evaluated though air dispersion modeling to ensure the sampling units are positioned properly.

Monitoring networks are established for surveillance of air particulates and tritium in the environs of the Livermore site and Site 300, as well as in the surrounding Livermore Valley and in the City of Tracy. There are 7 air particulate samplers on the Livermore site, 9 in the Livermore Valley, 1 in the City of Tracy, and 8 at Site 300. There are 12 air tritium samplers at the Livermore site, 6 in the Livermore Valley, and 1 at Site 300.

In general, air sampling locations are grouped in categories representing the following areas; perimeter, upwind, downwind, diffuse soures or areas of known contaminaiton, and special interest locations. The results from locations CRED and VIS serve as the SW-MEI for NESHAPs minor source compliance. Because resuspension of soil at Site 300 is the minor source of greatest interest, the average of all 8 locations serves as the SW-MEI for NESHAPs minor source compliance.

The air tritium sampling location B292 was removed in July and a new air tritium sampling location was added at CRED.

Beryllium is monitored at six Livermore site perimeter locations as required by the BAAQMD. Although there is no requirement to monitor beryllium at Site 300, as a best management practice, it is monitored at three locations on-site and at one location in the City of Tracy (see **Figure 3-2**).

Sample Analysis

Gross alpha and gross beta activities are determined by gas flow proportional counting; plutonium isotopes by alpha spectrometry; uranium isotopes by inductively coupled plasma-mass spectrometry; gamma emitters by gamma spectroscopy; and tritium by freeze-dried vacuum distillation followed by liquid scintillation. Procedures for analysis are summarized in the *Environmental Monitoring Plan* (Woods 2002). Beryllium metal concentration is determined by inductively coupled plasma-mass spectrometry as described in UCRL-POST-201469. See **Table 3-4** for the frequency of analysis at each location. In addition to using the analytical methods summarized in this section, the analytical laboratory also runs a series of quality control tests that include laboratory control spikes, blanks and duplicates. The analytical laboratory reports the actual instrumentation values, including negative results that arise when background measurements are higher than those for the sampled filters.

Because plutonium research occurs at the Livermore site, plutonium analyses are performed individually for all Livermore locations. However, plutonium is not used at Site 300; therefore, a composite from all locations is analyzed.

Uranium use at the Livermore site is very minimal so a composite from all the Livermore site perimeter locations is created and analyzed for uranium activity. However, at Site 300, where depleted uranium is used in explosives testing, specific locations are analyzed for uranium activity.

Results

As outlined in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991), gross alpha, gross beta, and gamma emitters on air filters are used as trend indicators; specific radionuclide analysis is done for plutonium, uranium, and tritium. Radiological analytical results are reported as a measured activity per volume of air. Regardless of whether any activity is considered to have been detected, the result of the analysis is reported. The activities shown in the tables, located in the file "Ch3 Ambient Air" included on the report CD, displaying monthly and biweekly data are measured concentrations and their associated $\pm 2\sigma$ counting errors.

Particle size distribution on air samples is not determined because the estimated effective dose equivalent to the maximally exposed individual (from the total particulate) is well below the 0.01-mSv (1-mrem) environmental regulatory guide allowable limit (U.S. DOE 1991) using the total particles collected.

Gross Alpha and Gross Beta Concentrations

The primary sources of the alpha and beta activities are the naturally occurring radioisotopes. **Figure 3-5** shows the three-year history of monthly gross alpha and gross beta median activities for the Livermore site perimeter, Livermore Valley, and Site 300 sampling locations. In 2003 the typical gross alpha activity (annual median value) for the Livermore site perimeter was 37 $\mu Bq/m^3$ (0.99 fCi/m^3); for the upwind Livermore Valley stations, the value was 31 $\mu Bq/m^3$ (0.84 fCi/m^3); for the downwind Livermore Valley stations, the value was 36 $\mu Bq/m^3$ (0.97 fCi/m^3); and for Site 300, the value was 31 $\mu Bq/m^3$ (0.84 fCi/m^3). The annual gross beta median for all downwind locations was 320 $\mu Bq/m^3$ (8.6 fCi/m^3); for upwind locations it was 300 $\mu Bq/m^3$ (8.2 fCi/m^3); for the Livermore site perimeter it was 330 $\mu Bq/m^3$ (8.8 fCi/m^3; and for Site 300 it was 320 $\mu Bq/m^3$ (8.6 fCi/m^3).

These data follow a pattern similar to previous years with a seasonal increase in the fall and early winter months. As local soils dry out during the summer months, the resuspended particulate can build up and increase until the winter rains begin. From May to November 2003, LLNL measured less than 0.5 inches of rainfall, while November and December recorded 3.5 and 6.7 inches, respectively. This increase in rainfall most likely reduced the resuspension contribution on air filters, subsequently showing a sharp decline in the gross alpha and gross beta activity detected once the rains started. Isotopic

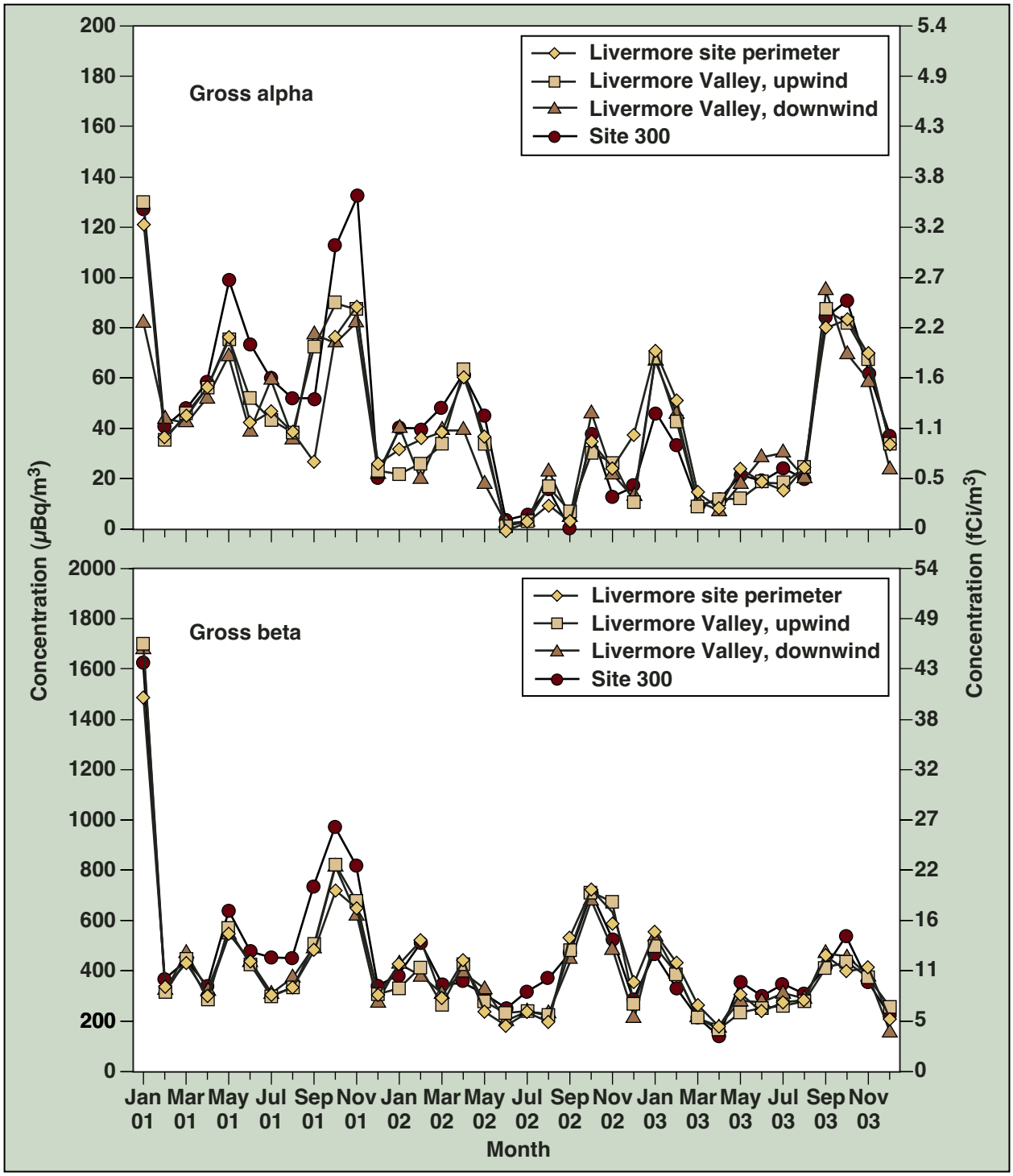

Figure 3-5. Three-year history of the median gross alpha and gross beta activities for all particulate samples grouped by area, 2001-2003

gamma results of these samples indicate that the higher activities are the result of naturally occurring isotopes (uranium, thorium, potassium, and lead) which are also routinely found in local soils.

Site 300 is less developed and has more barren soil compared to the Livermore site. As a result, Site 300 air samples tend to collect more particulate from resusupended soils. The pattern of activity as seen in **Figure 3-5** however is very similar to the Livermore air samples with a increase in the fall and early winter months then decrease during the winter time as rains reduce the resuspension effect. The highest weekly gross alpha sample measured at Site 300 was 218 µBq/m^3 (5.9 fCi/m^3) at WOBS. This sampler is near the active B851 bunker and the Contained Firing Facility (Building 801) where historical operations occurred in open-air shots.

The highest Site 300 onsite weekly gross beta value was 1060 µBq/m^3 (28.6 fCi/m^3) at 801E, also near the Contained Firing Facility. The offsite sampler for the Site 300 route, located in an industrial area, recorded the highest overall concentrations with a weekly maximum of 1360 µBq/m^3 (36.7 fCi/m^3), which is consistent with historical measurements from this sampling location. Because this sampler was in an industrial area, it does not represent a typical background location for Site 300. It was replaced in January 2004 with a more suitable location closer to Site 300 in a more rural area.

Gamma-Emitting Radionuclides

By analyzing air samples for gamma-emitting radionuclides, LLNL verifies that there is no evidence of release of the small inventories of mixed fission products and radiochemical tracers used by LLNL. This analysis will also reveal emissions from global fallout sources such as aboveground tests and the Chernobyl accident (Holland et al. 1987). Composite samples for the Livermore site and Site 300 are analyzed for an environmental suite of gamma-emitting radionuclide concentrations in air. Of those isotopes, beryllium-7 (cosmogenic in origin), lead-210 and potassium-40, all of which are naturally occurring in the environment, were consistently detected at both sites. The results are within known background levels (see file "Ch3 Ambient Air" on report CD for analytical results).

Plutonium Concentrations

Historical environmental plutonium 239+240 activity for the past 20 years is shown in **Figure 3-6**. Locations HOSP and VIS represent typical upwind and onsite sampling locations. Plutonium activity at both of these sites has been decreasing as fallout diminishes and surface areas of potential resuspension have been covered with pavement or buildings. These positive detections are likely due to resuspended soils. LLNL monitors all Livermore area samplers and a composite is created from all onsite Site 300 samplers.

Plutonium 239+240 was detected in 12 of the 187 samples tested from Livermore area air samples. Seven of those positive samples came from on-site samplers. The majority of these were from the SALV location that is in the southeast quadrant of LLNL. The southeast quadrant is an area of known plutonium contamination (see *Environmental*

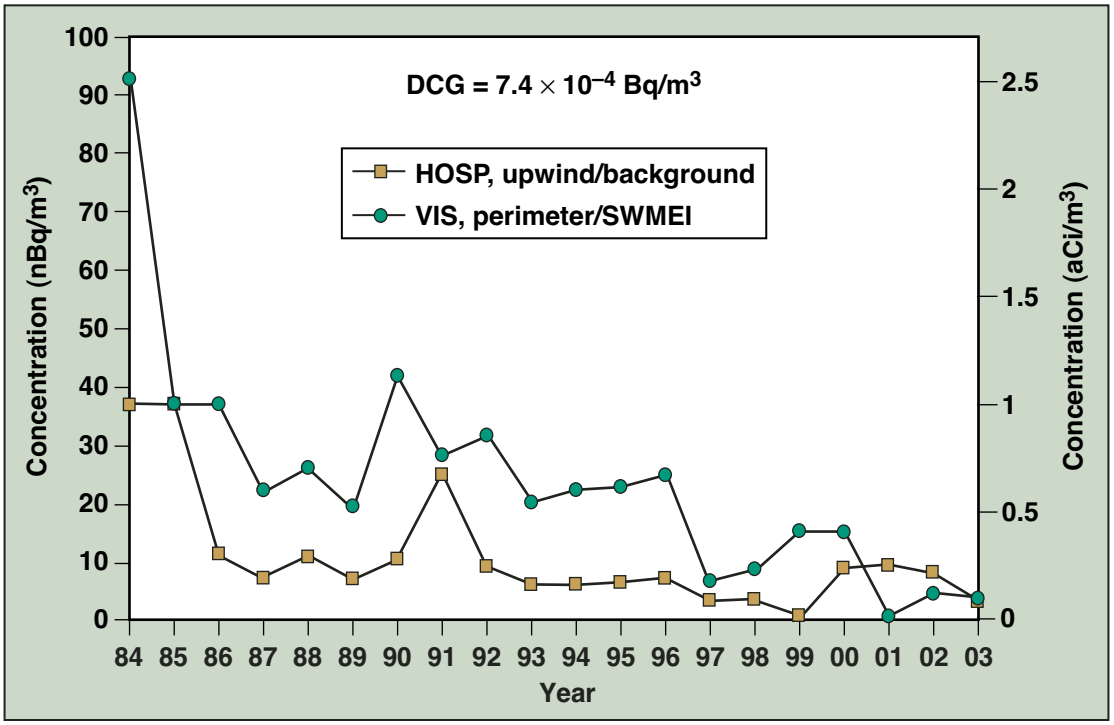

Figure 3-6. Calculated annual median concentrations of plutonium-239+240 for HOSP and VIS for the last 20 years

Report 1990 [Sims et al. 1991]). These plutonium detections can be attributed to the increased construction activities here during summer 2003 that created higher resuspension of localized soils. The highest recorded onsite plutonium 239+240 detection was in December at COW of 65.5 nBq/m^3 (1.77 aCi/m^3) (0.009% of the DCG), while the highest offsite detection occurred in June at the downwind location AMON. This result of 25.5 nBq/m^3 (0.69 aCi/m^3) is only 0.003% of the DCG. Plutonium was detected in 2 of the 12 composite samples collected from Site 300. The highest of these occurred in October with a value of 5.92 nBq/m^3 (0.16 aCi/m^3). This concentration is only 0.0008% of the DCG. All positive detections for plutonium from either site were far below the DCG of 0.74 mBq/m^3.

Uranium Concentrations

Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a mathematical ratio of uranium-235/uranium-238 of 0.00725 and depleted uranium has a uranium-235/uranium-238 ratio of 0.002.

Uranium isotopes are naturally occurring and all but one of the uranium-235 analyses had positive detections. The Livermore site composite had a uranium-235 median concentration of 0.17 µg/m^3 and a uranium-238 median concentration of 21.5 µg/m^3. This composite had a median ratio of 0.007, which is considered natural uranium.

The annual median uranium-235 concentration for the all Site 300 locations was 0.15 pg/m^3 (or less than 0.00003% of the DCG) and the uranium-238 median concentration was 22 pg/m^3 (or less than 0.0008% of the DCG). As with the Livermore site isotopic ratio for the annual median was 0.007, which is considered natural uranium.

Tritium Concentrations

Tritium data presented in **Table 3-5** summarize the biweekly tritium data provided in data tables on the report compact disk (see file "Ch3 Ambient Air" on the report CD). Locations are grouped by expected concentrations of tritium. The highest concentrations of tritium are from samplers on the Livermore site near locations of diffuse tritium (B292, B331, B514, and B624). The sources of tritium in these locations are mostly stored containers of tritium waste or tritium-contaminated equipment; B292 is near a pine tree that acts as a diffuse source of tritium because its roots are growing in water contaminated with tritium from an underground retention tank that previously leaked. Median concentrations for 2003 at the B292 location and the B514 location were comparable to those from 2002. The B292 sampling location was taken off-line in July 2003 because the results from this location have not been used since 1997 to demonstrate compliance with NESHAPS for the diffuse source at this location (see Chapter 5). The annual median concentrations for 2003 for the remaining two diffuse-source samplers (B331 and B624) were slightly elevated from concentrations in 2002 with the more substantial change at the B331 location.The highest biweekly concentration, 21.1 Bq/m^3 (5.6×10^{-10} Ci/m^3), was observed in October when cleanup activities involved the temporary storage of contaminated obsolete equipment outside Building 331.

Samplers on the perimeter of the Livermore site exhibit the next highest air tritium concentrations. Of the perimeter locations, POOL and DWTF (at the Decontamination and Waste Treatment Facility) exhibited the highest concentrations and the same median concentration which is 0.0034% of the DCG. Concentrations at POOL were comparable to those in 2002, but DWTF results were elevated by comparison. The increased concentrations at DWTF correlate to the Radioactive and Hazardous Waste Management Division starting to use the new Decontamination and Waste Treatment

Table 3-5. Tritium in air samples (mBq/m^3), 2003

Sampling locations	Detection frequency	Mean	Median	IQR	Maximum	Median Percent of DCG[(a)]
Diffuse on-site sources	95 of 95	1920	407	2600	21100	0.011
Livermore perimeter	194 of 223	138	64.4	105	1760	0.0017
Livermore Valley	70 of 161	28.2	13.2	29.6	744	0.00036
Site 300	5 of 26	2.83	3.13	12.9	29.3	0.000085

a DCG = Derived Concentration Guide of 3.7 x 10^6 mBq/m^3 for tritium in air.

Facility for operations that may include such items as storing containers of tritium waste or tritium-contaminated equipment. Median concentrations for 2003 for the perimeter locations were generally comparable to those for 2002. The several locations with slightly higher concentrations reflect higher emissions from the Tritium Facility (see "Air Effluent Monitoring" section). One new perimeter tritium sampling location was added to the network in July 2003. The CRED location was added as a monitoring point of compliance in lieu of inventory-based modeling for minor sources. See *NESHAPS 2002 Annual Report* (Harrach et al. 2003).

The median perimeter concentrations for 2003 (even when data from POOL and DWTF are omitted) are statistically higher than concentrations of tritium in air from the Livermore Valley. Sampling locations in the Livermore Valley demonstrate that LLNL tritium has only a small impact past the perimeter fence. Fifty-seven percent of the Valley samples had concentrations indistinguishable from zero. The median concentrations for the Valley locations for 2003 are comparable to those for 2002 except for AMON. Concentrations at AMON reflect the higher 2003 emissions from the Tritium Facility.

Table 3-5 shows the median concentration of tritium in air that was observed at the sampling location at Site 300 (see file "Ch3 Ambient Air" on report CD for biweekly data). Site 300 concentrations are mostly below the detection limit and most likely represent background levels of tritium unaffected by local sources of tritium.

Beryllium Metal Concentrations

LLNL measures the monthly concentrations of airborne beryllium for the Livermore site, Site 300, and the downtown Tracy sampling location (TFIR). (See file "Ch3 Ambient Air" on report CD for data.) The highest value at the Livermore site was 37.4 pg/m^3 which was recorded at location COW in March. This value is only 0.37% of the BAAQMD ambient concentration limit for beryllium (10,000 pg/m^3). With the exception of the slightly higher value in March, all data were similar to data collected from previous years.

Figure 3-7 is a plot of the median beryllium concentration at the Livermore site perimeter from 1975 through 2003. The decrease in median concentration in 1993 and the slight increase in 1999 were likely the result of a change in the analytical laboratory used to perform this analysis. LLNL monitors beryllium metals in air samples on the Livermore site as part of an agreement with the local BAAQMD.

There is no regulatory requirement to monitor beryllium in the San Joaquin County; however, LLNL analyzes samples from several Site 300 locations as a best management practice. The monthly median beryllium concentration for all Site 300 locations was 6.64 pg/m^3. The highest value for the Site 300 area samples occurred again in the October sample at the off-site location in Tracy (TFIR). The concentration at this location is typically higher than at all other locations (including Livermore area samplers) because it is located in a congested part of town and accumulates a greater amount of industrial particulate pollutants. This maximum value was 34.3 pg/m^3 with an annual median of 10.7 pg/m^3.

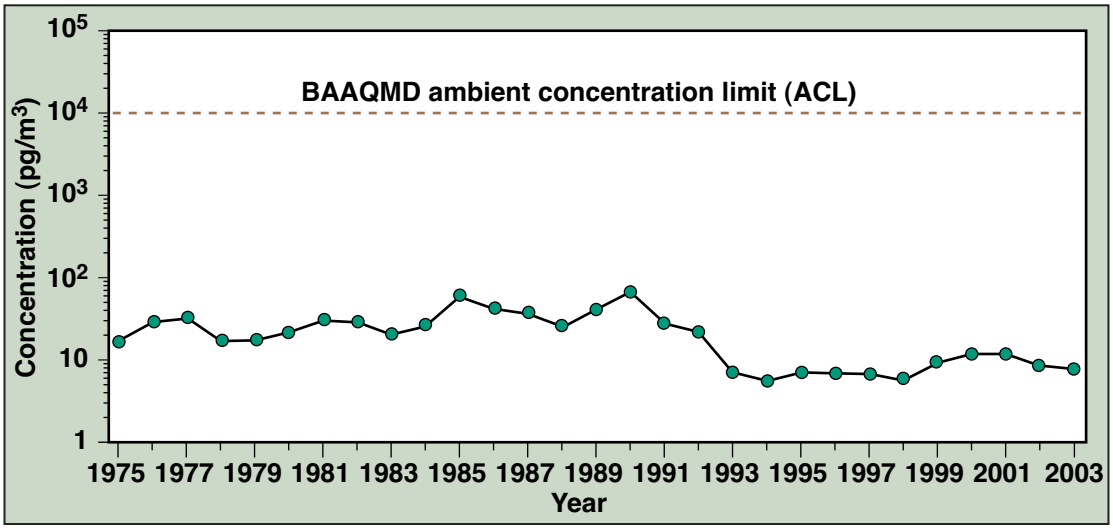

Figure 3-7. Median concentration of beryllium in air particulate samples taken at the Livermore site perimeter, 1975–2003

Environmental Impact on Ambient Air

LLNL operations involving radioactive materials had little impact on radionuclide concentrations in ambient air during 2003. Radionuclide particulate concentrations in air at the Livermore site and in the Livermore Valley were well below the levels that would cause concern for the environment or public health according to existing regulatory standards.

The diffuse tritium sources at DWTF, B292, B331, B514, and B624 had a small, localized effect with minimal impact, if any, on the public. Any potential dose received by a member of the public from the diffuse sources is included in doses calculated for tritium concentrations at the Livermore site perimeter. Tritium concentrations at the Livermore site perimeter which were slightly greater in 2003 than in 2002 correlate well with increased stack emissions in 2003. The increased tritium concentrations observed at the Livermore site perimeter had minimal impact on off-site concentrations.

A maximum tritium dose of 370 nSv/y to a member of the public at the Livermore site perimeter can be estimated based on the extraordinarily conservative assumption that the maximum biweekly concentration (1760 mBq/m^3) is maintained for an entire year and that a member of the public breathes that concentration for the entire year. This improbable inhalation dose to the public is just 0.37% of NESHAPs standard of 0.1 mSv/y arising as a result of releases of radionuclides to air from DOE facilities.

The concentrations of beryllium at both the Livermore site and Site 300 can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and the air of the Livermore area and the Central Valley typically contains 10 to 100 $\mu g/m^3$ of particulates. Using a value of 50 $\mu g/m^3$ for an average dust load and 1 ppm for beryllium content of dust, a conservative airborne beryllium concentration of 50 pg/m^3 can be predicted. The overall average for the Livermore site and Site 300 (including TFIR location in Tracy) are 7.81 pg/m^3 and 6.76 pg/m^3, respectively. These data are lower than predicted, well below standards, and do not indicate the presence of a threat to the environment or public health.

4 Water Monitoring Programs

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Lawrence Livermore National Laboratory monitors a multifaceted system of waters that includes wastewaters, storm water, and groundwater, as well as rainfall and local surface waters. Water systems can also operate differently between the Livermore site and Site 300. For example, Site 300 is not serviced by a publicly owned treatment works as is the Livermore site, so different methods of treating and disposing of sanitary waste are used at the two LLNL sites. As described below, many different regulatory drivers determine the appropriate methods and locations among the various water monitoring programs.

In general, water samples are collected according to written standardized procedures appropriate for the medium (see Woods 2002). The samples are then sent to outside analytical laboratories contracted by LLNL to be analyzed for some subset of the analyses listed in Appendix A. Sampling plans are prepared in advance by each network analyst, who is the LLNL staff person responsible for developing and implementing the specific monitoring programs or networks. The network analyst decides what analytes are to be sampled, at what frequency, and includes any permit-specified analyses. Except for certain sanitary sewer and retention tank analytes, the analyses were usually performed by off-site California-certified contract analytical laboratories.

Sanitary Sewer Effluent Monitoring

In 2003, the Livermore site discharged an average of 0.95 million liters (ML) per day of wastewater to the City of Livermore sewer system, 3.8% of the total flow into the city's 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 (**Figure 4-1**). In 2003, Sandia/California generated approximately 11% of the total effluent discharged from the Livermore site. LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below.

Livermore Site Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2002/2003 and 2003/2004) requires continuous monitoring of the effluent flow rate and pH. Samplers collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, toxic chemicals, and water-quality parameters at the Sewer Monitoring Station (SMS). In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might cause upset to the Livermore Water Reclamation Plant (LWRP) treatment process or otherwise impact the public welfare. The effluent is continuously

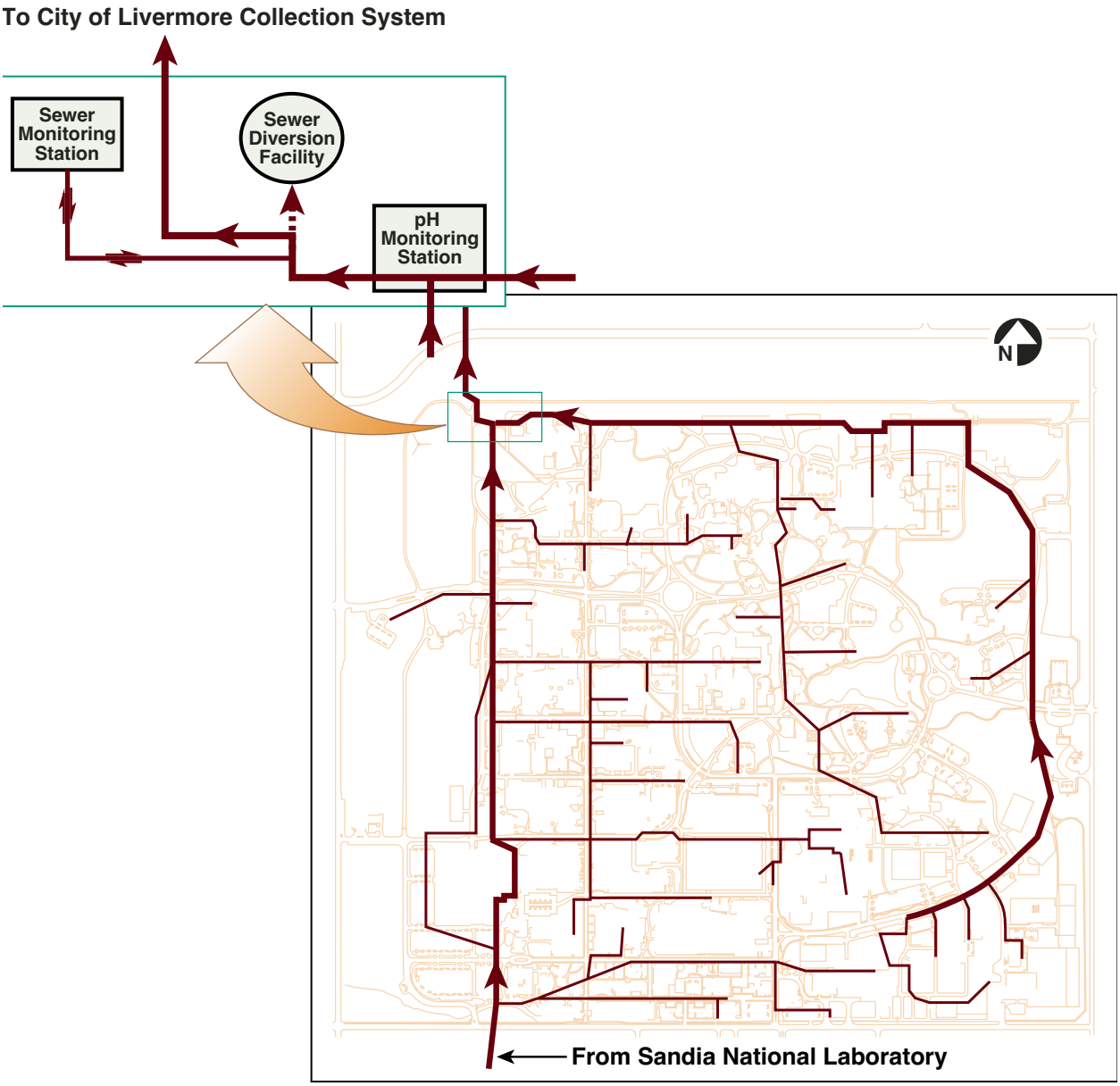


Figure 4-1. LLNL sanitary sewer system, monitoring stations, and diversion facility

analyzed for flow, pH, regulated metals, and gamma 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, and the site effluent is diverted to the Sewer Diversion Facility (SDF). The monitoring system provides a continuous check on sewage control, and the LWRP is notified of contaminant alarms. Trained LLNL staff respond to all alarms to evaluate the cause and take appropriate action.

In addition to the continuous monitoring at the SMS, LLNL monitors pH at the upstream pH Monitoring Station (pHMS) (see **Figure 4-1**). The pHMS continuously monitors pH during peak flow hours between 7 a.m. and 7 p.m. during the workweek and diverts pH discharges outside the permit range of 5 to 10 to the SDF. The pHMS duplicates the pH monitoring and diversion capabilities of the SMS but is able to initiate diversion earlier because it is located upstream of the SDF. Earlier detection allows LLNL to divert wastewater outside the permit limits detected by the pHMS.

LLNL maintains and operates a diversion system that activates automatically when either the SMS continuous monitoring system or the pHMS detects an anomalous condition. For SMS-activated alarms, the SDF ensures that all but the first few minutes of the potentially affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any potential cleanup. When the SDF is activated by the pHMS for pH excursions, even the first few minutes of affected wastewater flow are retained. Up to 775,000 L 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 it meets LLNL's wastewater discharge permit limits), shipped for off-site disposal, or treated at LLNL's Radioactive and Hazardous Waste Management (RHWM) facilities. All diverted sewage in 2003 was returned to the sanitary sewer.

Radiological Monitoring Results

Work Smart Standards (WSS) establish the standards of operation at LLNL (see Chapter 2), and include the standards for sanitary sewer discharges. For radioactive material releases, complementary (rather than overlapping) sections from Department of Energy (DOE) Order 5400.5 and 10 CFR Part 20 are both part of the standards. From DOE Order 5400.5, the WSS for sanitary sewer discharges include the criteria DOE established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeds its specific concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits. From 10 CFR Part 20, the numerical discharge limits for sanitary sewer discharges in the WSS include the annual discharge limits for radioactivity: 185 GBq (5 Ci) of tritium, 37 GBq (1 Ci) of carbon-14, and 37 GBq (1 Ci) of all other radionuclides combined. The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq) is primary over the DOE Order 5400.5 concentration-based limit for tritium for facilities such as LLNL that generate wastewater in large volumes. In addition to the DOE average concentration discharge limit for tritium and the 10 CFR Part 20 annual total discharge limit for tritium, the LWRP established in 1999 an effluent concentration discharge limit for LLNL governing daily releases of tritium. This limit is more stringent than the DOE discharge limit: it is a factor of 30 smaller and applies to a daily rather than an annualized concentration. The following discussion includes the specific radioisotopes with potential to be found in the sanitary sewer effluent at LLNL with respect to the appropriate discharge limit.

LLNL determines the total radioactivity released from tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. The 2003 combined releases of alpha and beta sources was 0.198 GBq (0.0053 Ci), which is 0.053% of the corresponding 10 CFR Part 20 limit (37 GBq [1 Ci]). The combined total is the sum of the alpha and beta results shown in **Table 4-1**. The tritium total was 1.11 GBq (0.03 Ci), which is 0.64% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

The annual mean concentration tritium samples in LLNL sanitary sewer effluent was 0.003 Bq/mL (0.081 pCi/mL). Summary results and statistics for tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 4-2**. The total monthly activity is calculated by multiplying each monthly concentration by the total flow volume over which the sample was collected. (Per DOE guidance, all total annual results presented in this chapter for radioactive emitters are calculated by using the analytical results regardless of whether they were above or below the detection limit. [U.S. DOE 1991])

As shown in **Table 4-2**, the median monthly concentration of tritium in LLNL sanitary sewer effluent (0.003 Bq/mL) was 0.0008% of the DOE DCG (370 Bq/mL), and the maximum monthly average concentration of tritium (0.008 Bq/mL) was 0.002% of the DCG (370 Bq/mL). The maximum daily concentration for tritium (0.2 Bq/mL) was 1.7% of the permit discharge limit (12 Bq/mL).

The historical trend in the monthly concentration of tritium is shown in **Figure 4-2** (before 2002, the figure shows the calculated monthly average). Also included in the figure are the limit of sensitivity (LOS) values for the tritium analysis and the DOE tritium limit (370 Bq/mL). Note that starting in 2002 the LOS values are approximately four times lower than previous years due to an improved analytical technique.

The concentrations of plutonium-239 and cesium-137 measured in the sanitary sewer effluent from LLNL and LWRP, and LWRP sludge are presented in **Tables 4-3** and **4-4**. The plutonium and cesium results are from monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. For 2003, the annual median concentration of cesium-137 in LLNL sanitary sewer effluent was 1.4×10^{-6} Bq/mL (3.7×10^{-5} pCi/mL); the annual median concentration of

Table 4-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2003

Radioactive emitter	Estimate based on effluent activity (GBq)[a]	Limit of sensitivity (GBq)
Tritium	1.11	0.73
Gross alpha sources	0.008	0.044
Gross beta sources	0.19	0.039

a 37 GBq = 3.7×10^{10} Bq = 1 Ci

Table 4-2. Summary statistics of tritium in sanitary sewer effluents, LLNL and LWRP, 2003

Monitoring results			
	LLNL		LWRP
	Daily	Monthly	Monthly
Maximum (Bq/mL)	0.2 ± 0.01[a]	0.008[b]	0.003[c]
Median (Bq/mL)	0.001	0.003	0.0005
IQR[d] (Bq/mL)	0.003	0.005	0.002
LLNL annual total (GBq)	1.11		

Discharge limits for LLNL effluent			
	Discharge limit	Monitoring results as percentage of limit	
		Maximum	Median
LWRP permit daily (Bq/mL)	12	1.7%	0.008%
DOE 5400.5 monthly (DCG)[e] (Bq/mL)	370	0.002%[f]	0.0008%[f]
10 CFR 20 annual total (GBq)	185	0.6%	

a This daily result is for an October sample.

b This is the monthly value for October. All monthly values above limit of sensitivity are plotted in **Figure 4-2.**

c This is the monthly result for May.

d IQR = Interquartile range

e DCG = Derived Concentration Guide

f Monitoring results as a percentage of limit are calculated using the LLNL monthly sample and the DOE annualized discharge limit.

plutonium-239 was 6.6×10^{-8} Bq/mL (1.8×10^{-6} pCi/mL). The annual total discharge of cesium-137 (2.2×10^{6} Bq/y) was 0.0011% of the DOE DCG; and the annual total plutonium-239 concentration (5.1×10^{4} Bq/y) was 0.00004% of the DOE DCG. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The median plutonium concentration observed in 2003 sludge (**Table 4-4**), 0.02 mBq/dry g, is 4650 times lower than the EPA preliminary remediation goal for residential soil (93 mBq/dry g) and is 18,500 times lower than the remediation goal for industrial or commercial soil (370 mBq/dry g).

Figure 4-3 summarizes the plutonium-239 monitoring data over the past 10 years. The historical levels observed since 1994 average approximately 1 µBq/mL (3×10^{-5} pCi/mL). These historical levels generally are 0.0003% of the DOE DCG for plutonium-239. The cyclic nature of the data in **Figure 4-3** suggests a potential

Table 4-3. Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2003

Month	Cesium-137 (μBq/mL)				Plutonium-239 (nBq/mL)			
	LLNL		LWRP		LLNL		LWRP	
	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC
Jan	-1.01 ± 3.7	3.2	0.666 ± 3.3	2.9	49.95 ± 6.5	5.2	2.92 ± 1.7	4.1
Feb	0.83 ± 3.6	3.2	-151.0 ± 4.1	3.5	22.35 ± 5.0	6.5	-1.53 ± 0.77	6.1
Mar	0.99 ± 3.7	3.3	0.803 ± 0.42	1.2	54.02 ± 7.5	7.0	1.84 ± 1.3	3.6
Apr	111[a] ± 4.6	3.9	-1.595 ± 4.1	3.5	77.70 ± 16	2.6	-0.70 ± 3.8	6.5
May	-0.41 ± 3.9	3.4	0.143 ± 4.4	3.8	48.84 ± 11	1.9	1.21 ± 6.0	10
Jun	-1.39 ± 5.0	4.2	1.006 ± 4.0	3.6	78.07 ± 16	6.2	-0.34 ± 0.68	4.0
Jul	2.39 ± 4.6	4.1	-0.548 ± 4.6	4.0	84.36 ± 32	20	1.11 ± 2.1	3.6
Aug	1.75 ± 4.1	3.8	0.039 ± 4.3	3.8	127.7 ± 23	6.4	-0.29 ± 0.58	3.4
Sep	10.0 ± 37	37	0.840 ± 3.7	3.5	288.2 ± 34	7.0	1.79 ± 2.5	3.4
Oct	1.71 ± 2.3	2.8	-0.977 ± 6.4	3.8	880.6 ± 105	21	4.44 ± 8.4	14
Nov	1.89 ± 3.1	2.9	-0.559 ± 6.9	6.1	54.39 ± 14	6.5	-1.41 ± 37	7.5
Dec	4.14 ± 5.9	5.2	3.123 ± 5.1	4.7	47.36 ± 14	7.1	0.63 ± 2.8	5.6
Median	1.4		0.09		66		0.87	
IQR[b]	2.6		1.5		46		2.2	
	Annual LLNL total discharge by radioisotope							
	Cesium-137				**Plutonium-239**			
Bq/y[c]	7.6×10^{5}				5.1×10^{4}			
Ci/y	2.0×10^{-5}				1.4×10^{-6}			
	Fraction of limit [d]							
DOE 5400.5 DCG[e]	3.7×10^{-6}				4.0×10^{-7}			

Note: Results in this table are reported as radioactivity (the measured concentration and a ± 2σ counting uncertainty) along with the detection limit or minimum detectable concentration (MDC). A measure concentration exhibiting a 2σ counting uncertainty greater than or equal to the measured concentration is considered to be a nondetection.

a Limit of sensitivity is used because the measured value is a negative statistical outlier.

b IQR= Interquartile range

c 1 Ci = 3.7×10^{10} Bq

d Fraction of limit calculations are based on the annual total discharge for a given isotope and the corresponding concentration-based limit (0.56 and 0.37 Bq/mL for cesium-137 and plutonium-239, respectively) multiplied by the annual volume of Livermore site effluent.

e DCG = Derived Concentration Guide

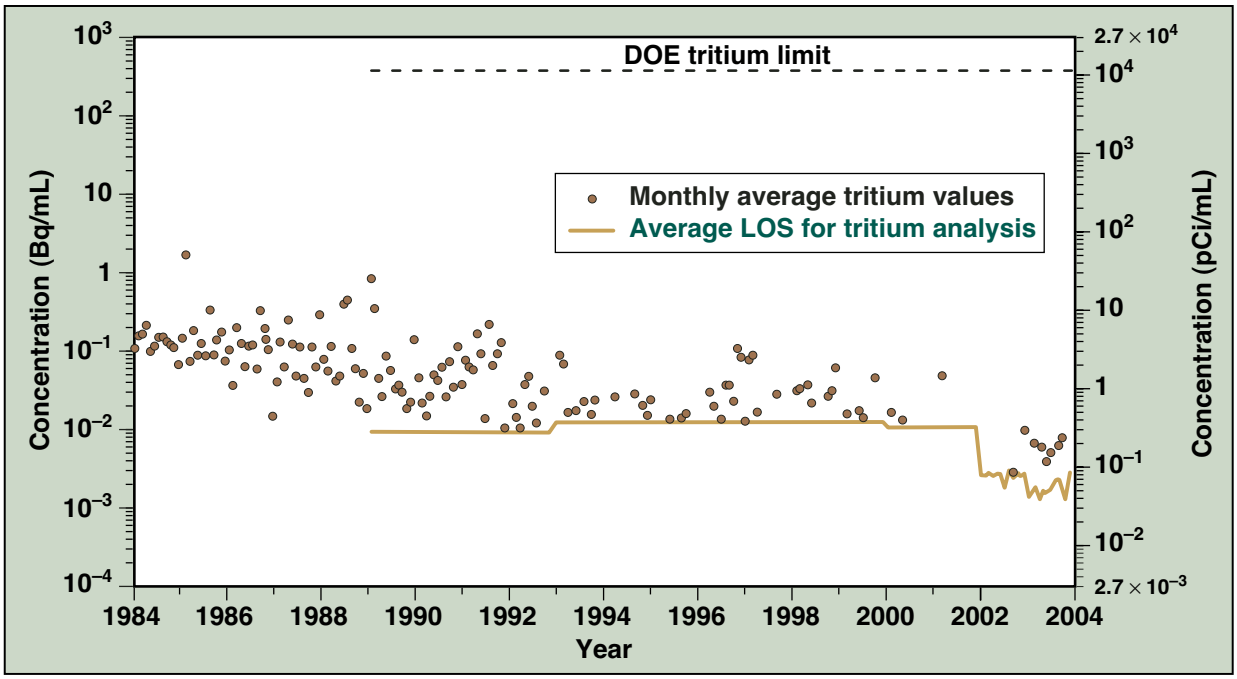
Table 4-4. Cesium and plutonium in LWRP sludge, 2003

Month	Cesium-137 (mBq/dry g)		Plutonium-239 (mBq/dry g)	
	LWRP sludge[a]			
	Radioactivity	MDC	Radioactivity	MDC
Mar	0.312 ± 0.188	0.470	0.0189 ± 0.00279	0.0006
Jun	0.342 ± 0.209	0.570	0.0951 ± 0.0269	0.0148
Sep	0.226 ± 0.143	0.444	0.0088 ± 0.0232	0.0117
Dec	0.072 ± 0.263	0.736	0.0182 ± 0.00511	0.0025
Median	0.27		0.02	
IQR[b]	0.13		0.02	

Note: Results in this table are reported as radioactivity (the measured concentration and a ± 2σ counting uncertainty) along with the detection limit or minimum detectable concentration (MDC). A measure concentration exhibiting a 2σ counting uncertainty greater than or equal to 100% is considered to be a nondetection. See Chapter 8.

a Sludge from LWRP digesters is dried before analysis. The resulting data indicate the plutonium concentration of the sludge prepared by LWRP for disposal at the Vasco Road Landfill in Alameda County.

b IQR= Interquartile range



Note: Only values above the limit of sensitivity (LOS) of the analytical method used are plotted.

Figure 4-2. Historical tritium concentrations in the Livermore site sanitary sewer effluent

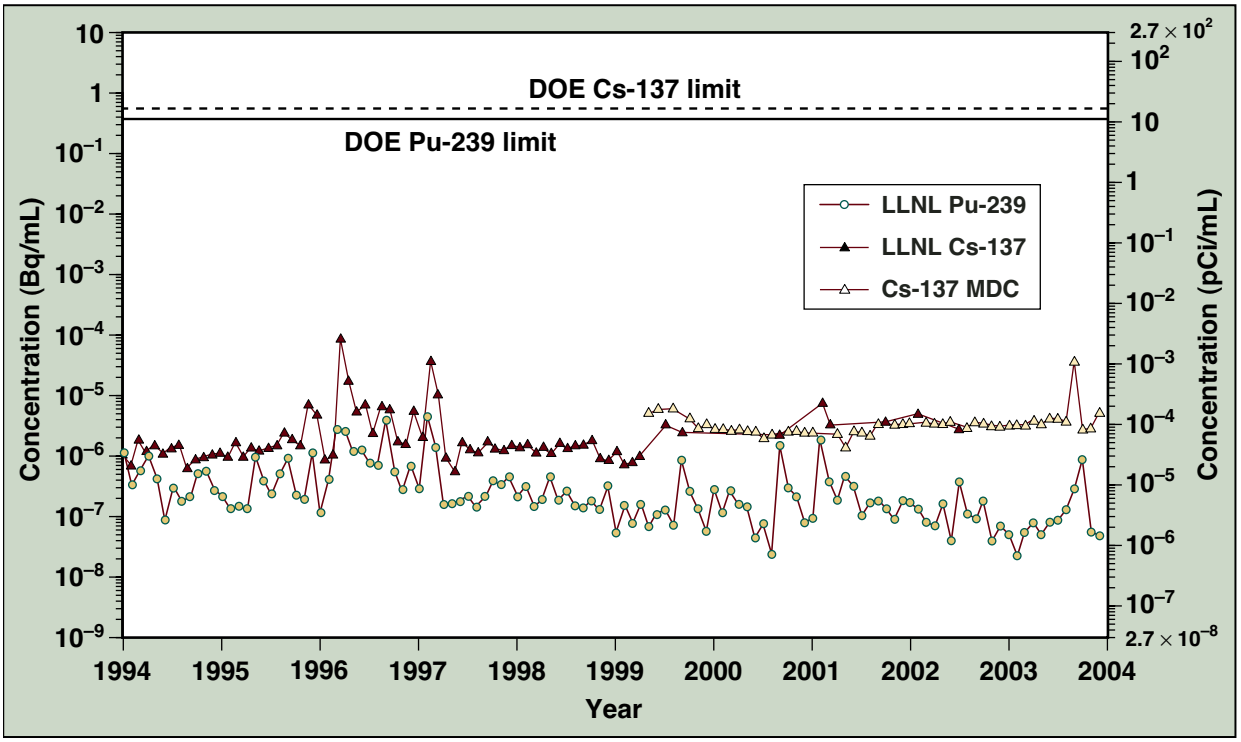


Figure 4-3. Average monthly plutonium and cesium concentrations in LLNL sanitary sewer effluent

frequency relationship in LLNL sewer lines for radionuclide buildup and subsequent liberation by line cleaning. Regardless, the higher plutonium and cesium concentrations are all well below applicable DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 4-5** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2003, a total of 1.11 GBq (0.03 Ci) of tritium was discharged to the sanitary sewer, an amount that is well within environmental protection standards and is comparable to the amounts discharged during the past 10 years.

Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL's wastewater discharge permit requires LLNL to collect monthly 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected

Table 4-5. Historical radioactive liquid effluent releases from the Livermore site, 1994–2003

Year	Liquid effluent (GBq)	
	Tritium	Plutonium-239
1994	6.9	1.9×10^{-4}
1995	6.0	1.2×10^{-4}
1996	12[a]	4.2×10^{-4}
1997	9.1	2.1×10^{-4}
1998	10	0.77×10^{-4}
1999	7.1	0.68×10^{-4}
2000	5.0	0.96×10^{-4}
2001	4.9	1.1×10^{-4}
2002	0.74	0.42×10^{-4}
2003	1.11	0.51×10^{-4}

a In 1995, Sandia/California ceased all tritium facility operations. Therefore, the annual tritium totals beginning with the 1996 value do not include contributions from Sandia/California.

continuously throughout the year. LLNL's wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL, are daily samples collected during the corresponding period analyzed to determine if any of their concentrations are above the EPL.

To better understand the characteristics of the Livermore site sanitary sewer effluent, LLNL also tracks the flow-weighted monthly concentrations for all regulated metals in LLNL's sanitary sewer effluent; **Table 4-6** presents the flow-weighted monthly concentrations for 2003. To obtain these concentrations, each weekly composite is weighted by the total flow volume for the period during which the sample was collected. This flow-weighted monthly concentration represents the characteristic concentration for that month. In 2003, the flow-weighted monthly concentration is generally typical of the values seen over the past ten years. The median flow-weighted monthly concentrations for the nine regulated metals were within the range of the respective median historical values. During 2003, medians of the flow-weighted monthly concentrations were less than 10% of the wastewater discharge permit limits for all but copper and zinc, which were at 17% and 14% of the wastewater discharge permit limit respectively.

Figure 4-4 presents historical trends for the monthly 24-hour composite sample results from 1994 through 2003 for eight of the nine regulated metals; cadmium is not presented because this metal is typically not detected above the practical quantitation

Table 4-6. Monthly average results for regulated metals in LLNL sanitary sewer effluent (mg/L), 2003

Month	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Jan	0.015	0.0044	<0.0050	0.019	0.17	0.00048	0.0080	0.044	0.37
Feb	<0.010	0.0047	<0.0050	0.015	0.10	0.00023	0.0061	0.010	0.29
Mar	<0.010	0.0034	<0.0050	0.020	0.27	0.0026	0.012	0.024	0.81
Apr	<0.010	0.0030	<0.0050	0.017	0.16	0.00046	0.0090	0.013	0.48
May	<0.010	0.0069	<0.0050	0.032	0.20	0.00031	0.012	0.026	0.53
Jun	<0.010	0.0049	<0.0050	0.020	0.18	0.00024	0.010	0.014	0.43
Jul	<0.010	0.0054	<0.0050	0.028	0.19	0.00037	0.0093	0.030	0.40
Aug	<0.010	0.0060	<0.0050	0.029	0.27	0.00026	0.011	0.050	0.47
Sep	<0.010	0.0052	<0.0050	0.023	0.18	0.00034	0.0079	0.022	0.39
Oct	<0.010	0.0045	<0.0050	0.021	0.16	0.00039	0.0077	0.016	0.40
Nov	0.011	0.0045	<0.0050	0.019	0.15	0.00070	0.0090	0.013	0.42
Dec	0.014	0.0030	<0.0050	0.015	0.10	0.00022	0.0070	0.0080	0.30
Median	<0.010	0.0046	<0.0050	0.020	0.17	0.00036	0.0090	0.019	0.41
IQR[a]	—[b]	0.0011	—[b]	0.0057	0.035	0.00021	0.0026	0.014	0.091
EPL[c]	0.20	0.06	0.14	0.62	1.0	0.01	0.61	0.20	3.00
Median fraction of EPL	<0.05	0.08	<0.04	0.03	0.17	0.04	0.01	0.09	0.14

Note: Monthly values are presented with less-than signs when all weekly composite sample results for the month are below the detectable concentration.

a IQR = Interquartile range

b Because of the large number of nondetects, the interquartile range cannot be calculated. See Chapter 8.

c Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2002/2003, and 2003/2004)

limit of 0.005 mg/L. All of the monthly 24-hour composite samples were in compliance with LLNL's wastewater discharge permit limits. As noted in recent years, arsenic, copper, lead, and zinc continue to show an occasional elevated concentration. These elevated values, however, never exceeded 15% of the EPL in 2003; except for copper, which peaked at 21% of the EPL. The other metals (silver, chromium, nickel, and mercury), which in past years have shown one or more elevated concentrations, exhibited no discernible trends in the 2003 monthly 24-hour composite concentrations.

The monthly 24-hour composite and weekly composite concentrations for 2003 are presented in **Figure 4-5** for eight of nine regulated metals as a percentage of the corresponding EPL; cadmium results are not presented because the metal was not detected above the practical quantitation limit of 0.005 mg/L in any of the weekly or monthly samples. As previously mentioned, all of the monthly 24-hour composite samples are

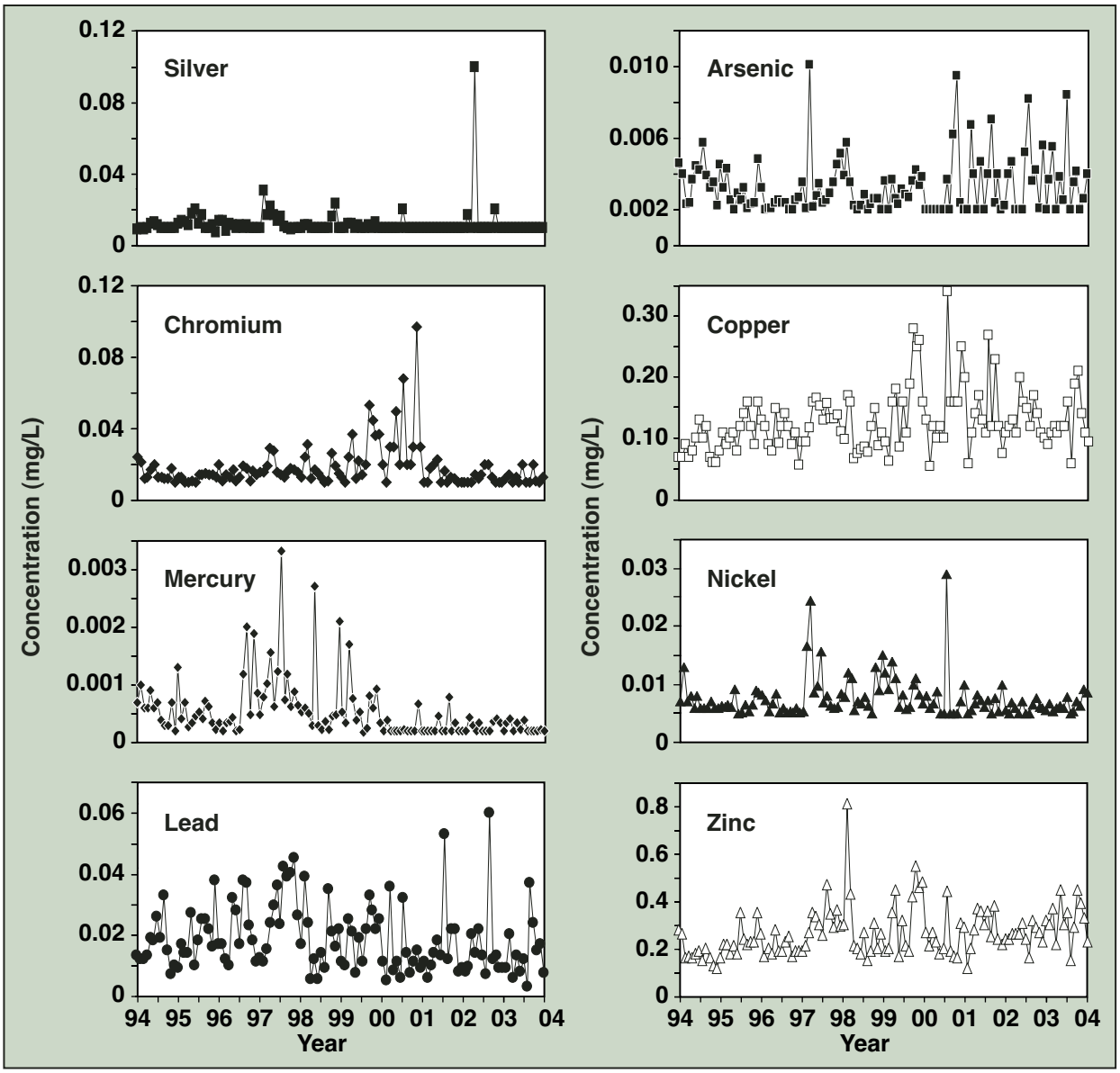


Figure 4-4. Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary fewer effluent showing historical trends

well below 50% of their respective EPLs. Of the weekly composites, only two mercury samples and one lead sample showed concentrations at or above 50% of their respective EPLs (**Figure 4-5**).

The two elevated mercury values, reported at 50% of the EPL for the weeks of March 13–19 and March 20–26, can be attributed to an analytical artifact resulting from matrix interference. Lead concentrations in the daily composite samples from the week of January 16–22 show one sample exceeding the 0.20 mg/L permitted discharge limit

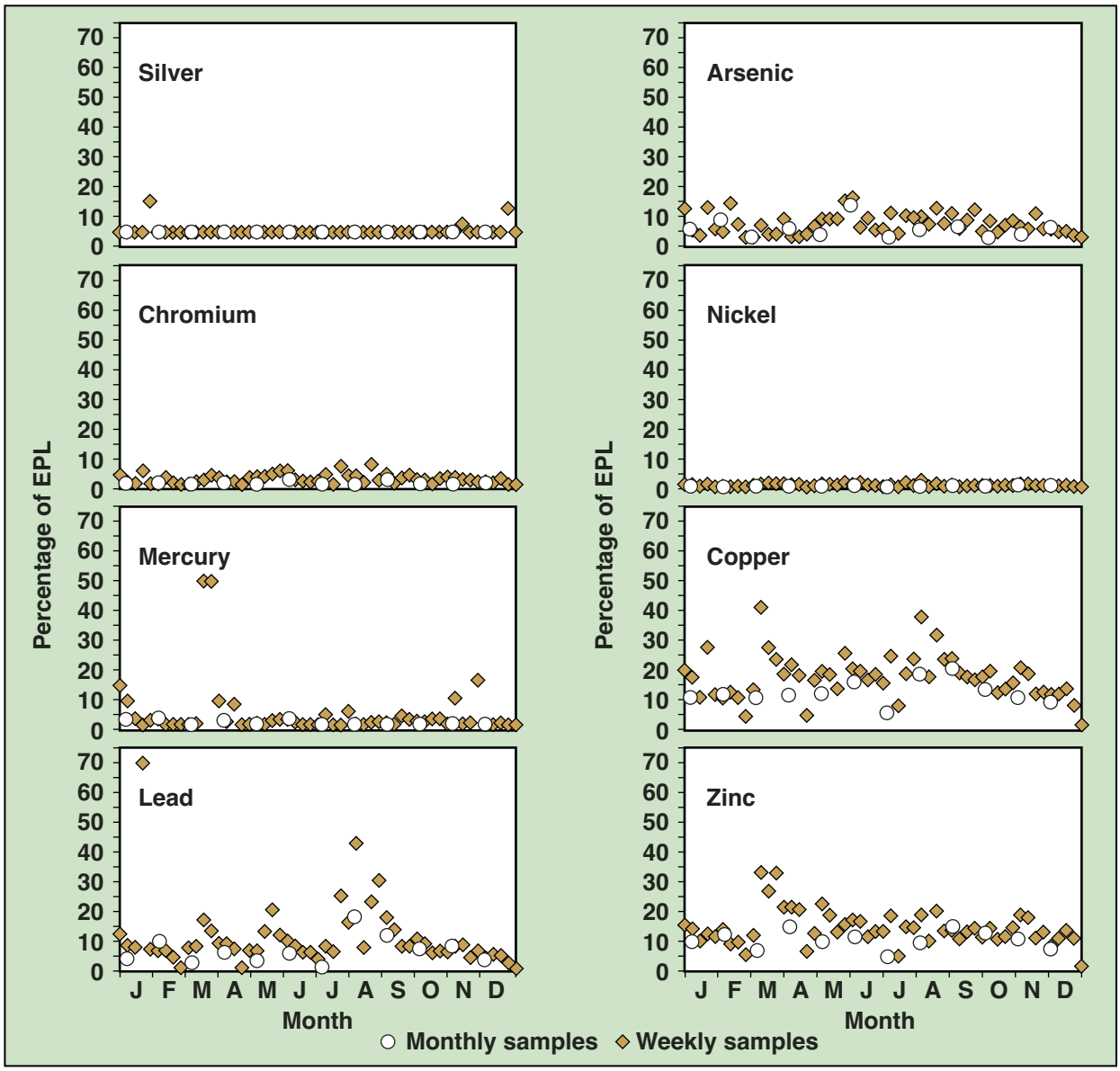


Figure 4-5. Results as percentages of effluent pollutant limits (EPLs) for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2003

for lead (January 16 at 0.235 mg/L, representing effluent collected during the prior 24-hour period). As a result of this exceedance, the LWRP issued a Warning Notice requiring that a 30-day series of LLNL daily effluent samples (January 16 – February 14, inclusive) be analyzed for lead by a state-certified contract laboratory. All results from the 30-day series were in compliance with LLNL's wastewater permit discharge limit for lead, and no daily sample showed a lead concentration greater than 0.026 mg/L. Because LLNL had demonstrated a return to compliance and sufficient measures had

been taken to investigate this inadvertent discharge, no corrective action was required by the LWRP. Although this incident was reported to the LWRP, it did not represent a threat to the integrity of the LWRP operations.

Detections of anions, metals, and organic compounds and summary data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 4-7**. (All analytical results are included in the file "Ch4 LV Wastewater" provided

Table 4-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2003[a]

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
24-hour composite sample parameter (mg/L)					
Alkalinity					
Bicarbonate alkalinity (as $CaCO_3$)	12 of 12	220	280	255	15
Carbonate alkalinity (as $CaCO_3$)	3 of 12	<5	49	<5	—[d]
Total alkalinity (as $CaCO_3$)	12 of 12	240	280	260	20
Anions					
Bromide	11 of 12	<0.1	0.7	0.25	0.2
Chloride	12 of 12	47	250	54	7
Fluoride	12 of 12	0.11	1.3	0.19	0.088
Nitrate (as N)	2 of 12	<0.1	0.7	<0.1	—[d]
Nitrate (as NO_3)	2 of 12	<0.4	3.1	<0.4	—[d]
Nitrate plus Nitrite (as N)	3 of 12	<0.1	0.7	<0.1	—[d]
Nitrite (as N)	6 of 12	<0.02	0.31	<0.022	—[d]
Nitrite (as NO_2)	6 of 12	<0.065	1	<0.071	—[d]
Orthophosphate	12 of 12	12	25	19	3
Sulfate	12 of 12	9.7	52	13	3.8
Nutrients					
Ammonia nitrogen (as N)	12 of 12	29	63	49	7.5
Total Kjeldahl nitrogen	12 of 12	50	84	70	11
Total phosphorus (as P)	12 of 12	7	15	11	3.3
Oxygen demand					
Biochemical oxygen demand	12 of 12	101	360	248	105
Chemical oxygen demand	12 of 12	286	908	682	195
Solids					
Settleable solids	11 of 12	<0.5	46	35	8
Total dissolved solids (TDS)	12 of 12	230	720	295	54.5
Total suspended solids (TSS)	12 of 12	78	550	340	133
Volatile solids	12 of 12	180	513	440	39.8
Total metals					
Aluminum	11 of 12	<0.2	0.96	0.6	0.36
Calcium	12 of 12	13	45	20	5.3
Iron	12 of 12	0.55	3.1	2	0.8
Magnesium	12 of 12	2.3	19	3.2	0.65
Potassium	12 of 12	20	27	24	3
Selenium	1 of 12	<0.002	0.0024	<0.002	—[d]
Sodium	12 of 12	40	160	45	9.5
Total organic carbon (TOC)	12 of 12	39	87	60	6.8

Table 4-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2003[a] (continued)

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
Grab sample parameter					
Semivolatile organic compounds (μg/L)					
Benzoic acid	4 of 12	<9	44	<10	—[d]
Benzyl alcohol	10 of 12	<2	250	9.8	54
Bis(2-ethylhexyl)phthalate[e]	4 of 12	<5	8.1	<5	—[d]
Butylbenzylphthalate[e]	4 of 12	<2	3.7	<2	—[d]
Dibutylphthalate[e]	3 of 12	<2	8	<2	—[d]
Diethylphthalate[e]	12 of 12	7.5	37	21	6.3
Phenol[e]	8 of 12	<2	10	5.1	—[d]
m- and p-Cresol	9 of 12	<2	22	4.6	—[d]
Total oil and grease (mg/L)[f]	8 of 8	18	31	25.5	4.3
Volatile organic compounds (μg/L)					
Acetone	12 of 12	260	900	470	120
Benzene[e]	1 of 12	<0.5	13	<0.5	—[d]
Bromodichloromethane[e]	1 of 12	<0.5	1.6	<0.5	—[d]
Bromoform[e]	1 of 12	<0.5	3.4	<0.5	—[d]
Chloroform[e]	12 of 12	1.2	15	9.9	2.9
Dibromochloromethane[e]	1 of 12	<0.5	3.4	<0.5	—[d]
Ethylbenzene[e]	1 of 12	<0.5	0.78	<0.5	—[d]
Styrene	1 of 12	<0.5	3.1	<0.5	—[d]
Toluene[e]	3 of 12	<0.5	3.6	<0.5	—[d]
Total xylene isomers	1 of 12	<1	6.1	<1	—[d]
Trichloroethene[e]	1 of 12	<0.5	0.81	<0.5	—[d]

a The monthly sample results and nondetected values are not included in this table.

b 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).

c IQR = Interquartile range

d When the detection frequency is less than or equal to 50%, or there is no range, or there are fewer than six results for a sample parameter, the interquartile range is omitted.

e Priority toxic pollutant parameter used in assessing compliance with the total toxic organic (TTO) permit limit of 1 mg/L (1000 μg/L), LLNL Wastewater Discharge Permit 1250, 2002/2003, and 2003/2004

f The requirement to sample for oil and grease has been suspended until further notice per LWRP letter of April 1, 1999. LLNL collects these samples (four per day) semiannually as part of the source control program.

on the report CD.) Although the monthly 24-hour composite samples were analyzed for hydroxide alkalinity (as CaCO3), beryllium, cadmium, and silver, these analytes were not detected in any monthly sample acquired during 2003, and so are not presented in Table 4-6. Similarly, analytes not detected in any of the 2003 monthly grab samples are not shown in Table 4-7. The 2003 results are similar to typical values seen in previous years for the two regulated parameters, cyanide and total toxic organics (TTO), and all other nonregulated parameters. Cyanide (permit limit 0.04 mg/L) was below analytical

detection limits (0.02 mg/L) in both the January and July semiannual samples, and in the annual (October 2003) joint LLNL/LWRP co-sampling. The monthly TTO values ranged from 0.013 mg/L to 0.045 mg/L (with a TTO median value of 0.023 mg/L), well below the TTO permit limit of 1.0 mg/L. In addition to the organic compounds regulated under the TTO standard, six nonregulated organics were also detected in LLNL's sanitary sewer effluent: three volatile organic compounds (acetone, styrene, and xylene) and three semivolatile organic compounds (benzoic acid, benzyl alcohol, and 3- & 4-methylphenol).

In 2003, the SMS continuous monitoring system detected a total of two inadvertent discharges outside the permitted pH range of 5 to 10. One of these events, with a pH below 5, was completely captured by the SDF. The other event, also with a pH below 5, occurred off-hours (Sunday, May 4, 2003) when the upstream pHMS was off-line. As a result, a front-end volume of low pH sanitary effluent was released to the LWRP system before a diversion to the SDF could be made. The LWRP was immediately notified of this low pH discharge; however, this incident did not represent a threat to the integrity of the operations of the LWRP, nor was it considered an enforceable exceedance of permit conditions. The lowest pH recorded for effluent contained in the May 4 release was 4.8.

Categorical Processes

The U.S. Environmental Protection Agency (EPA) publishes Categorical standards for broad categories of specific industrial processes determined to be the most significant contributors to point-source water pollution. These standards contain specific numerical limits for the discharge of industry-specific pollutants from individual processes. At LLNL, the federal Categorical requirements are incorporated into the wastewater discharge permit, which is administered by the LWRP. The number of processes at LLNL using these pollutants is subject to change as programmatic requirements dictate. During 2003, the LWRP identified 14 specific LLNL wastewater-generating processes that fall under the definition of two categorical standards: Electrical and Electronic Components (40 CFR 469), and Metal Finishing (40 CFR 433). Only those processes that discharge to the sanitary sewer require sampling, inspection, and reporting. Three of the 14 identified processes meet these criteria. In 2003, LLNL analyzed compliance samples for all regulated parameters from these three processes and demonstrated compliance with all federal Categorical discharge limits. Other processes that do not discharge to the sanitary sewer but would otherwise be regulated under the Metal-Finishing Point Source Category include printed circuit board manufacturing, electrolysis plating, chemical etching, electroplating, anodizing, coating, electrical discharge machining, and abrasive jet machining. These 11 nondischarging processes are evaluated semiannually. Wastewater from these nondischarging processes is either recycled or contained for eventual removal and appropriate disposal by LLNL's RHWM Division. Because these processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in 40 CFR Part 433.

During 2003, discharging Categorical processes were sampled semiannually and inspected and sampled annually by the LWRP staff. These samples were analyzed for all regulated parameters and were all within federal Categorical discharge limits. As part of normal operations, LLNL retains and analyzes all discharges from the Building 153 Categorical processes prior to discharge to the sanitary sewer. All monitoring data is reported to the LWRP in semiannual reports each January and July (Grayson and Brigdon 2003, 2004).

Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2002-2004) allows treated groundwater from the Livermore site Ground Water Project (GWP) to be discharged in the City of Livermore sewer system. (See Chapter 7 for more information on the GWP.) During 2003, there were ten discharges to the sanitary sewer from the GWP. The total volume of treated groundwater discharged to sewer was 32,705 liters. In each of these discharge events, the groundwater released to the sanitary sewer originated from the lower zone, beneath the LLNL site. These volumes of groundwater (except the two cases noted below) were acquired at one of the on-site treatment facilities and used to condition new ion exchange resin columns. The two exceptions are 1) a volume of water that was collected directly from a well (rather than at a treatment unit) to study the production capacity of that well location and 2) a volume of water that was collected from a portable treatment unit and used as input to an electrocoagulation experiment. These ten events were separately sampled and discharged to the sewer during 2003, all in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in the *Ground Water Discharge Annual Self-Monitoring Report for 2003* (Revelli 2004a).

Environmental Impact on Sanitary Sewer Effluent

During 2003, no discharges exceeded any discharge limits for release of radioactive materials to the sanitary sewer. The data are comparable to the lowest historical values. All the values reported are a fraction of a percent of their corresponding limits with the exception of the maximum daily tritium value, which is 1.74%. The data demonstrate that LLNL has continued the trend of excellent control of radiological and nonradiological discharges to the sanitary sewer.

Monitoring results for 2003 reflect an extremely effective year for LLNL's wastewater discharge control program and indicate no adverse impact to the LWRP or the environment from LLNL sanitary sewer discharges. Overall, LLNL achieved greater than 99% compliance with the provisions of its wastewater discharge permit.

Site 300 Sewage Ponds and Surface Impoundments

Wastewater samples from the sewage evaporation pond influent and overflow, photographic Chemistry and Explosives Process Areas, and discharges to the Class II surface impoundments were obtained in accordance with the written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002). Standard sample handling and hygiene procedures were employed to prevent cross-contamination (e.g., wearing disposable gloves, decontaminating equipment between uses, and maintaining samples at 4 ± 2 °C). Duplicates, field blanks, and trip blanks were obtained for quality assurance/quality control (QA/QC) purposes.

Sewage Evaporation and Percolation Ponds

Sewage generated at buildings in the General Services Area is discharged into a lined evaporation pond. The wastewater is disposed of through evaporation from the pond. However, during rare periods of high rainfall, treated wastewater may overflow into an unlined percolation pond, where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter collectively referred to as sewage ponds) are specified in the Monitoring and Reporting Program (MRP) for Waste Discharge Requirements Order No. 96-248 (WDR 96-248). The monitoring requirements include both wastewater monitoring and groundwater monitoring to detect potential impacts of the sewage on groundwater quality. Wastewater is sampled quarterly at a pond influent location (ISWP) and within the sewage evaporation pond (ESWP). Overflows into the adjacent percolation pond are also permitted under WDR 96-248 and are sampled as needed at discharge location DSWP. Nine groundwater monitoring wells are sampled semiannually to provide information on the groundwater quality in the vicinity of the sewage ponds. All sampling locations are shown in **Figure 4-6**. The wells are screened in three different geological formations: Qal, $Tnbs_1$, and $Tnsc_1$ (see Chapter 7). $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2003. There was one continuous overflow to the percolation pond that began in December 2002 and continued into the first quarter of 2003. This permitted discharge was sampled twice and reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). For details, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2002* (Brown 2003a) and *LLNL*

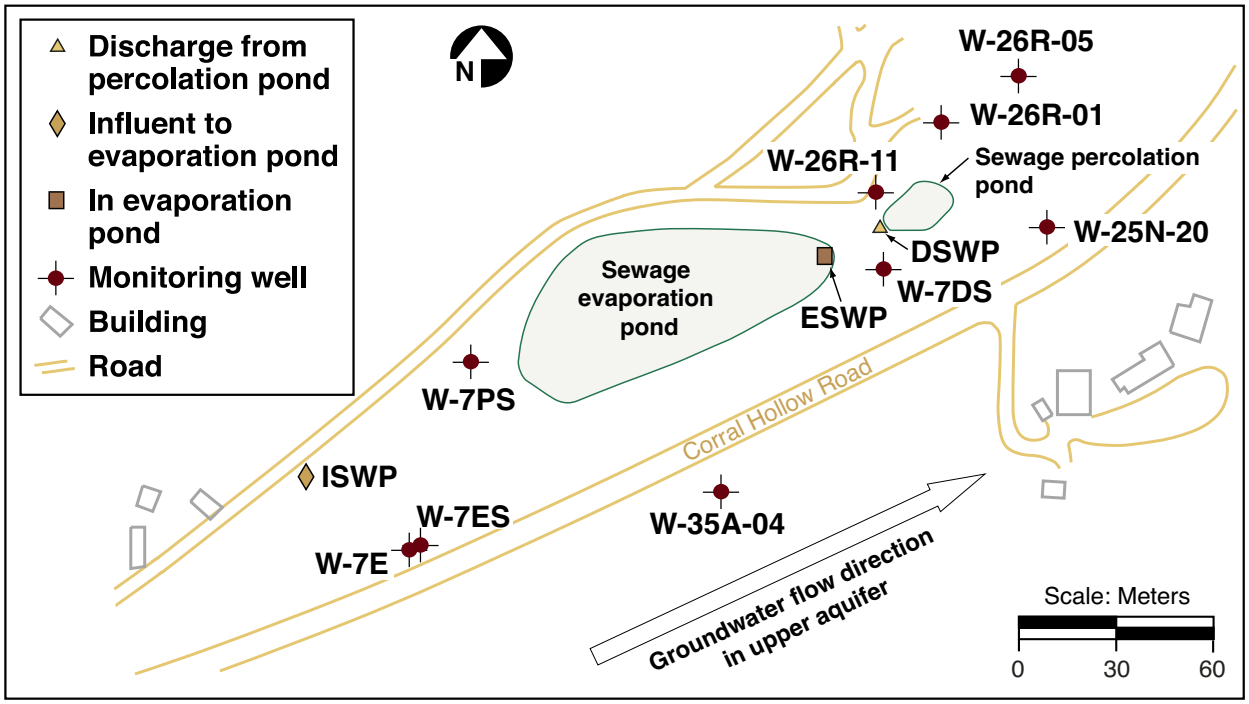


Figure 4-6. Sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations

Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, First Quarter Report 2003 (Brown 2003b). All of the monitored groundwater constituents were also in compliance with permit limits.

Surface Impoundments

WDR 96-248 also establishes the basis for compliance monitoring of two connected Class II surface impoundments at Site 300 that receive wastewater and rinsewater discharges from the Explosives Process Area, chemistry buildings, and photographic processes. This includes monitoring of various influent waste streams to the surface impoundments, quarterly monitoring of the groundwater, and visual observations of the leachate collection and removal systems. Influent monitoring complements administrative control of chemicals that could degrade the polyethylene liners of the impoundments. A two-tiered monitoring program comprising weekly visual inspections of the leachate collection and removal systems, and quarterly sampling of monitoring wells is in place to detect any release of chemicals from the surface impoundments.

Explosives process water discharges to the surface impoundments are analyzed for constituents of concern (COCs) that have been found (or are likely to be found) in the process water from each specified building within the Explosives Process Area. This

monitoring program includes process wastewater from Buildings 806/807, 809, and 817. WDR 96-248 requires annual analysis of this waste stream. WDR 96-248 also establishes limits for discharges of COCs into the surface impoundments and requires monitoring of the photographic process and Chemistry Area wastewater retention tanks that discharge to the surface impoundments. Influent streams are monitored at a prescribed frequency for area-specific COCs. Retention tanks containing photographic process rinsewater from Buildings 801, 823, and 851 are regulated by effluent discharge limits specified in WDR 96-248. Discharges to the surface impoundments occur after samples are obtained, except for rinsewater from the Building 823 retention tanks, which is discharged automatically to the surface impoundments and sampled quarterly. Samples of process wastewater from the Chemistry Area (Buildings 825, 826, and 827 Complex) are collected when the retention tanks are ready for discharge to the surface impoundments. The wastewater is held in retention tanks until analytical results indicate compliance with WDR 96-248.

LLNL is required to obtain groundwater samples quarterly from four monitoring wells (see **Figure 4-7**) and has established statistical concentration limits for COCs in groundwater beneath the surface impoundments. These requirements are part of the MRP for the surface impoundments detailed in WDR 96-248.

No release of water to ground from the surface impoundments occurred during 2003. For a detailed account of compliance monitoring of the Site 300 surface impoundments, including tables of groundwater measurements, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2003* (Laycak 2004).

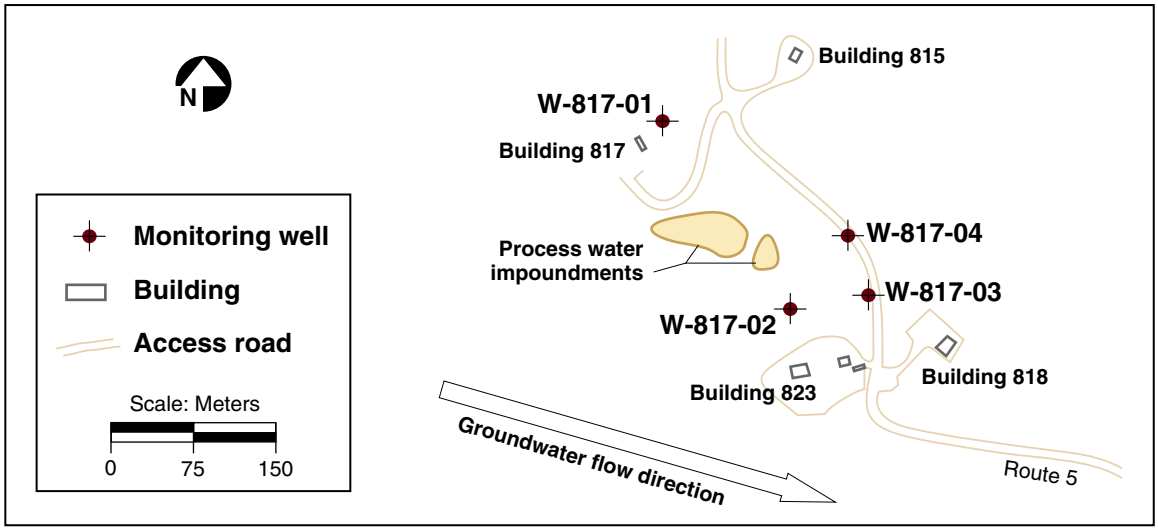


Figure 4-7. Locations of compliance groundwater monitoring wells in the Explosives Process Area

During 2003, all discharges into the surface impoundments were in compliance with discharge effluent limits. Groundwater concentrations of some inorganic COCs were higher than the statistical limits during 2003. LLNL determined that the elevated concentrations of these COCs do not originate from leakage from the surface impoundments to the groundwater. LLNL continues to monitor and to track these concentrations. For details, see Laycak (2004).

The two leachate collection and removal systems were monitored weekly for the presence of liquids to identify potential leaks. None was observed during 2003. No water has been observed in the leachate collection and removal system since liner repairs were made in 1997.

Explosive compounds (HMX, RDX, and breakdown products) and perchlorate are the compounds most indicative of discharges to groundwater from the Explosives Process Area surface impoundments. However, prior to 1985, explosives wastewater was discharged into unlined ponds in the vicinity of the present surface impoundments where it infiltrated the soil; some of the explosives wastewater reached groundwater. Because of this past practice, it is necessary under regulations to discriminate between new releases from the surface impoundments and past releases from the unlined ponds.

Percolation Pits

Percolation pits that are designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. In other remote Site 300 facilities, these types of waste streams are discharged to septic systems. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows. Overflows of the percolation pits, should they occur, are sampled and analyzed to determine the concentrations of any metals present. During 2003, the percolation pits at Buildings 806A, 827C, 827D, and 827E operated normally with no overflows (Laycak 2004).

Environmental Impact on Sewage Ponds and Surface Impoundments

All discharges from the Site 300 sewage evaporation and percolation ponds, as well as discharges to the Class II surface impoundments from the Explosives Process Area, were in compliance with discharge limits. Groundwater monitoring related to these areas indicates that there were no measurable impacts to the groundwater from these LLNL wastewater discharges.

Storm Water Compliance and Surveillance Monitoring

To assess compliance with permit requirements, LLNL monitors storm water at the Livermore site in accordance with WDR 95-174, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0030023, issued in 1995 by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1995). LLNL monitors storm water discharges at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activity (WDR 97-03-DWQ), NPDES Permit No. CAS000001, State Water Resources Control Board (SWRCB 1997). In 2003, for construction projects that disturb 0.4 hectares (1 acre) of land or more LLNL also met the storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ, NPDES Permit No. CAS000002) (SWRCB 1999) and subsequent modifications.

In addition, Site 300 storm water monitoring meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998), which includes specific monitoring and reporting requirements. In addition to the storm water quality constituents required by the closure plan, LLNL monitors other constituents to provide a more complete water quality profile. Appendix A includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

Storm water monitoring at both sites also follows the requirements in the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (U.S. DOE 1991) and meets the applicable requirements of DOE Order 5400.5, Radiation Protection of the Public and the Environment.

At all monitoring locations at both the Livermore site and Site 300, grab samples are collected from the storm water runoff flowing in the storm drains and stream channels. Grab samples are collected by partially submerging sample bottles directly into the water and allowing them to fill with the sample water. If the water to be sampled is not directly accessible, a stainless-steel bucket or an automatic water sampler is used for sampling. The bucket is triple-rinsed with the water to be sampled, then dipped or submerged into the water and withdrawn in a smooth motion. Sampling is conducted away from the edge of the arroyo to prevent the collection of sediment into the water samples. Sample vials for volatile organics are filled before sample bottles for all other constituents and parameters. In addition to chemical monitoring, LLNL is required by NPDES permit WDR 95-174 to conduct acute and chronic fish toxicity testing on samples from the Arroyo Las Positas (Livermore site) once per wet season. LLNL is not required to test for fish toxicity at Site 300.

For the purpose of evaluating the overall impact of the Livermore site and Site 300 operations on storm water quality, storm water flows are sampled at upstream and downstream locations. Because of flow patterns at the Livermore site, storm water at sampling locations includes runoff from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. In contrast, storm water at Site 300 is sampled at locations that target specific on-site activities with no run-on from off-site sources. These samples provide information used to evaluate the effectiveness of LLNL's storm water pollution control program.

NPDES permits for storm water require that LLNL sample effluent two times per year. In addition, LLNL is required to visually inspect the storm drainage system during the first hour of one storm event per month in the wet season (defined as October of one year through April [Livermore site] or May [Site 300] of the following year) to observe runoff quality and twice during the dry season to identify any dry weather flows. Influent sampling is also required at the Livermore site. LLNL monitors up to four storm events each year at the Livermore site in support of DOE Order 5400.5. In addition, annual facility inspections are required to ensure that the best management practices (BMPs) to control storm water pollution are implemented and adequate.

Constituent Criteria

There are no numeric criteria that limit concentrations of specific constituents in LLNL's storm water effluent. The U.S. Environmental Protection Agency (EPA) established parameter benchmark values, but stressed that these concentrations are not intended to be interpreted as effluent limits (U.S. EPA 2000). Rather, the values are levels that the EPA has used to determine if storm water discharged from any given facility merits further monitoring. Although these criteria are not directly applicable, they are used as comparison criteria to help evaluate LLNL's storm water management program. To further evaluate the storm water management program, LLNL established or calculated site-specific threshold comparison criteria for a select group of parameters. A value exceeds the threshold if it is greater than the 95% confidence limit computed for the historical mean value for a specific parameter (**Table 4-8**). The threshold comparison criteria are used to identify out-of-the-ordinary data that merit further investigation to determine if concentrations of that parameter are increasing in the storm water runoff. For a better understanding of how LLNL storm water data relate to other target values, water samples are also compared with criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin* (SFBRWQCB 1995), *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Sacramento and San Joaquin River Basins* (CVRWQCB 1998), state and federal maximum contaminant levels (MCLs), and ambient water quality criteria (AWQC). The greatest importance is placed on the site-specific comparison criteria calculated from historical concentrations in storm runoff.

Table 4-8. Threshold comparison criteria for selected water quality parameters.

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L[a]	1,700 mg/L[a]
Chemical oxygen demand (COD)	200 mg/L[a]	200 mg/L[a]
pH	<6.0, >8.5[a]	<6.0, >9.0[b]
Nitrate (as NO_3)	10 mg/L[a]	not monitored
Orthophosphate	2.5 mg/L[a]	not monitored
Beryllium	0.0016 mg/L[a]	0.0016 mg/L[a]
Chromium (VI)	0.015 mg/L[a]	not monitored
Copper	0.013 mg/L[c]	not monitored
Lead	0.015 mg/L[d]	0.03 mg/L[a]
Zinc	0.35 mg/L[a]	not monitored
Mercury	above RL[e]	0.001[a]
Diuron	0.014 mg/L[a]	not monitored
Oil and grease	9 mg/L[a]	9 mg/L[a]
Tritium	36 Bq/L[a]	3.17 Bq/L[a]
Gross alpha radioactivity	0.34 Bq/L[a]	0.90 Bq/L[a]
Gross beta radioactivity	0.48 Bq/L[a]	1.73 Bq/L[a]

Note: The sources of values above these are examined to determine if any action is necessary.

a Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for zinc, TSS, and COD.

b EPA benchmark

c Ambient water quality criteria (AWQC)

d California and EPA drinking water action level

e RL = reporting limit = 0.0002 mg/L for mercury

Storm Water Inspections

Each directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the storm water pollution prevention plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's associate directors certified in 2003 that their facilities complied with the provisions of LLNL's storm water permits. LLNL submits annual storm water monitoring reports to the SFBRWQCB and to the CVRWQCB with the results of sampling, observations, and inspections (Sanchez 2003a,b).

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual observations of construction sites before, during, and after storms to assess the effectiveness of BMPs. Annual compliance certifications summarize these inspections. Annual compliance certifications for 2003 covered the period of June 2002 through May 2003. When requested by the respective regional water quality control board (RWQCB), LLNL completes annual compliance status reports that cover the same reporting period. During the 2002/2003 reporting period, LLNL had active permits for seven projects located at the Livermore site (see **Table 2-2**). The SFBRWQCB requested completion of compliance status reports for all the Livermore site construction projects in 2003.

Livermore Site

As is commonly the case in urbanized areas, the surface water bodies and runoff pathways at LLNL do not represent the natural conditions. The drainage at the Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 km 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 (see **Figure 4-8**).

The Drainage Retention Basin (DRB) was excavated and lined in 1992 to prevent infiltration of storm water that was dispersing groundwater contaminants. It also serves storm water diversion and flood control purposes. The DRB collects about one-fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (**Figure 4-9**). When full, the DRB discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the site drains either directly or indirectly into the two arroyos by way of storm drains and swales. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas follows the northeastern and northern boundaries of the site and exits the site near the northwest corner.

The routine Livermore site storm water runoff monitoring network consists of ten sampling locations (**Figure 4-9**). Seven locations characterize storm water either entering (influent: ALPE, ALPO, ASS2, ASSE, and GRNE) or exiting (effluent: ASW and WPDC) the Livermore site. Locations CDB and CDB2 characterize runoff from the southeastern quadrant of the Livermore site entering the DRB, and location CDBX characterizes water leaving the DRB. LLNL collected samples at all ten locations on April 28, 2003. LLNL collected samples on December 11 and December 29, 2003, for all but location ASSE, which is an influent location.

As required by WDR 95-174, grab samples were also collected and analyzed for acute and chronic toxicity using fathead minnows (*Pimephales promelas*) as the test species. In the acute test, 96-hour survival is observed in undiluted storm water collected from location WPDC.

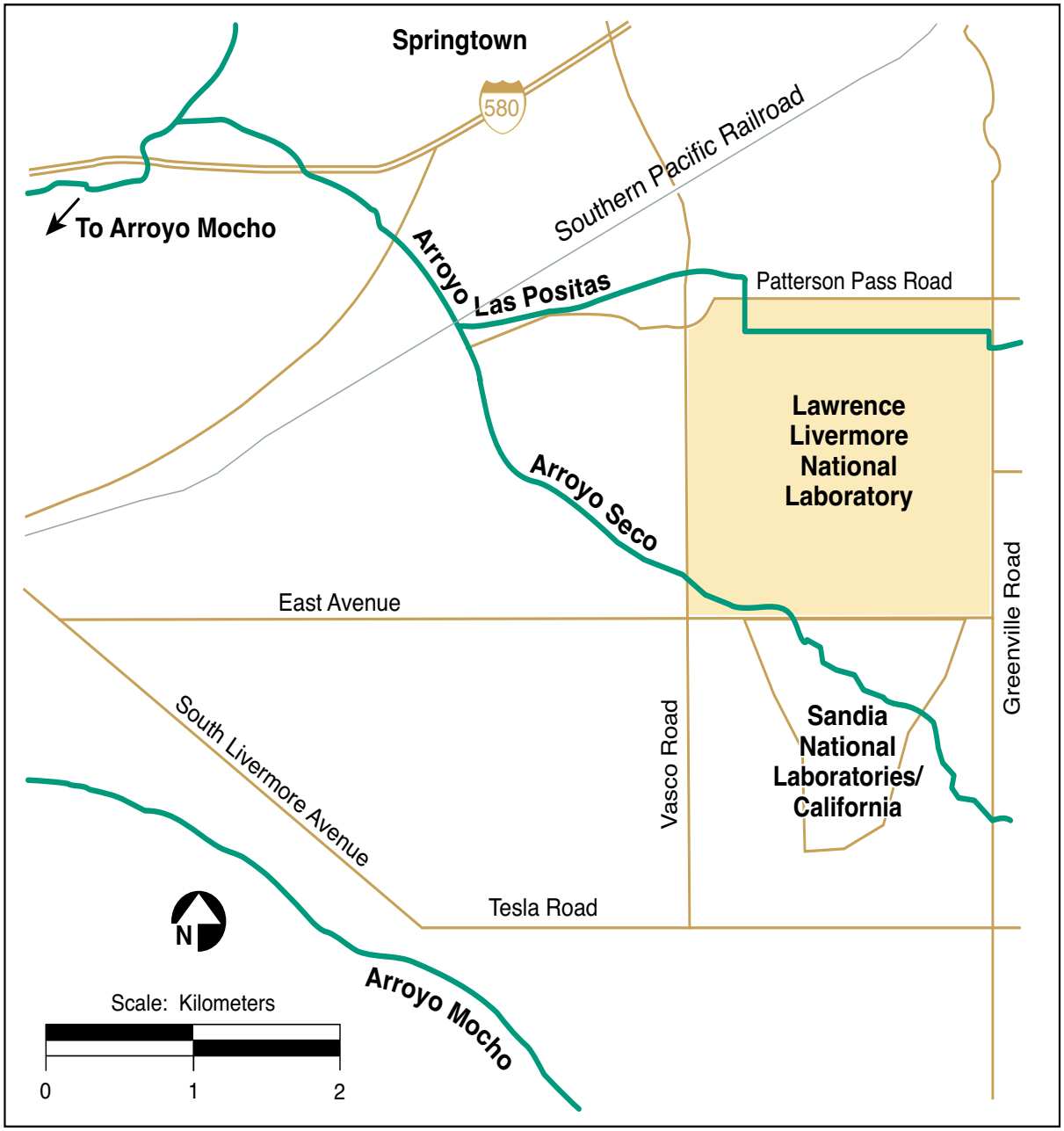


Figure 4-8. Surface waterways in the vicinity of the Livermore site

Radiological Monitoring Results

Storm water sampling and analysis were performed for gross alpha, gross beta, plutonium, and tritium. Storm water gross alpha, gross beta, and tritium results are summarized in **Table 4-9**. (Complete analytical results are included in the file "Ch4 Storm

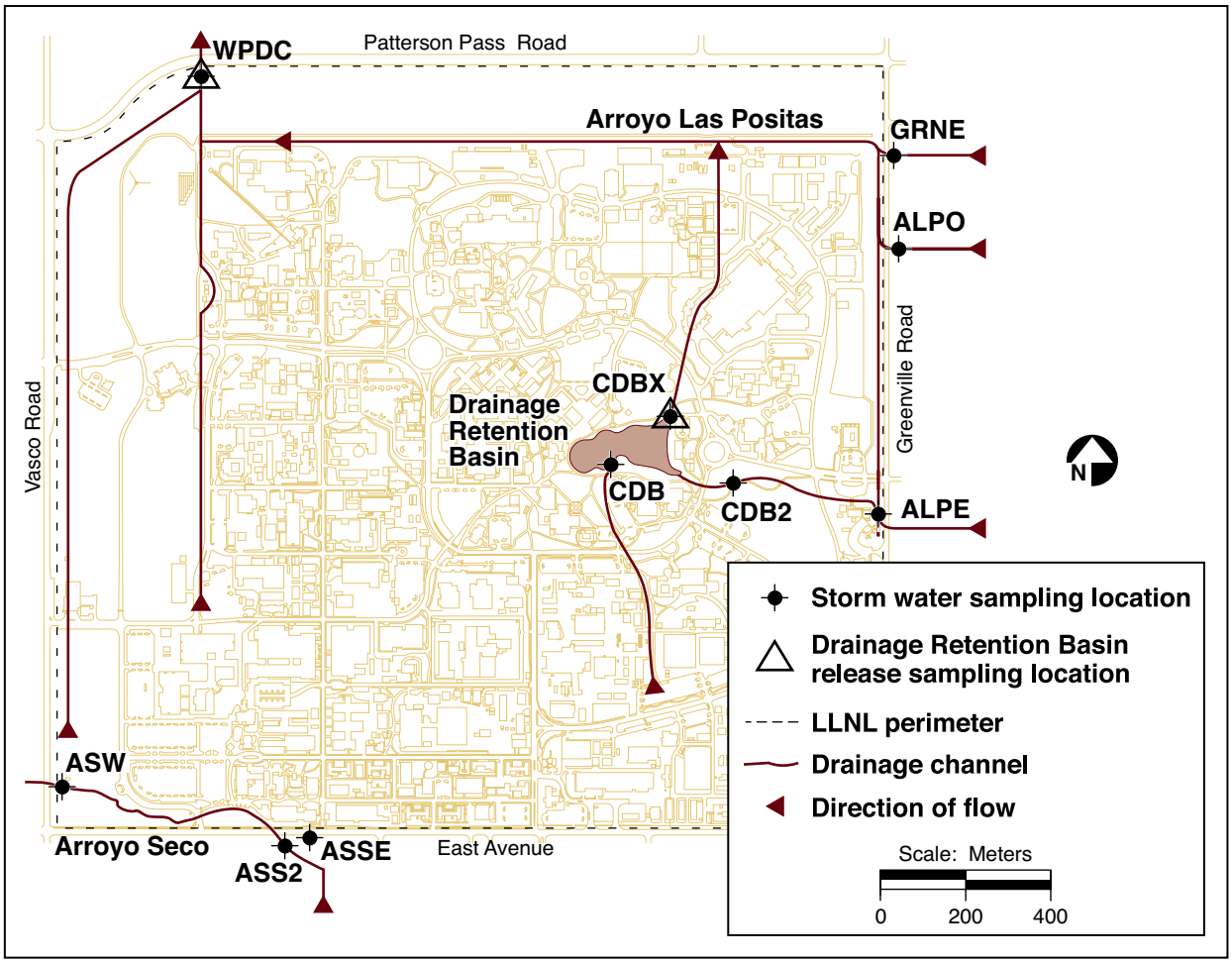


Figure 4-9. Storm water runoff and Drainage Retention Basin sampling locations, Livermore site, 2003

Water" provided on the report CD.) Tritium activities at effluent locations were less than 2% of the MCL. Gross alpha and gross beta radioactivity in the storm water samples collected during 2003 were generally low, with medians around background levels. Concentrations of tritium, gross alpha and gross beta radioactivities are higher in influent storm water samples than in effluent samples.

LLNL began analyzing for plutonium in storm water in 1998. Samples from the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC) are analyzed. In 2003, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.100 pCi/L).

Table 4-9. Statistics on radioactivity in storm water from the Livermore site, 2003[a]

Parameters	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Median	3.7	0.043	0.17
Minimum	–1.5	0.012	0.081
Maximum	33	0.35	0.45
Effluent			
Median	2.4	0.032	0.11
Minimum	0.24	0.0035	0.089
Maximum	13	0.10	0.23

a See Chapter 8 for an explanation of calculated values.

Nonradiological Monitoring Results

In addition to radioactivity, storm water was analyzed for other water quality parameters. Sample results were compared with the comparison criteria in **Table 4-8**. Of interest are the constituents that exceed comparison criteria at effluent points and whose concentrations are lower in influent than in effluent. If influent concentrations are higher than effluent concentrations, the source is generally assumed to be unrelated to LLNL operations and LLNL conducts no further investigation. (Complete analytical results are included in the file "Ch4 Storm Water" provided on the report CD.) Constituents that exceeded comparison criteria for effluent and influent locations are listed in **Table 4-10**. Many of the values above threshold comparison criteria for the Livermore site were found at influent tributaries to Arroyo Las Positas. For instance, all diuron concentrations above threshold limits are at influent locations east of the Livermore site as has occurred in past years. In most cases where the Livermore site threshold limit was exceeded at WPDC, which is an effluent location, concentrations from an influent location were similar or greater, demonstrating that LLNL was not the source. However, concentrations of lead detected in a sample collected from WPDC on April 28, 2003, and concentrations of zinc detected in a sample collected at the same effluent location on December 11, 2003, did not have corresponding high values in influent concentrations. Concentrations above the comparison criteria are sporadic and elevated metals are generally associated with particulates suspended in the storm water. LLNL will continue to monitor storm water concentrations to determine if any trends are developing.

LLNL conducted both acute and chronic fish toxicity analyses on storm water samples collected on December 11 in order to catch the first flush of runoff that occurs at the beginning of the wet season. WDR 95-174 states that an acceptable survival rate for the toxicity monitoring is 20% lower than a control sample. The testing laboratory provides water for the control sample, which consists of EPA synthetic moderately-hard water.

Table 4-10. Nonradioactive water quality parameters in storm water runoff above LLNL-specific threshold comparison criteria, Livermore site[a] in 2003

Parameter	Date	Location	Influent or Effluent	Result (mg/L)	LLNL threshold criteria (mg/L)
Copper[b]	12/29	ALPO	Influent	0.015	0.013
	12/29	WPDC	Effluent	0.016	0.013
Diuron	12/11	ALPO	Influent	0.58	0.014
	12/11	GRNE	Influent	0.18	0.014
	12/29	ALPE	Influent	0.073	0.014
	12/29	ALPO	Influent	1.20	0.014
Lead[b]	04/28	WPDC	Effluent	0.022	0.015
Mercury[b]	12/29	ALPO	Influent	0.00041	0.0002
Nitrate (as NO_3)	12/11	GRNE	Influent	15	10
	12/29	CDBX	Internal	11	10
	12/29	GRNE	Influent	15	10
Oil and grease	12/29	ALPO	Influent	9.2	9
	12/29	WPDC	Effluent	10	9
Zinc[b]	12/11	WPDC	Effluent	0.62	0.35

a No storm water runoff samples were collected from Site 300 in 2003.

b Total metals including particulates

Thus, a difference of more than 20% between location WPDC and the control sample with the lowest survival rate is considered a failed test. If the test is failed, the permit requires LLNL to conduct toxicity testing during the next significant storm event. After failing two consecutive tests, LLNL must perform a toxicity reduction evaluation to identify the source of the toxicity. During 2003, survival in the acute test at WPDC was 90%, while the control sample survival rate was 95% (**Table 4-11**). The results show that LLNL's effluent water sample shows no toxicity, either acute or chronic, to the fathead minnows.

Table 4-11. Fish acute toxicity test results, Livermore site, December 11, 2003

Storm Water	Percent survival		
	Replicate A	Replicate B	Mean
Lab Control	90	100	95
WPDC	90	90	90

Site 300

Surface water at Site 300 consists of seasonal runoff, springs, and natural and man-made ponds. The primary waterway in the Site 300 area is Corral Hollow Creek, an ephemeral stream that borders the site to the south and southeast. No naturally continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainage for most of Site 300; it extends from the northwest portion of the site to the east–central area. Elk Ravine drains the center of the site into Corral Hollow Creek, which drains eastward toward the San Joaquin River Basin. Some smaller canyons in the northeast portion of the site drain to the north and east toward Tracy.

There are at least 23 springs at Site 300. Nineteen are perennial, and four are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation. Several artificial surface water bodies at Site 300 that are in fact wastewater treatment units are discussed above. Three wetlands created by now-discontinued flows from cooling towers located at Buildings 827, 851, and 865 were maintained in 2003 by discharges of potable water.

Seven on-site Site 300 storm water sampling locations were selected to characterize storm water runoff at locations that could be affected by specific Site 300 activities. Off-site location CARW is used to characterize Corral Hollow Creek upstream and therefore is unaffected by Site 300 industrial storm water discharges. Location GEOCRK is used to characterize Corral Hollow Creek downstream of Site 300. These locations are shown in **Figure 4-10**.

The Site 300 storm water permit specifies sampling a minimum of two storms per rainy season. Typically, a single storm does not produce runoff at all Site 300 locations because Site 300 receives relatively little rainfall and is largely undeveloped with few paved areas. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff can occur. At some of the sampling locations in some years, there is not enough rain to generate runoff over an entire rainy season. In 2003, no storm water runoff samples were collected from Site 300 drainages. Runoff did occur on December 29, 2003, but no runoff was collected for sampling because there was insufficient staff.

Environmental Impact on Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impacts in 2003. Tritium activities in storm water runoff effluent were less than 2% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples were both less than 20% of their respective MCLs. The fish toxicity tests showed no discernible toxicity in Livermore site storm water runoff.

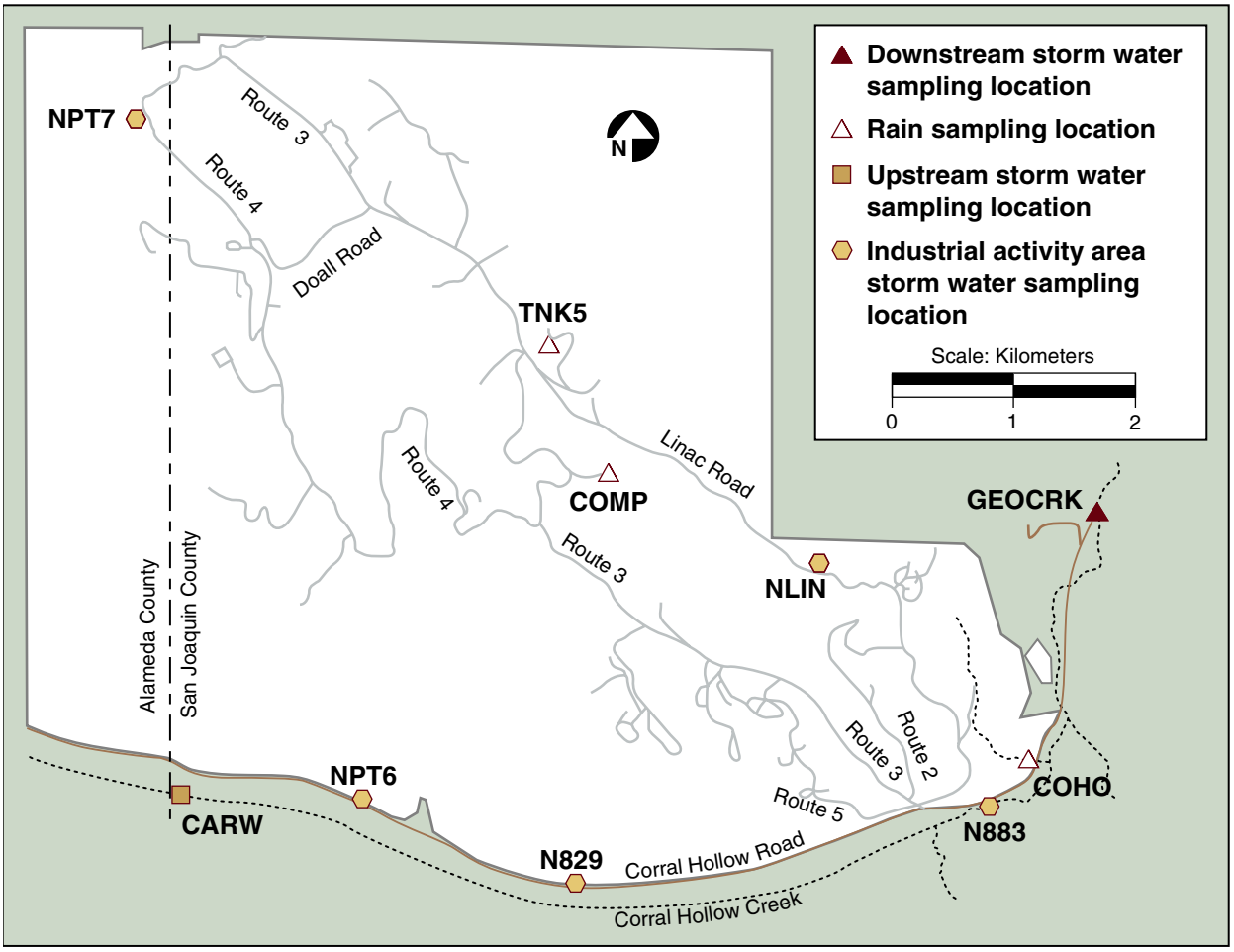


Figure 4-10. Storm water and rainwater sampling locations at Site 300, 2003

GROUNDWATER

Groundwater monitoring affirms LLNL's commitment to protect the environment. LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 in the Altamont Hills through networks of wells and springs that include private wells off site and DOE Comprehensive Environmental Response Compensation Liability Act (CERCLA) wells on site.

The groundwaters of the two monitored areas are not connected; they are separated by a major drainage divide and numerous faults. The Livermore site in the Livermore Valley drains to the San Francisco Bay via Alameda Creek. Most of Site 300 drains to the San Joaquin River Basin via Corral Hollow Creek, with a small undeveloped portion in the north draining to the north and east onto grazing land.

To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used. A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, it can detect contamination before it significantly impacts groundwater resources. Wells at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan.

Historically, the surveillance and compliance monitoring programs have detected higher than natural background concentrations of various metals, nitrate, perchlorate, and depleted uranium (uranium-238) in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants, including uranium-238, to past operations, while the sources of other contaminants, such as nitrate and perchlorate, are the objects of continuing study.

Beginning in January 2003, LLNL implemented a new CERCLA comprehensive compliance monitoring plan at Site 300 (Ferry et al. 2002) that adequately covers the DOE requirements for on-site groundwater surveillance; LLNL monitoring related to CERCLA activities are described in Chapter 7. Additional compliance monitoring programs at Site 300 comply with numerous federal and state controls such as state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to surface impoundments, sewage ponds, and percolation pits, the latter discussed previously in this chapter. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Table 2-2** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and effluents to be monitored, COCs and parameters to be measured, frequency of measurement, inspections to be conducted, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical integrity of closed facilities and their monitoring networks. As described in a previous section, LLNL conducts additional operational monitoring of wastewater effluents discharged to surface impoundments and sewage evaporation and percolation ponds to comply with WDRs. Quarterly and annual written reports of analytical results, inspection findings, and maintenance activities are required for each compliance monitoring network.

Typically, analytical methods approved by EPA are used to measure dissolved constituents in water because they are both accurate and sensitive. Appendix A lists the analytical methods and reporting limits that are used to detect organic and inorganic constituents

in groundwater (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods). The listed methods are not all used at each groundwater monitoring location. Rather, for cost effectiveness, each groundwater sampling location monitors only those contaminants that have been detected historically or that might result from continuing LLNL operations. However, present-day administrative, engineering, and maintenance controls at both LLNL sites are specifically tailored to prevent releases of potential contaminants to the environment.

During 2003, representative samples of groundwater were obtained from monitoring wells in accordance with the LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs) (Goodrich and Depue 2003). These protocols cover sampling techniques and specific information concerning the chemicals that are routinely searched for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps, or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results are compared with drinking water limits (MCLs); however, the MCLs do not apply as regulatory limits to any of these groundwaters.

Livermore Site and Environs

Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant from LLNL. Rain and storm water runoff in the Livermore Valley, which recharge local aquifers, contain small amounts of HTO from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 3 and 6 for further discussion of air emissions, and other parts of this chapter for further discussion of rain and storm water runoff.)

Groundwater is recharged at the Livermore site, primarily from arroyos by rainfall. Groundwater flow beneath the Livermore site is generally southwestward. Groundwater flow is discussed generally in Chapter 1 and in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and in the *LLNL Ground Water Project 2003 Annual Report* (Karachewski et al. 2004).

Groundwater samples were obtained during 2003 from 23 of 25 water wells in the Livermore Valley (see **Figure 4-11**) and measured for tritium activity. Two wells were either dry or could not be sampled during 2003.

Tritium measurements of Livermore Valley groundwaters are contained in the file "Ch4 LV Groundwater" provided on the report CD. They continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for

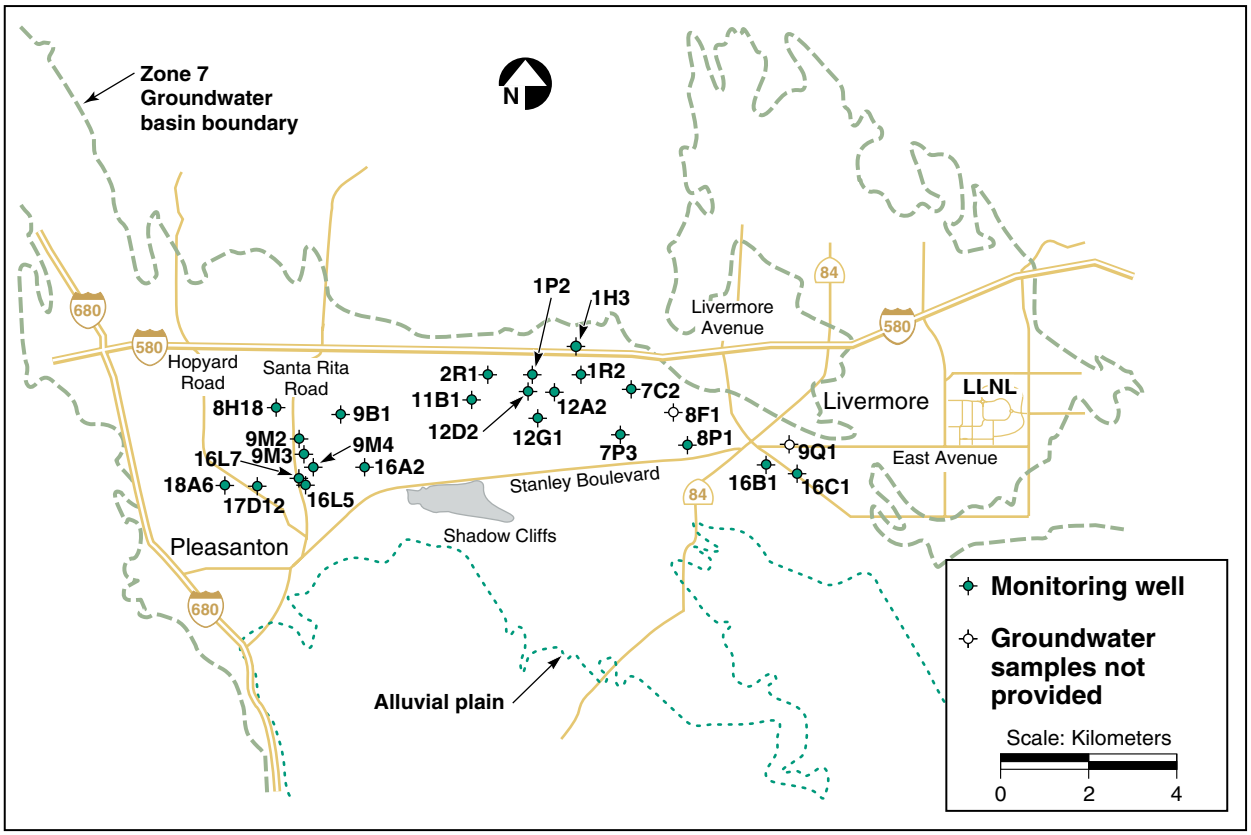


Figure 4-11. Locations of off-site tritium monitoring wells in the Livermore Valley, 2003

drinking water in California. The maximum tritium activity measured off site was in the groundwater at well 12D2, located about 11 km west of LLNL (see **Figure 4-11**). The measured activity there was 5.5 Bq/L in 2003, less than 1% of the MCL.

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Site GWP (discussed in Chapter 7). The intent of the surveillance monitoring network is to monitor for potential groundwater contamination from continuing LLNL operations. The perimeter portion of this surveillance groundwater monitoring network makes use of three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven (downgradient) monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 4-12**). These seven wells, located in the regions of groundwater Treatment Facilities (TF) A, B, and C (see **Figure 7-2**) are located at or beyond the hydrologically downgradient boundary of the Livermore site. The western perimeter wells are screened (depth range from which groundwater is drawn) in the uppermost aquifers near the areas where groundwater is being remediated. The screened interval for

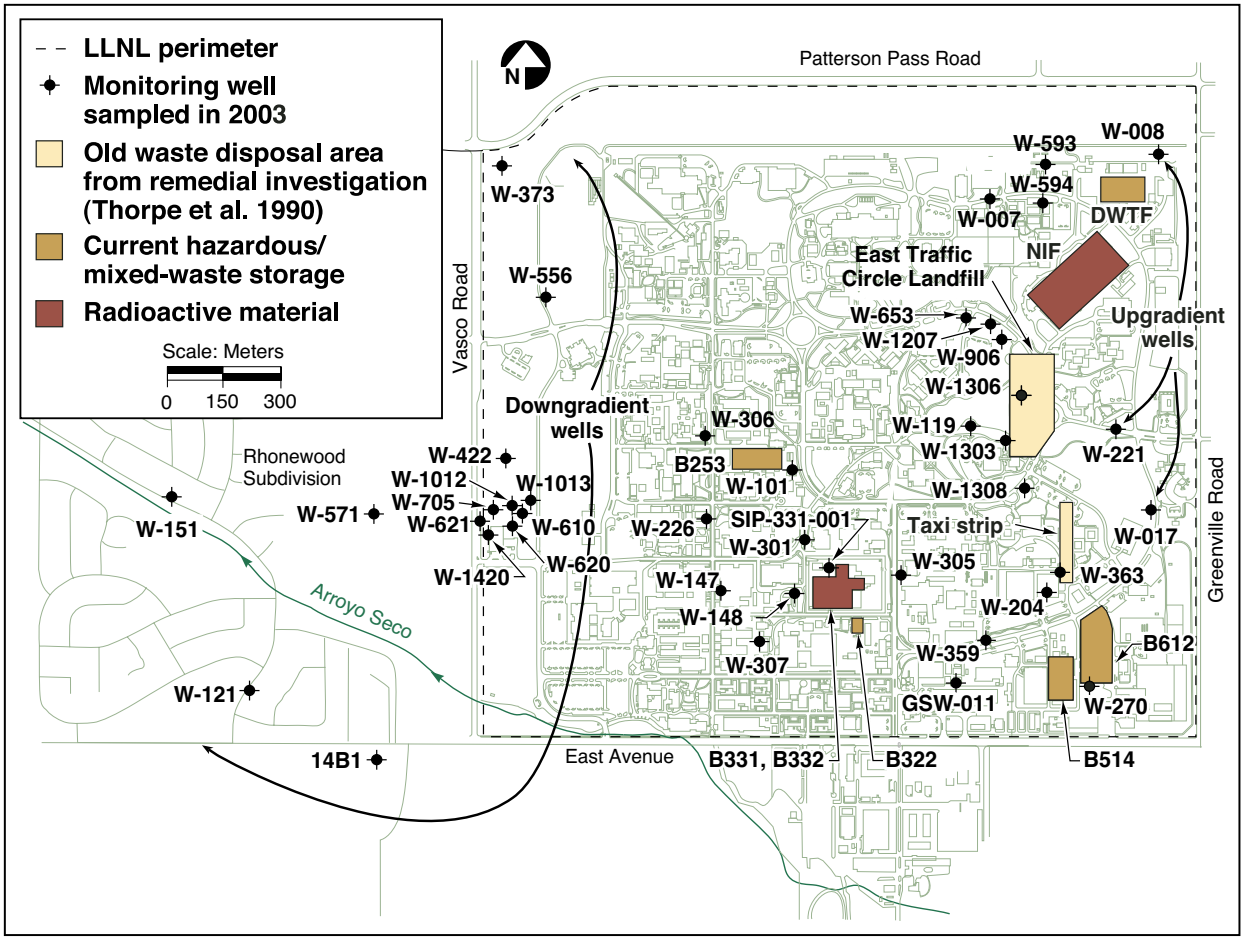


Figure 4-12. Locations of routine surveillance groundwater monitoring wells at the Livermore site

each surveillance monitoring well is in the uppermost saturated aquifer (or aquifers) at that well location. As discussed in Chapter 7, the alluvial sediments have been divided into seven hydrostratigraphic units (HSUs) dipping gently westward, which are shown in Figure 7-1. Screened intervals for these monitoring wells range from the shallow HSU 1B, in which some of the western monitoring wells are screened, to the deeper HSU 5, in which background well W-017 and some wells around Buildings 514 and 612 are screened.

Two of the background wells, W-008 and W-221, are screened partially in HSU 3A; well W-017 is considered a background well for the deeper HSU 5. These background wells were sampled and analyzed in 2003 for pesticide and herbicide compounds that are used on site and off site, for nitrate, for hexavalent chromium (chromium(VI)), and for certain radioactive constituents including plutonium.

Except for well 14B1, the seven western downgradient wells are screened in shallower HSUs 1B and 2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 is screened over a depth range that includes HSUs 2, 3A, and 3B.) These wells were sampled and analyzed at least once for pesticides, herbicides, radioactive constituents, nitrate, and chromium(VI).

Analytical results for the Livermore site background wells and perimeter wells are contained in the file "Ch4 LV Groundwater" provided on the report CD. No pesticide or herbicide organic compounds were detected above analytical reporting limits in the groundwater during 2003. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater at variable concentrations. The concentrations detected in the groundwater samples from the background wells represent background values for 2003, although there have been variations in the concentrations since regular surveillance monitoring began in 1996.

Concentrations of nitrate detected in groundwater samples from downgradient well W-1012 since 1996 have been greater than the MCL of 45 mg/L. Concentrations of nitrate detected in samples from this well in 2003 were 62 to 68 mg/L. Because of the hydrologic influence of TFB that pumps and treats groundwater from HSUs 1B and 2, groundwater with high nitrate concentrations is restrained from moving off site to the west. The highest concentration measured in an off-site well was below the MCL at 42 mg/L, in downgradient monitoring well W-571. Monitoring well W-571 is off site and downgradient to the west, and is screened in HSU 1B. During 2003, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 22 mg/L to 27 mg/L. Detected concentrations of nitrate in western perimeter wells, with the exception of well W-1012, ranged from 14 mg/L (in well W-373) to 42 mg/L (in well W-571).

Nitrate was not detected at concentrations greater than the MCL in any other western perimeter surveillance monitoring well (besides on-site monitoring well W-1012) during 2003. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in groundwater from the western perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

Nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells (**Figure 4-12**), screened in HSUs 1B and 2. Other than well W-1012, no groundwater sample had a nitrate concentration greater than the MCL.

Of the selected trace metal analytes, no concentration analyzed in any groundwater sample collected in 2003 exceeded the California or federal MCL.

Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past or where previously detected COCs have low concentrations that do not require CERCLA remedial action. Wells selected for

monitoring are screened in the uppermost aquifers, and are situated downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 4-12**. All analytical results are included in the file "Ch4 LV Groundwater" provided on the report CD.

No concentrations of plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium and radium isotopes remain well below drinking water MCLs.

The Taxi Strip and the East Traffic Circle Landfill areas within the Livermore site are two potential sources of groundwater contamination. Samples from monitoring wells screened in HSUs 2 (W-204) and 3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2003 for copper, lead, zinc, americium-241, plutonium-238, plutonium–239, radium-226, radium-228, and tritium. Samples from monitoring wells screened at least partially in HSU 2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for the same elements as in the Taxi Strip Area. The trace metals copper, lead, and zinc were not detected in samples from any of these monitoring wells in 2003.

Although the National Ignition Facility (NIF) has not yet begun full operations, LLNL obtains a baseline of groundwater quality prior to start of operations. Analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSUs 3A and 2, respectively) downgradient of NIF for minerals, selected metals, gross alpha and beta radiation, radium-226, and tritium. Another potential source of groundwater contamination is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of LLNL. Samples were obtained downgradient from this facility from wells W-007, W-593 (screened in HSU 3A), and W-594 during 2003 and were analyzed for minerals, selected metals, americium-241, plutonium-238, plutonium 239, radium-226, and tritium. Monitoring wells W-007 and W-594 (screened in HSUs 2/3A and 2, respectively) were added to this monitoring network in 2003.

Monitoring results from the wells near NIF and DWTF show very low concentrations of tritium present and only minor concentrations of gross alpha and gross beta radiation in the groundwater samples collected. Monitoring will continue near these facilities to determine baseline conditions.

The old hazardous waste/mixed waste storage facilities around Area 514 and Building 612 are also a potential source of contamination. They are monitored by wells W-270 and W-359 (screened in HSU 5), and well GSW-011 (screened in HSU 3A). Groundwater from these wells was sampled and analyzed for selected trace metals, general minerals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2003. No significant contamination was detected in the groundwater samples collected from wells W-270, W-359, or GSW-011 downgradient from this area in 2003.

Groundwater samples were obtained downgradient from areas where releases of metals to the ground have occurred. Samples were obtained from monitoring well W-307 (screened in HSU 1B), downgradient from a fume hood vent on the roof of Building 322, a metal plating shop. Soil samples obtained from the area show elevated

concentrations (in comparison with Livermore site's background levels) of total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals will migrate from the site.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253 (Jackson 1997). These samples were obtained from monitoring wells W-226 and W-306, which are screened in HSUs 1B and 2, respectively.

In 2003 dissolved chromium was detected at elevated concentrations in groundwater samples from well W-306, which is downgradient from the Building 253 catch basin. Concentrations of chromium(VI) were measured as 11 µg/L at well W-226 and 22 µg/L at well W-306. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). No concentration of either dissolved chromium or chromium(VI) was greater than the MCL of 50 µg/L for total chromium in drinking water.

Additional surveillance groundwater sampling locations established in 1999 surround the area of the Plutonium Facility (Building 332) and the Tritium Facility (Building 331) (see **Figure 4-12**). Possible contaminants include plutonium-239 and americium-241 from the Plutonium Facility and tritium from the Tritium Facility. Both plutonium and americium are much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, could migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2; downgradient wells W-101, W-147, and W-148 are screened in HSU 1B; and SIP-331-001 and well W-301 are screened in HSU 2.

In August 2000, relatively elevated tritium activity was measured in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L) that was concluded to be most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater of this area have been cyclic since that time. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium contents remain below environmental levels of concern.

Site 300 and Environs

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells and springs on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year at every monitoring location; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity.

Figure 4-13 shows the locations of numerous wells and three springs at or near Site 300 that are used for groundwater surveillance monitoring. The locations of compliance monitoring wells are shown in Figures 4-14, 4-15, 4-16, and 4-17. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from LLNL surface or sub-surface operations at Site 300.

Twelve groundwater monitoring locations are off site. Two are springs, identified as MUL2 and VIE1, which are located near the northern boundary of Site 300. Off-site surveillance well VIE2 is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells located near the southern boundary of Site 300 in or adjacent to the Corral Hollow Creek floodplain.

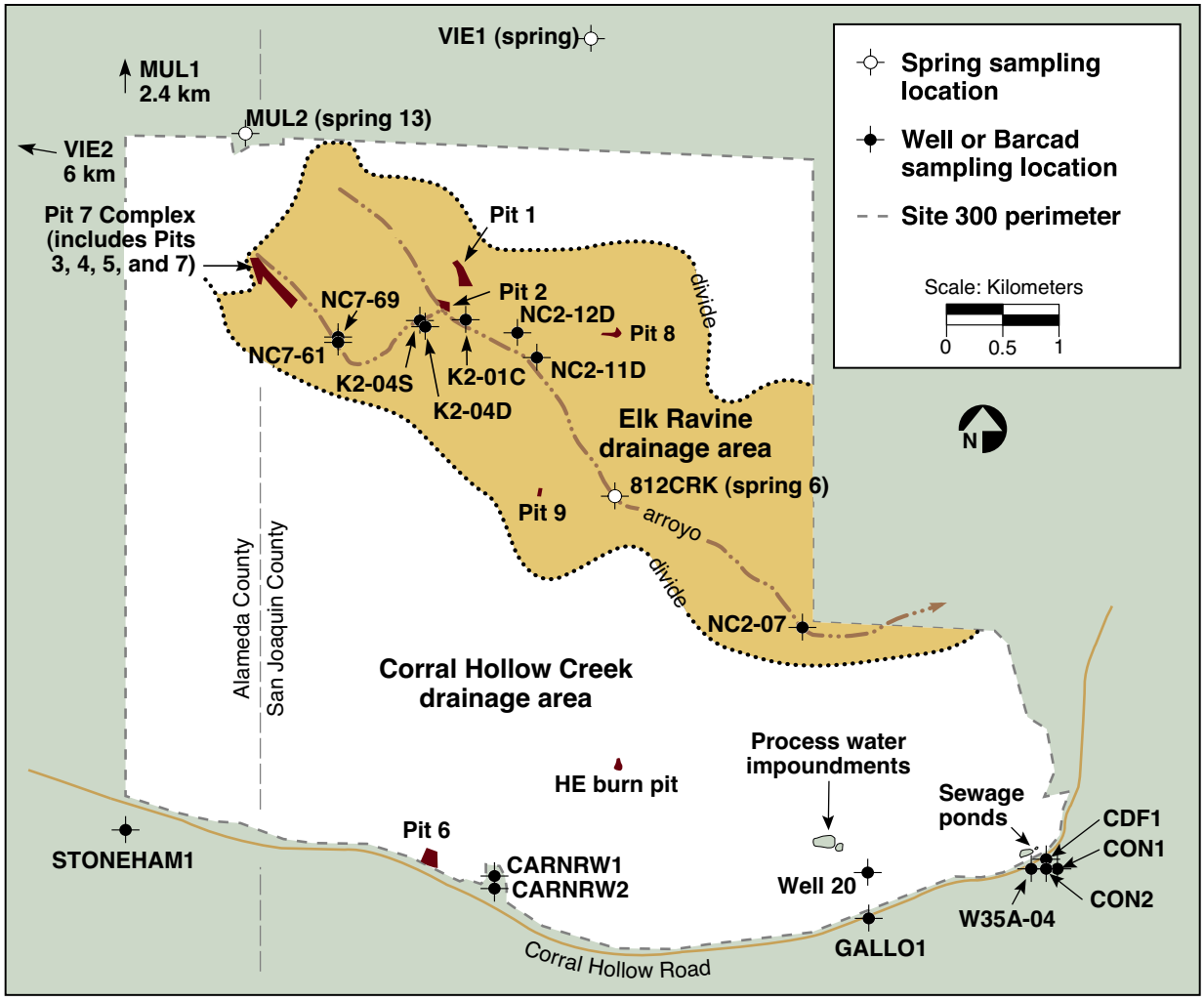


Figure 4-13. Locations of surveillance groundwater wells and springs at Site 300, 2003

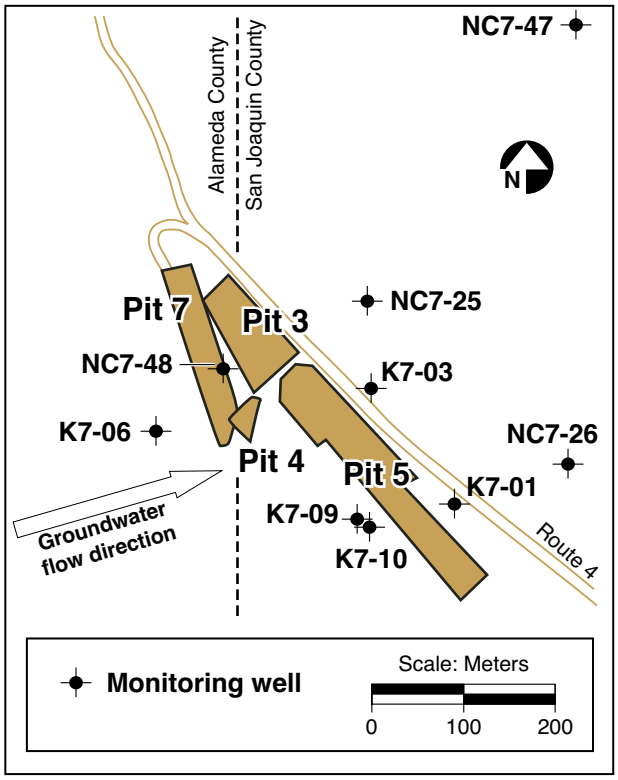


Figure 4-14. Locations of Pit 7 compliance groundwater monitoring wells, 2003

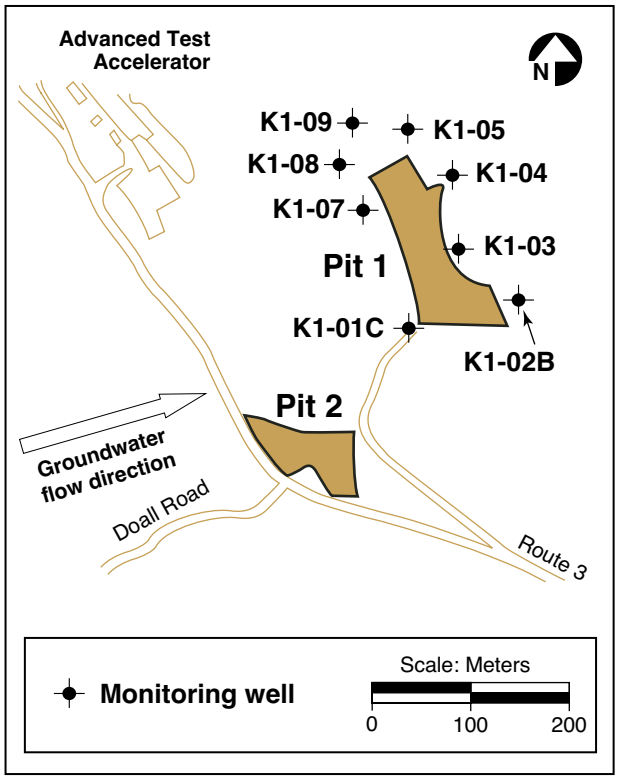


Figure 4-15. Locations of Pit 1 compliance monitoring wells, 2003

On-site wells, installed primarily for CERCLA site-characterization studies, continue to be used to monitor closed landfills, a former open-air high explosives (HE) burn pit, two connected surface water impoundments, and two connected sewer ponds (**Figure 4-13**). The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are located in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit, the two process water impoundments, and the sewage ponds are located in the southern portion of Site 300 in the Corral Hollow Creek drainage area. Two on-site water supply wells, identified as wells 18 and 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby potable supply well.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. Networks of wells within the Elk Ravine drainage area are described first, followed by the well networks in the Corral Hollow Creek drainage area. Subsets of CERCLA wells, installed mainly for site characterization, have been selected for compliance and surveillance monitoring use based on their locations and our general understanding of local geologic and hydrogeologic conditions at Site 300. (Chapter 7 includes a summary of Site 300 stratigraphy and hydrogeology. All analytical data from 2003 are included in the file "Ch4 S300 Groundwater" provided on the report CD.)

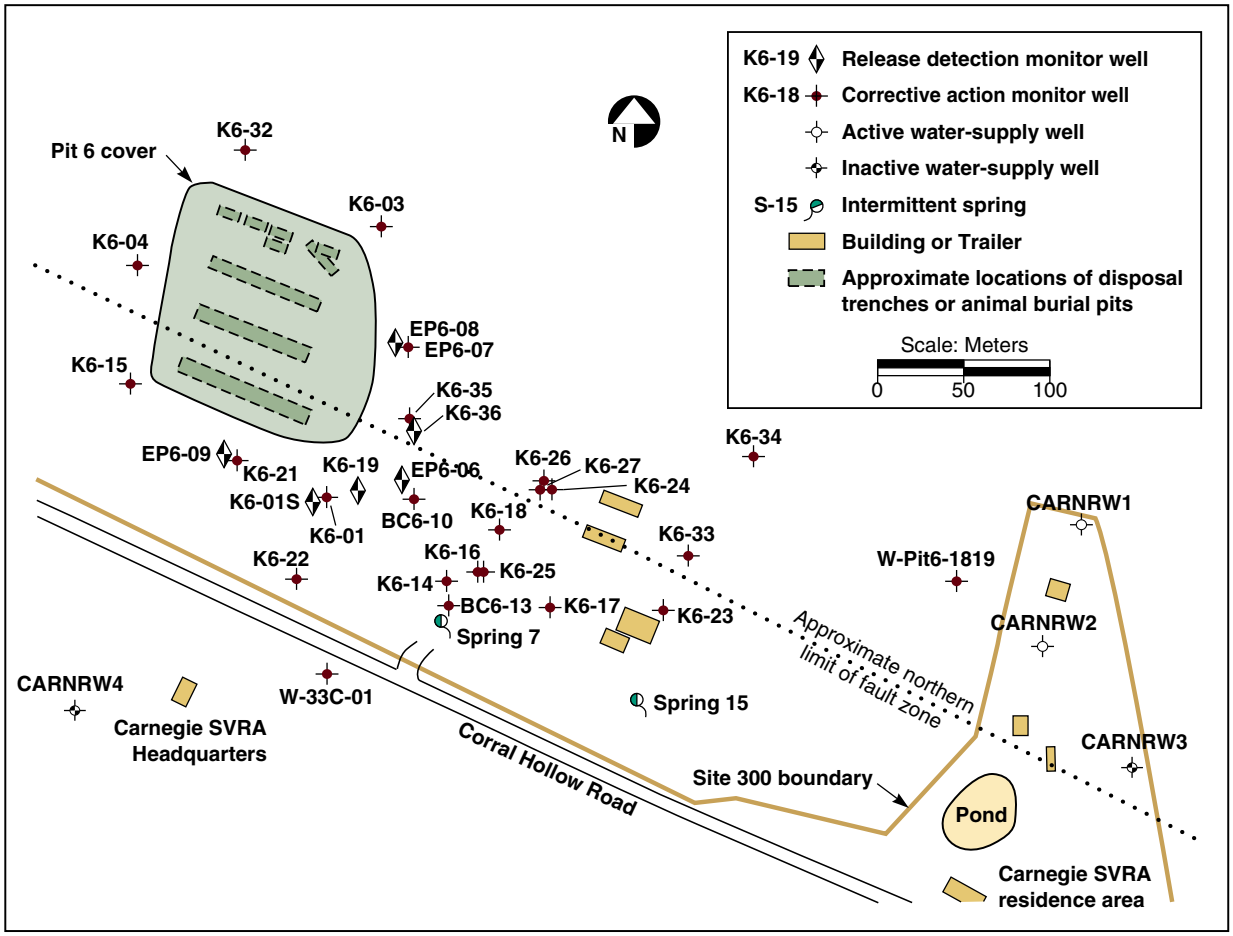


Figure 4-16. Locations of Pit 6 compliance groundwater monitoring wells and springs, 2003

Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 4-13**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs because of the system of surface and underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills known as Pits 1 through 5 and 7 through 9 and firing tables where explosives tests are conducted. None of the closed landfills has a liner, which is consistent with disposal practices in the past when the landfills were constructed. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See Chapter 7 for a review of groundwater contamination in this drainage area as determined from numerous CERCLA remedial investigations.)

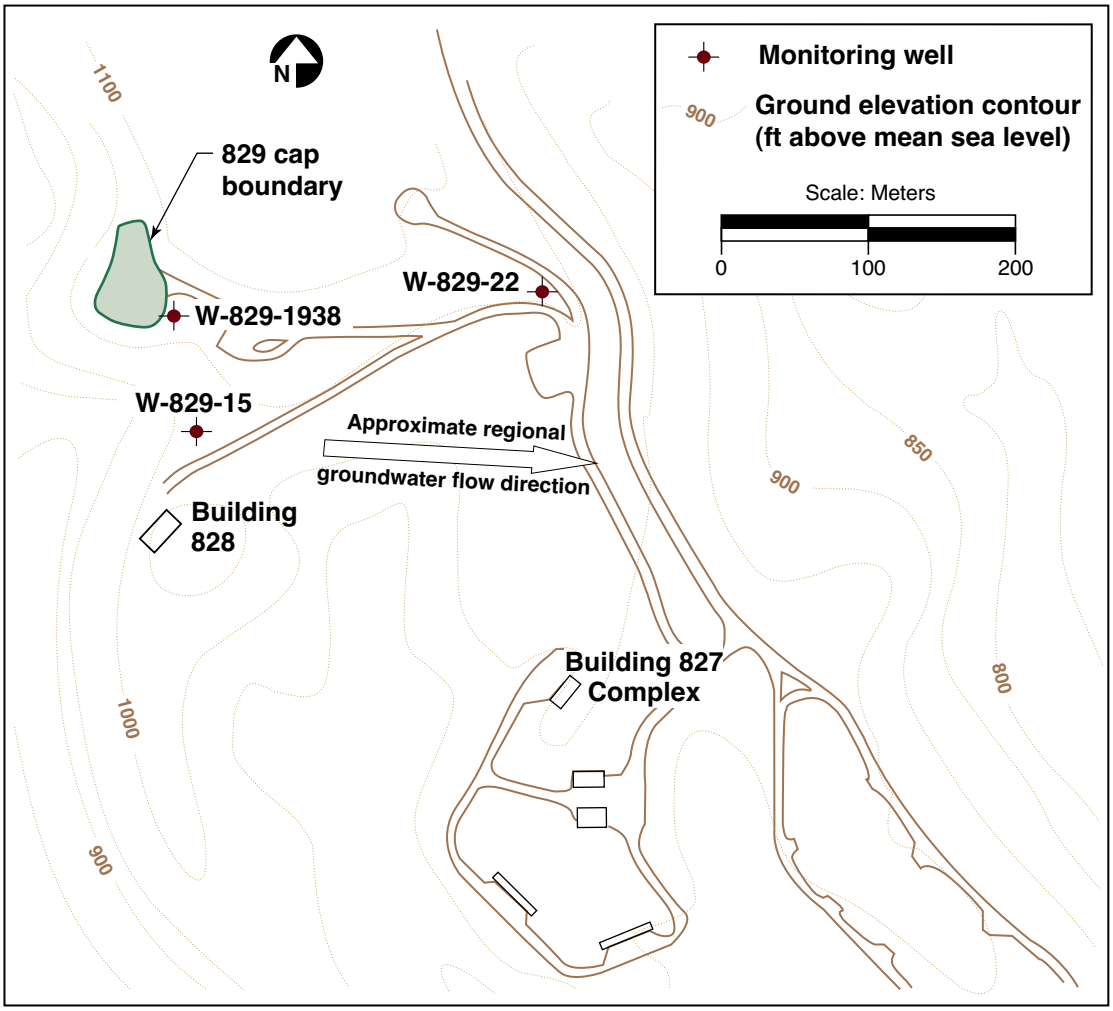


Figure 4-17. Locations of Building 829 closed burn pit compliance groundwater monitoring wells

Pit 7 Complex

Monitoring requirements for the Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA) in 1993, are specified in WDR 93-100 administered by the CVRWQCB (1993 and 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

The Pit 7 Complex area is located at an elevation of about 400 m in the most elevated portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 4-14**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic,

wood, tritium, uranium-238, beryllium, lead, and other metals in trace amounts. In 1988, 9440 m^3 of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in any landfill at Site 300. **Figure 4-13** shows the locations of surveillance groundwater wells and springs at Site 300.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2003 from the Pit 7 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and volatile organic compounds (VOCs). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs to groundwater from Pit 7 is evident in the chemical data obtained during 2003. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs. These are associated with releases that occurred prior to 2003. The primary sources of COCs detected by the network of Pit 7 monitoring wells are the closed landfills known as Pits 3 and 5, which are adjacent to Pit 7 (**Figure 4-14**). Natural sources in the rocks and sediments surrounding Pit 7 also have contributed arsenic, barium, uranium, and, possibly nitrate to the groundwater. In the past, especially during the El Niño winters of 1982/1983 and 1997/1998, excessive seasonal rainfall caused groundwater levels to rise into Pit 3 and Pit 5 from beneath, leading to the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have fallen generally at Site 300, thus reducing the potential for releases to occur by this mechanism. CERCLA modeling studies indicate that tritium and other COCs released in the past will not reach off-site aquifers at concentrations above MCLs. See Chapter 7 for a review of CERCLA activities regarding groundwater contamination in the upper reaches of the Elk Ravine drainage area. For a detailed account of Pit 7 compliance monitoring during 2003, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2003* (Christofferson and MacQueen 2004).

Elk Ravine

Groundwater samples were obtained twice during 2003 from the widespread Elk Ravine surveillance monitoring network (see **Figure 4-13**). Samples were analyzed for inorganic constituents (mostly metallic elements), VOCs, general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

As in past years, no new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2003. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituent measurements for the Elk Ravine drainage area surveillance monitoring network are listed in Appendix A.

Concentrations of arsenic range up to 43 µg/L (well NC2-07) in Elk Ravine monitoring wells. Earlier CERCLA characterization studies determined that the arsenic is from natural sources, particularly from the dissolution of the mineral arsenopyrite, which is a component of the underlying volcanogenic sediments and sedimentary rocks (Raber and Carpenter 1983). It should be noted that there are no wells in this area that are used for potable domestic, livestock, or industrial water supply. However, a perennial spring in Elk Ravine (location 812CRK on **Figure 4-13**), which is used by the indigenous wildlife there, contains concentrations of naturally occurring arsenic (28 µg/L arsenic in 2003).

Tritium activity was relatively elevated in many of the shallow groundwater surveillance samples obtained during 2003 from Elk Ravine. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The largest HTO plume, which extends eastward more than a kilometer from a source beneath the Building 850 firing table area to the vicinity of Pits 1 and 2, is confined to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium.

The majority of the Elk Ravine surveillance network tritium measurements made during 2003 support earlier CERCLA studies that show that the tritium in the plume is diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998). For example, tritium activity in groundwater at well NC7-61 has decreased from 6500 Bq/L in 1996 to 1600 Bq/L in 2003. CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary. Note that the tritium plume has not yet reached the surveillance monitoring perennial spring location 812CRK, which is approximately one mile upstream from where the Site 300 boundary crosses Elk Ravine.

Except in the immediate vicinity of Pit 7, groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine are all low and are indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements including arsenic, barium, chromium, selenium, vanadium, and zinc are all within the natural ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 1

Monitoring requirements for the Pit 1 landfill, which was closed under RCRA in 1993, are also specified in WDR 93-100 administered by the CVRWQCB (1993 and 1998) and in (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater.

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Pit 1 landfill and the positions of the eight groundwater wells used to monitor it are shown in **Figure 4-15**. The eight wells are K1-01C, K1-02B, K1-03, K1-04, K1-05, K1-07, K1-08, and K1-09.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2003 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta),

activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA method 601). Every other quarter, analyses were conducted for an additional seven elements. Additional annual analyses were conducted on fourth-quarter samples for extractable organics (EPA method 625), pesticides and PCBs (EPA method 608), and herbicides (EPA method 615). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection.

As in past years, no release of COCs to groundwater from Pit 1 is evident in the monitoring data collected during 2003. A detailed account of Pit 1 compliance monitoring during 2003, including tables and graphs of groundwater COC analytical data, appears in Christofferson and MacQueen (2004).

Tritium activity measured above background level (about 4 Bq/L) in the groundwater at Pit 1 monitoring wells K1-01C (24 Bq/L), K1-02B (150 Bq/L), K1-03 (23 Bq/L), and K1-08 (9.0 Bq/L) during 2003. The tritium activity in the groundwater sampled at these wells represents a distal lobe of the Building 850 tritium plume. Measurements of radium, thorium, and uranium made during 2003 in groundwater samples from Pit 1 compliance monitoring wells showed low activities indistinguishable from background levels.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) decreased from a maximum concentration of 140 µg/L measured in 1999 to 41 µg/L in 2003 in groundwater at Pit 1 monitoring wells K1-05 (13 µg/L), K1-08 (19 µg/L), and K1-09 (41 µg/L). The drinking water MCL for this VOC is 1200 µg/L. Previous CERCLA investigations have linked the Freon 113 detected in Pit 1 monitoring wells to past spills of Freon in the Advanced Test Accelerator area, about 200 m northwest of the affected wells (Webster-Scholten 1994; Taffet et al. 1996).

Corral Hollow Creek Drainage Area

Pit 6

Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in the *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1998) and in the *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2002). The closed Pit 6 landfill covers an area of about 1 hectare (2.5 acres), at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over all the trenches, and a storm water drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) north of the Corral Hollow Creek flood plain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 4-16**. Beneath the northern two-thirds of Pit 6, groundwater flows south-southeast, following the inclination of the underlying sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10 to 20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for groundwater to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994).

Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Program (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Program (CAMP), which monitors the movement and fate of historical releases. **Figure 4-16** shows the locations of Pit 6 and the wells used to monitor the groundwater there.

To comply with monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2003 from specified Pit 6 monitoring wells. DMP samples were obtained quarterly and were analyzed for beryllium and mercury, general radioactivity (gross alpha and beta), tritium and uranium activity, specified VOCs, nitrate and perchlorate. CAMP samples were measured for VOCs, tritium activity, nitrate and perchlorate. Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs from Pit 6 is indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2003. COCs that were released prior to constructing an impermeable cap over the closed landfill in 1997 continued to be detected in the groundwater at low concentrations during 2003. These COCs include tritium, perchlorate, trichloroethylene (TCE), perchloroethylene (PCE), and cis-1,2-dichloroethene (cis-1,2-DCE). All contaminant plumes associated with Pit 6 are confined to shallow depths. None has been detected beyond the Site 300 boundary. For a detailed account of Pit 6 compliance monitoring during 2003, including tables of groundwater analytical data and map figures showing the distribution of COC plumes, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2003* (Christofferson and Blake 2004).

Buildling 829 Closed HE Burn Facility

Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in the *Final Closure Plan for the High-Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Experimental Test Site 300* (Mathews and Taffet 1997), and in the *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Facility – Volume 1* (LLNL 2001) as modified by the Hazardous Waste Facility Post-Closure Permit for the Building 829 HE Open Burn Facility (DTSC 2003).

The former HE Open Burn Treatment Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m. The facility included three shallow, unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The facility was used to thermally treat explosives process waste generated by operations at Site 300 and similar waste from explosives research operations at the Livermore site. The facility was covered with an impervious cap in 1998 following RCRA guidance.

Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km to the south at Corral Hollow Road. Stratified rocks of the Neroly (Tn) formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m, is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m, represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$).

Based on groundwater samples recovered from boreholes, previous CERCLA remedial investigations determined that the perched groundwater near the burn facility was contaminated with VOCs, primarily TCE, but that the deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994). Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of HE compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer primarily because its downward movement is blocked by more than 100 m of unsaturated Neroly Formation sediments that include interbeds of claystone and siltstone.

Beginning in 1999, LLNL implemented the intensive groundwater monitoring program for this area described in the post-closure plan (Mathews and Taffet 1997) to track the fate of contaminants in the soil and the perched water-bearing zone, and to monitor the deep regional aquifer for the appearance of any potential contaminants from the closed burn facility.

This monitoring program remained in effect through the first quarter of 2003, at which time LLNL began implementation of the provisions specified in the *Hazardous Waste Facility Post-Closure Permit for the B829 Facility* (DTSC 2003). Following the guidance outlined in the DTSC *Technical Completeness* (DTSC 2002) assessment, LLNL installed one additional groundwater monitoring well at the point of compliance (POC) within three meters of the edge of the capped High Explosive Open Burn Treatment Facility. This well (W-829-1938) was screened in the regional aquifer, the uppermost aquifer beneath the Building 829 Facility. This new well will be sampled as part of the permit-specified groundwater monitoring network (**Figure 4-17**), beginning in the first quarter of 2004. Also shown in **Figure 4-17** are two previously existing wells (W-829-15 and W-829-22) that were used throughout 2003 for quarterly collection of groundwater samples from the regional aquifer. Two other deep wells (W-827-04 and W-827-05), which had been sampled under the *B-829 Final Closure Plan* (Mathews and Taffet

1997), were removed from the groundwater monitoring network specified in the permit; therefore, these wells were sampled only during the first quarter of 2003. As in past years of this monitoring program, well W-827-04 was dry.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2003 from the Building 829 monitoring well network. Groundwater samples from the wells screened in the deep regional aquifer were analyzed quarterly for inorganic COCs (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA method 624), extractable organics (EPA method 625), pesticides (EPA method 608), herbicides (EPA method 615), general radioactivity (gross alpha and beta), radium activity, total organic carbon (TOC), total organic halides (TOX), and coliform bacteria.

During the first quarter of 2003, groundwater samples from the two wells (W-829-06 and W–829-08) screened in the shallow perched water-bearing zone were collected and analyzed for explosive compounds and VOCs. These two shallow wells, which had been sampled under the *B-829 Final Closure Plan* (Mathews and Taffet 1997), were also removed from the groundwater monitoring network specified in the permit (DTSC 2003).

No new release of COCs to groundwater from the closed HE burn facility is indicated by the monitoring data obtained during 2003. For a detailed account of compliance monitoring of the closed HE burn pit during 2003, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility— Annual Report 2003* (Revelli 2004b).

The two shallow wells, W-829-06 and W-829-08, were sampled as part of this groundwater monitoring network only during the first quarter of 2003. (Beginning in the second quarter of 2003, LLNL's CERCLA Compliance Monitoring Program took responsibility for sampling these two wells.) The primary contaminant in the perched groundwater is TCE. The maximum TCE concentration measured during 2003 was 210 µg/L, in a first quarter sample from W-829-06. This sample also contained the other contaminant detected in 2003, 1,2-dichloroethene (1,2-DCE), measured at 1.2 µg/L.

Wells W-827-05, W-829-15, and W-829-22 were all sampled during the first quarter of 2003; quarterly sampling of W-829-15 and W-829-22 continued throughout the year. The analytical results from these wells, used to monitor the deep regional aquifer beneath the Building 829 facility, are generally typical of the values seen in previous years. The inorganic constituents that were detected during 2003 show concentrations that represent background level concentrations of substances dissolved from natural sources in the underlying rocks. Only selenium was detected at a concentration slightly above its statistical limit in first-quarter samples. However, this constituent (found at Site 300 in naturally occurring minerals) is present in other uncontaminated Site 300 wells at background levels above those reported for the HE Burn Area. Selenium was not detected in the subsequent second-, third-, and fourth-quarter samples from well W-829-22.

Water Supply Well

Water supply well 20, located in the southeastern part of Site 300 (**Figure 4-13**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1500 L/min of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2003 from well 20. Groundwater samples were analyzed for inorganic COCs (mostly metals), VOCs, general radioactivity (gross alpha and gross beta), and tritium activity.

Quarterly measurements of groundwater from well 20 do not differ significantly from previous years. As in past years, the primary potable water supply well at Site 300 showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

Off-site Surveillance Wells and Springs

As planned for surveillance purposes, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2003. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04, are adjacent to the site on the south (**Figure 4-13**). Well W35A-04 is a DOE CERCLA well that was installed off site for monitoring purposes only. The remaining seven wells south of Site 300 are privately owned and were constructed to supply water either for human consumption, stock watering, or fire suppression. They are monitored to determine the concentrations of dissolved constituants in the groundwater beneath the Corral Hollow Creek flood plain.

Groundwater samples were obtained quarterly during 2003 at six of the off-site surveillance well locations south of Site 300. As planned, CARNRW1 and CON2 samples were analyzed only for VOCs. Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA method 502.2). Additional annual analyses were conducted on third-quarter samples for uranium activity and extractable organic compounds (EPA method 625).

Groundwater samples were obtained once (annually) during 2003 from the remaining off-site surveillance monitoring locations—MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA method 625).

Generally, no COC attributable to LLNL operations at Site 300 was detected in the off-site groundwater samples. Arsenic and barium were widely detected at the off-site locations, but their concentrations were below MCLs and their occurrence is consistent with

natural sources in the rocks. Scattered detections of metals are probably related to metals used in pumps and supply piping. As in past years, TCE was detected at concentrations of less than 1 µg/L in the groundwater samples obtained from well GALLO1. Previous CERCLA remedial investigations concluded that the TCE in the GALLO1 well water was likely caused by a localized surface spill on the property, possibly solvents used to service the private well (Webster-Scholten 1994). (Surveillance monitoring of a similarly sited well, GALLO2, was terminated in 1991 because of contamination from chemicals leaking from the pumping apparatus.) Radioactivity measurements of off-site groundwater are all indistinguishable from background activities.

Environmental Impact on Groundwater

Groundwater monitoring at and the surrounding environs of the Livermore site and Site 300 indicates that LLNL operations have minimal impact on groundwater beyond the site boundaries. During 2003, neither radioactivity nor concentrations of elements or compounds detected in groundwater were confirmed to be above potable water MCLs.

Other Monitoring Programs

Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. LLNL collects rainwater samples according to written standardized procedures which are summarized in the *Environmental Monitoring Plan* (Woods 2002). Rainwater is simply collected in stainless-steel buckets at fixed locations. The buckets are in open areas and are mounted about 1 m above the ground to prevent collection of splashback water. Rainwater samples are decanted into 250 mL amber glass bottles with Teflon-lined lids. The tritium activity of each sample is measured at a contracted laboratory by a scintillation counting method equivalent to EPA Method 906 that has a low reporting limit of about 3.7 Bq/L. All analytical results are included in the file "Ch4 Other Waters" provided on the report CD.

Livermore Site and Environs

Historically, the tritium activity measured in rainwater in the Livermore Valley was caused by atmospheric emissions of HTO from stacks at LLNL's Tritium Facility (Building 331), and prior to 1995, from the former Tritium Research Laboratory at Sandia/California (see Chapter 3). During 2003, tritium activity in air-moisture and,

thence, in rainwater at the Livermore site and in the Livermore Valley, resulted primarily from atmospheric emissions of HTO from stacks at Building 331. Atmospheric emission of HTO from Building 331 in 2003 was approximately 4.1 TBq (110 Ci), up from 1.2 TBq (33 Ci) in 2002. Additional comparatively minor diffuse sources of HTO vapor at LLNL during 2003 were the Waste Management Area (WMA) at Building 612 and the newly operating DWTF.

The rain sampling locations are shown in **Figure 4-18**. The fixed locations are used to determine the areal extent of detectable tritium activity in rainwater. A new rain-tritium sampling location, DWTF, was established in mid-year 2003. Historically, and in 2003, the maximum tritium activity was measured at location B343, which is the on-site location nearest to Building 331. Historically, the more distant off-site stations (AMON, PATT, VINE, and SLST) have rarely shown detectable tritium activity in rainwater samples and serve to bound the area of detectable activity.

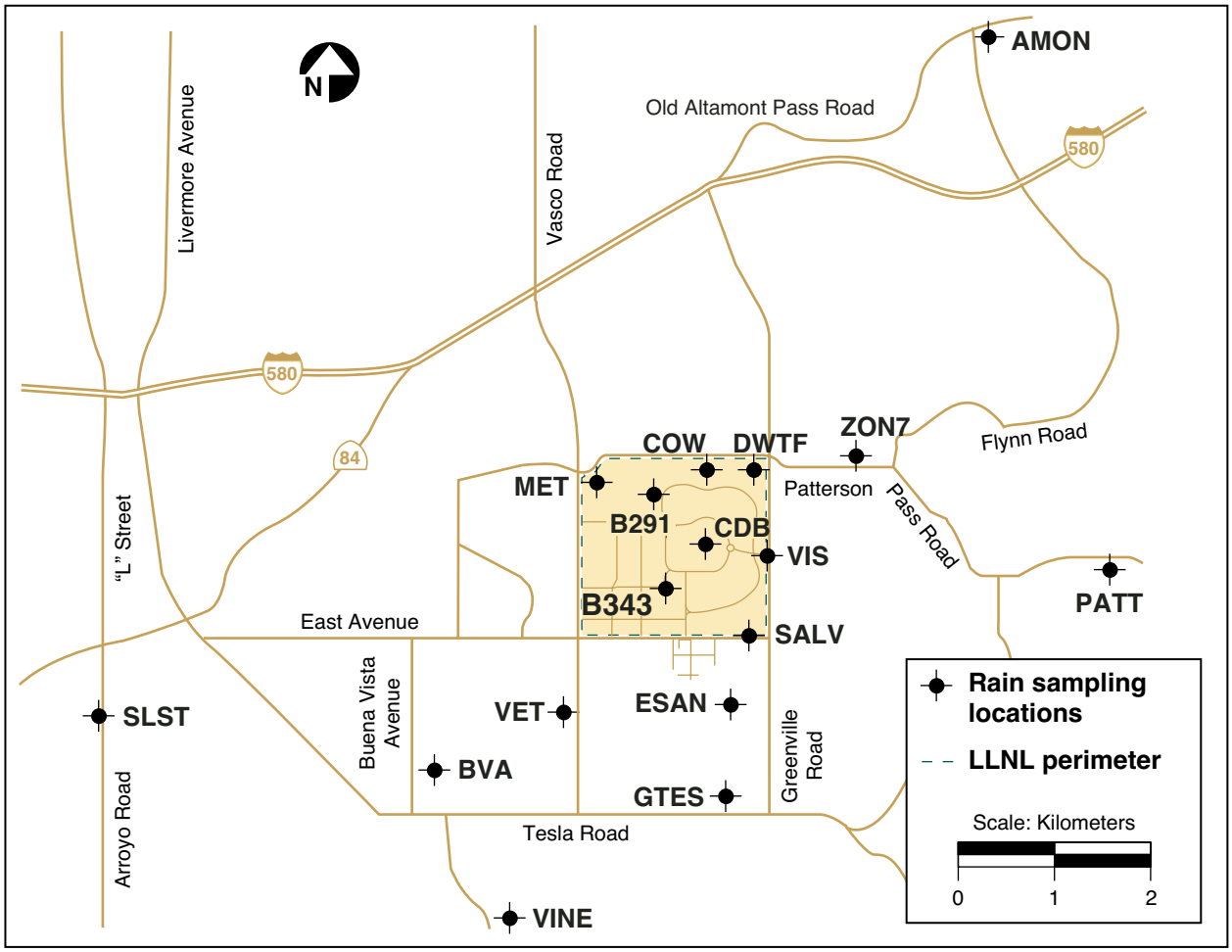


Figure 4-18. Rain sampling locations, Livermore site and Livermore Valley, 2003

During 2003, LLNL collected sets of rainwater samples following three rain events in the Livermore Valley (27 total routine samples obtained) and at the Livermore site (24 total routine samples obtained).

Although the Livermore site rainwater has exhibited elevated tritium activities in the past (Gallegos et al. 1994), during 2003, no on-site measurement of tritium activity was above the MCL of 740 Bq/L established by the EPA for drinking water. As in past years, the on-site rainwater sampling location B343 showed the highest tritium activity for the year, 160 Bq/L, for the rain event that was sampled on April 28. The maximum tritium activity measured in an off-site rainwater sample during 2003 was 8.9 Bq/L in the rainwater sample obtained on December 30 from location GTES, located about 1 mile south of LLNL (**Figure 4-18**). The maximum off-site activity equals 1.2% of the MCL for tritium activity in drinking water.

Site 300 and Environs

Three on-site locations (COHO, COMP, and TNK5) were positioned to collect rainfall for tritium activity measurements at Site 300 during 2003 (**Figure 4-10**). Because of the sparse rainfall at the semi-arid location of Site 300 during 2003, only two rain events could be sampled and they yielded a total of only four (of six possible) rainwater samples. As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2003 had tritium activities above the analytical laboratory reporting limit of 3.7 Bq/L.

Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. Surface and drinking water near the Livermore site and in the Livermore Valley are sampled at the locations shown in **Figure 4-19**. Off-site sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water bodies; of these, DEL, ZON7, and CAL are drinking water sources. BELL, GAS, PALM, ORCH, and TAP are drinking water outlets. Location POOL is the on-site swimming pool. Radioactivity data from drinking water sources and drinking water outlets are used to calculate drinking water statistics (see **Table 4-12**) and doses (see Chapter 6).

Samples are analyzed according to written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002). LLNL sampled these locations semiannually, in January and August 2003, for gross alpha, gross beta, and tritium. The on-site swimming pool location (POOL) was sampled semiannually for gross alpha and gross beta, and quarterly for tritium. All analytical results are included in the file "Ch4 Other Waters" provided on the report CD.

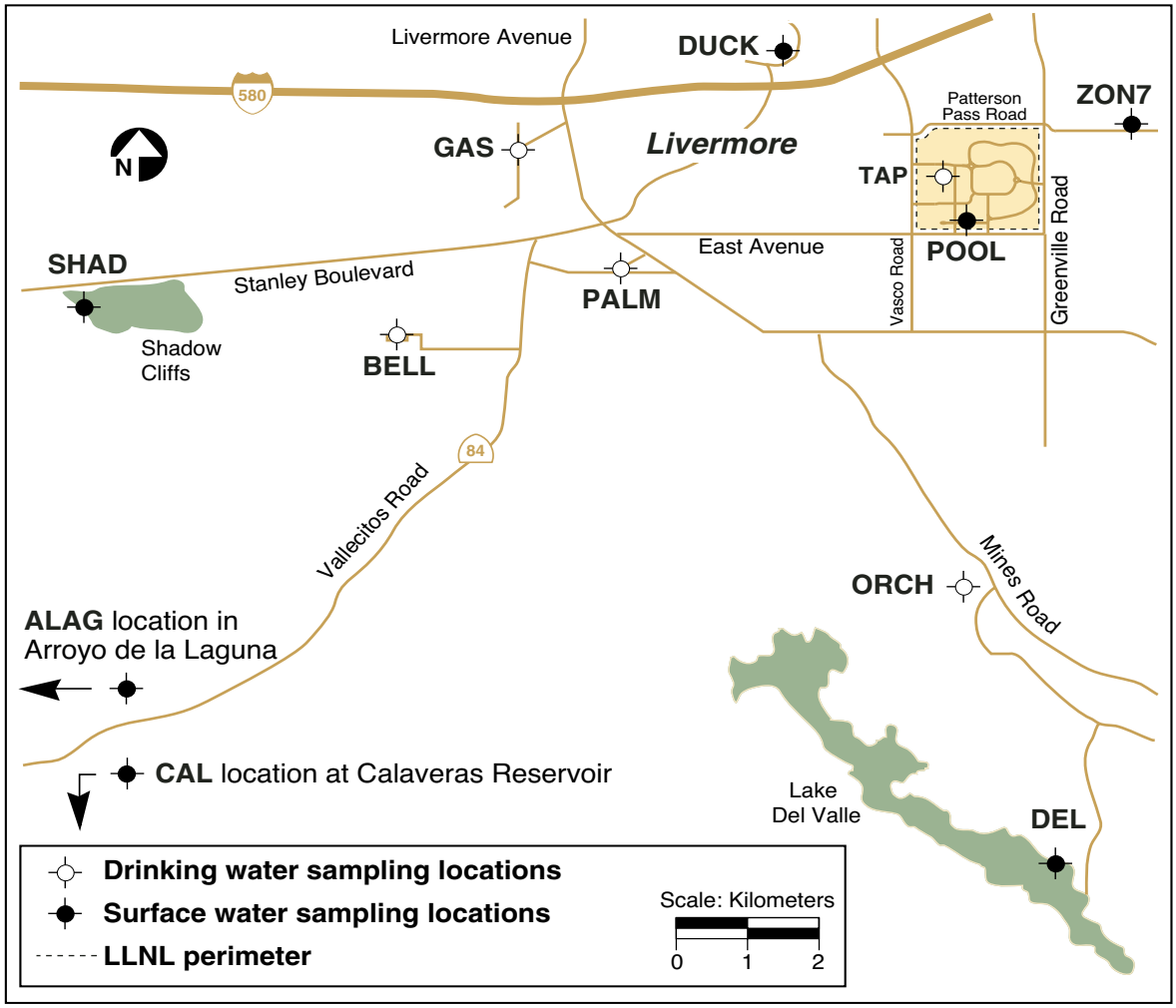


Figure 4-19. Livermore Valley surface and drinking water sampling locations, 2003

The median activity for tritium in surface and drinking waters was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. The maximum tritium activity detected was less than 1% of the MCL in drinking water from the on-site location POOL (**Figure 4-19**). Median activities for gross alpha and gross beta radiation in surface and drinking water samples were both less than 5% of their respective MCLs. Maximum activities detected for gross alpha and gross beta, respectively, were 0.041 Bq/L and 0.256 Bq/L; both less than 15% of their respective MCLs (see **Table 4-12**). Historically, gross alpha and gross beta radiation have fluctuated around the laboratory minimum detectable activities. At these very low levels, the counting error associated with the measurements are nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data.

Table 4-12. Radioactivity in surface and drinking waters in the Livermore Valley, 2003

Locations	Tritium (Bq/L)	Gross alpha (Bq/L)	Gross beta (Bq/L)
All locations			
Median	-0.457	0.003	0.083
Minimum	-2.59	-0.143	0.007
Maximum	5.74	0.041	0.256
Interquartile range	3.24	0.019	0.057
Drinking water locations			
Median	-0.775	-0.001	0.079
Minimum	-2.59	-0.01	0.01
Maximum	1.52	0.04	0.26
Interquartile range	1.32	0.01	0.063
Drinking water MCL	740	0.555	1.85

Note: A negative number means the sample radioactivity was less than the background radioactivity.

Historical median tritium values in surface and drinking waters in the Livermore Valley since 1988 are shown in **Figure 4-20**. Since 1988, when measurements began, water in the LLNL swimming pool has had the highest tritium activities because it is close to tritium sources within LLNL.

Drainage Retention Basin Release

The DRB was constructed and lined in 1992 after remedial action studies indicated that infiltration of storm water from the existing basin increased dispersal of groundwater contaminants. Located in the center of the Livermore site, the DRB can hold approximately 45.6 ML (37 acre-feet) of water. Previous *Environmental Reports* detail the history of the construction and management of the DRB (see Harrach et al. 1995, 1996, 1997). Beginning in 1997, LLNL discharges to the DRB included routine treated groundwater from TFD and TFE, and from related portable treatment units. These discharges contribute a year-round source of water entering and exiting the DRB. Discharge rate is approximately 100 gpm. Storm water runoff still dominates wet weather flows through the DRB, but discharges from the treatment facilities now constitute a substantial portion of the total water passing through the DRB.

The SFBRWQCB regulates discharges from the DRB. The document *Drainage Retention Basin Monitoring Plan Change* (Jackson 2002) lists constituents of interest, sample frequencies, and discharge limits based on the Livermore site CERCLA Record of Decision (ROD) (U.S. DOE 1993), as modified by the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory*

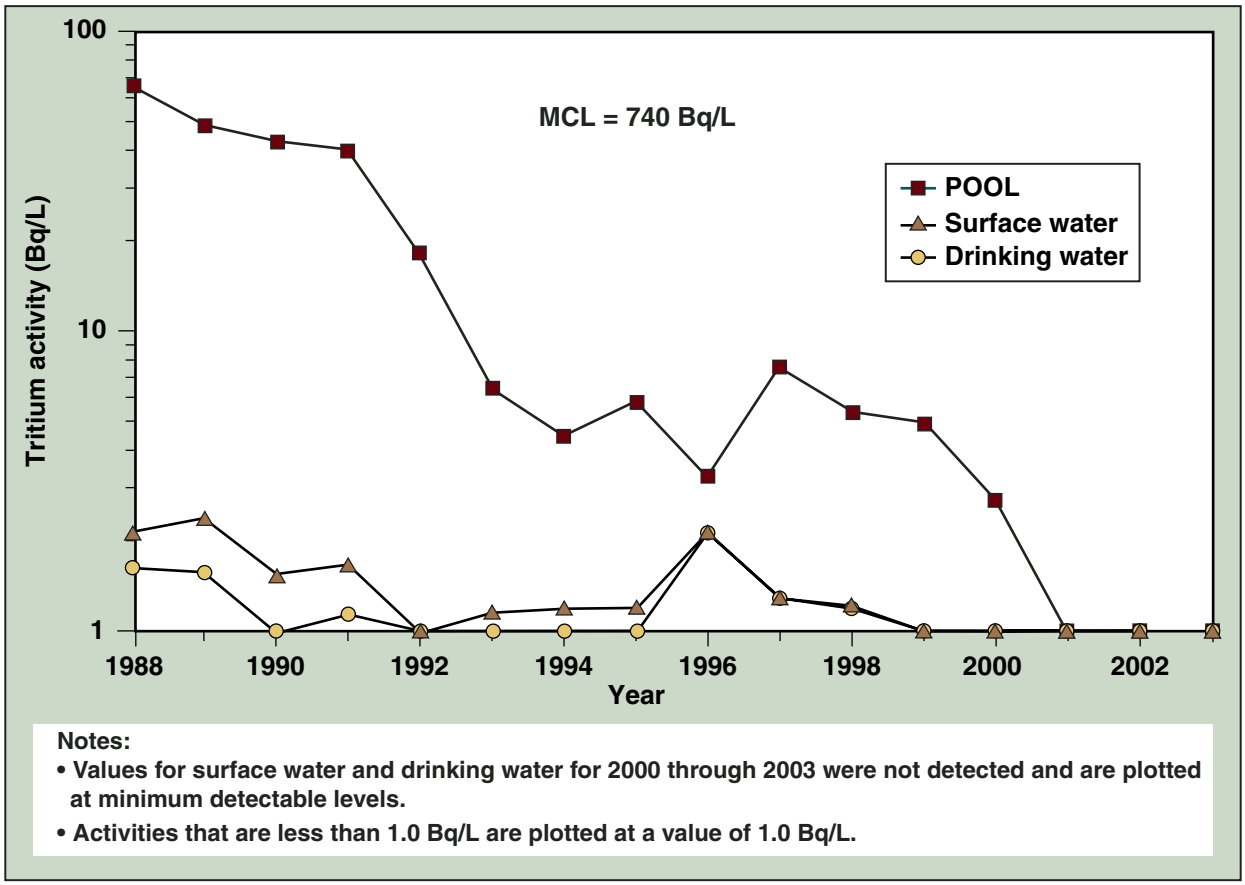


Figure 4-20. Annual median tritium activity in Livermore Valley surface and drinking water, 1988 to 2003

Livermore Site (Berg et al. 1997). The ROD established discharge limits for all remedial activities at the Livermore site to meet applicable, relevant, and appropriate requirements derived from laws and regulations identified in the ROD, including federal Clean Water Act, federal and state Safe Drinking Water Acts, and the California Porter-Cologne Water Quality Control Act.

The DRB sampling program implements requirements established by the SFBRWQCB. The program consists of monitoring wet and dry weather releases for compliance with discharge limits and performing routine reporting. For purposes of determining discharge monitoring requirements and frequency, the wet season is defined as October 1 through May 31, the period when rain-related discharges usually occur (Galles 1997). Discharge limits are applied to the wet and dry seasons as defined in the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site* (Berg et al. 1997) (wet season December 1 through March 31, dry season April 1 through November 30).

To characterize wet-season discharges, LLNL samples DRB discharges at location CDBX and the Livermore site outfall at location WPDC during the first release of the rainy season, and from a minimum of one additional release (chosen in conjunction with storm water runoff sampling). During the dry season, samples are collected from each discrete discharge event or monthly while discharge is continuous. Discharge sampling locations CDBX and WPDC are shown in **Figure 4-9**. LLNL collects samples at CDBX to determine compliance with discharge limits. Sampling at WPDC is done to identify any change in water quality as the DRB discharges travel through the LLNL storm water drainage system and leave the site.

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2002). All samples of DRB release water are collected as grab samples. Field measurements for turbidity are collected with a calibrated field instrument. Field Tracking Forms are used to record all information about sampling events including instrument measurements and sample times. A chain of custody is used to track custody of all samples as they move from the sampler to the analytical lab and then the data as it moves from the analytical laboratory back to ORAD data management personnel for review, reporting and archival. State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in the file "Ch4 Other Waters" provided on the report CD.

Water releases occurred continuously to maintain relatively low nutrient levels in the DRB. Samples collected at CDBX and WPDC exceeded only the pH discharge limits. The higher pH readings seen in the DRB discharge samples during the summer and fall correspond to the peak of the summer and fall algae blooms within the DRB. During 2003, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to the DRB. While some metals were detected, none were above discharge limits. All organics, pesticides, and PCBs were below analytical reporting limits. Gross alpha, gross beta, and tritium levels were well below discharge limits.

LLNL collects and analyzes samples for acute fish toxicity using fathead minnow (*Pimphales promelas*) and for chronic toxicity using three species (fathead minnow, water flea daphnid [*Ceriodaphnia dubia*], and green algae [*Selanastrum capricomutum*]). LLNL collects acute toxicity samples at the first wet-season release and from each discrete dry season release from location CDBX. Samples for chronic fish toxicity are collected at location CDBX at the first wet-season release. Aquatic bioassay for toxicity showed no toxicity effects in DRB discharge water. One sample at location WPDC showed 50% survival for the acute test. The reason for the toxicity result is unknown. Two follow-up samples from location WPDC showed 100% survival.

Site 300 Drinking Water System

LLNL samples large-volume discharges from the Site 300 drinking water system that reach surface water drainage courses in accordance with the requirements of WDR 5-00-175, NPDES General Permit No. CAG995001. The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB.

Discharges that are subject to sampling under WDR 5-00-175 and their monitoriung requirements are:

- Drinking water storage tanks—discharges that have the potential to reach surface waters are monitored.
- System flushes—one flush per pressure zone per year is monitored for flushes that have the potential to reach surface waters.
- Dead-end flushes—all flushes that have the potential to reach surface waters, and for any discharge that continues for more than four months are monitored.

Discharges must comply with the effluent limits for residual chlorine and pH established by the permit, that is, residual chlorine must not be greater than 0.02 mg/L, and the pH must be between 6.5 and 8.5. Discharges are also visually monitored to ensure that no erosion results and no other pollutants are washed into surface waters. To meet the chlorine limit, drinking water system discharges with the potential to reach surface waters are dechlorinated.

Sample collection procedures are discussed in the *Lawrence Livermore National Laboratory Site 300 Water Suppliers' Pollution Prevention and Monitoring and Reporting Program* (Mathews 2000). Grab samples are collected in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002). Residual chlorine and pH are immediately analyzed in the field, using a spectrophotometer and calibrated pH meter, respectively.

Samples are collected at the point of discharge and at the point where the discharge flows into a surface water. If the discharge reaches Corral Hollow Creek, samples are collected at the upstream sampling location, CARW, and the downstream sampling location, GEOCRK.

Monitoring results are detailed in the quarterly self monitoring reports to the CVRWQCB. Releases occurred in the third quarter of 2003. These releases met the effluent limits and quickly percolated into the drainage ditches or streambed and did not reach Corral Hollow Creek, the receiving water (Raber 2003).

Site 300 Cooling Towers

The CVRWQCB rescinded WDR 94-131, NPDES Permit No. CA0081396, on August 4, 2000, which previously governed discharges from the two primary cooling towers at Site 300. The CVRWQCB determined that these cooling towers discharge to the ground rather than to surface water drainage courses. Therefore, the CVRWQCB is issuing a new permit to incorporate these cooling tower discharges, and other low-threat discharges, going to ground. Pending the issuance of the new permit, LLNL continues to monitor the cooling tower wastewater discharges following the WDR 94-131 monitoring requirements at the direction of CVRWQCB staff.

Two primary cooling towers, located at Buildings 801 and 836A, regularly discharge to the ground. Blowdown flow from the cooling towers located at these two buildings is monitored biweekly. Total dissolved solids (TDS) and pH are monitored quarterly at both of these locations. The 13 secondary cooling towers routinely discharge to percolation pits under a waiver of Waste Discharge Requirements from the CVRWQCB. Cooling tower locations are shown in **Figure 4-21**

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2002). To determine the effects of the cooling tower blowdown on Corral Hollow Creek, LLNL quarterly monitors pH, both upstream (background) and downstream of the cooling tower discharges, whenever the creek is flowing. CARW is the upstream sampling location, and GEOCRK is the downstream sampling location (**Figure 4-21**).

The GEOCRK sampling location is also fed by discharges of treated groundwater from Site 300. Therefore, even when the upstream location is dry, there may be flow at GEOCRK. Field pH measurements, taken by LLNL using calibrated meters, are used to monitor Corral Hollow Creek. LLNL also performs the required visual observations that are recorded on field tracking forms along with the field pH measurements.

If the blowdown flow from any of the 13 secondary cooling towers is diverted to a surface water drainage course, the discharge is sampled for pH and TDS immediately. If the discharge continues, that location is monitored for the same constituents and on the same schedule as the primary cooling towers.

Monitoring results in 2003 indicate only one discharge from the Buildings 801 and 836A cooling towers that was above the maximum values that were previously imposed for discharges to surface water drainage courses under WDR 94-131. The second quarter sample from the Building 836A tower showed a TDS value (2620 mg/L) above the previous limit of 2400 mg/L for discharges to surface waters. LLNL continues to monitor these discharges at the direction of CVRWQCB staff. Resampling at this location, completed one month after the routine second quarter sampling, showed a TDS value of 1160 mg/L, which is a value consistent with the results from previous quarters. **Table 4-13** summarizes the data from the quarterly TDS and pH monitoring, as well as the biweekly measurements of blowdown flow.

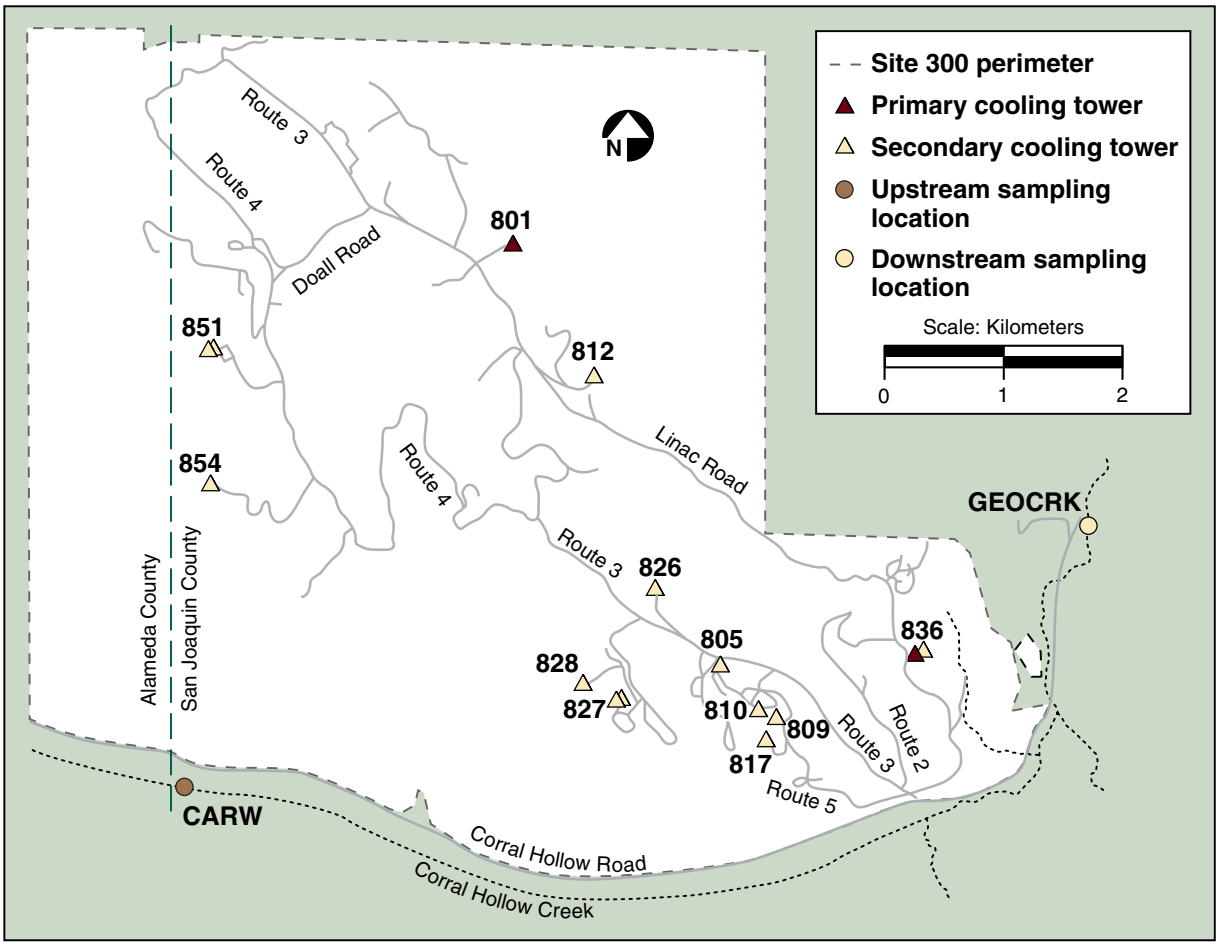


Figure 4-21. Cooling tower locations and receiving water monitoring locations, Site 300, 2003.

The biweekly observations at CARW and GEOCRK reported dry or no flow conditions for both sampling locations throughout 2003. These results are consistent with the determination that these cooling towers discharge to the ground rather than to surface water drainage courses. Visual observations of Corral Hollow Creek were performed each quarter, and no visible oil, grease, scum, foam, or floating suspended materials were noted in the creek during 2003.

The maximum tritium activity measured in a Livermore Valley rainwater sample during 2003 was 1.2% the MCL. Measured tritium activities of rainwater from Site 300 were all below the analytical reporting limit of 3.7 Bq/L. All gross alpha, gross beta, and tritium activities measured in Livermore Valley surface and drinking waters were below their respective MCLs. No drinking water nor cooling water releases from Site 300 reached Corral Hollow Creek. There is no evidence of any adverse environmental impact on surrounding waters resulting from LLNL activities during 2003.

Table 4-13. Summary data from monitoring of primary cooling towers, Site 300, 2003

Test	Tower no.	Minimum	Maximum	Median	Interquartile range	Number of samples
Total dissolved solids (TDS) (mg/L)	801	1400	1480	1430	—(a)	4
	836A	723	2620	1230	470	5
Blowdown (L/day)	801	0	14324	4334	4953	27
	836A	0	10535	1261	4153	27
pH (pH units)	801	8.9	9.1	9.0	—(a)	4
	836A	8.4	9.3	8.9	0.3	5

a Not enough data points to determine

5 Terrestrial Radioactivity, Ambient Radiation, and Wildlife and Rare Plant Surveys

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Introduction

Lawrence Livermore National Laboratory measures the radioactivity present in soil, sediment, vegetation, and wine. LLNL also measures absorbed gamma radiation dose at ground level receptors from terrestrial and atmospheric sources. The LLNL monitoring program is designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. All monitoring activity follows U.S. Department of Energy (DOE) guidance. Monitoring on site or in the vicinity of the Livermore site or Site 300 detects radioactivity released from LLNL that may contribute to radiation dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiation dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see Chapter 6) is calculated using a simple screening model that requires knowledge of radionuclide concentrations in soils, sediments, and surface water.

Surface soil samples are analyzed for plutonium and gamma-emitting radionuclides. Gamma-emitting radionuclides in surface soils include uranium isotopes, which are used to provide data about the natural occurrence of uranium as well as data about the effects of explosive tests at Site 300, some of which contain depleted uranium. Other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) provide additional data about local background conditions, and the long-lived fission product cesium-137 provides information on global fallout from historical nuclear weapons testing. In addition, soils at Site 300 are analyzed for beryllium, a potentially toxic metal used there. With the addition of tritium, a similar suite of nuclides is analyzed in the sediments. Vadose zone soil concentrations are compared with de minimis concentrations for organic compounds, tritium, and metals. Vegetation and wine samples are measured for tritium alone because tritium is the only nuclide released from LLNL that can be measured in these products. Cosmic radiation accounts for about half the absorbed gamma dose measured by the TLDs; naturally occurring isotopes of the uranium-thorium-actinium decay series provide the dose from natural background radiation found in the earth's crust. By characterizing the background radiation, LLNL can determine what, if any, excess dose can be attributed to laboratory operations.

Surface soils near the Livermore site and Site 300 have been sampled since 1971. Around the Livermore site, sediments (from selected arroyos and other drainage areas) and vadose zone soils have been sampled since 1988 and 1996, respectively; sampling of sediments or vadose zone soils is not warranted at Site 300. LLNL has been monitoring tritium in

vegetation to some extent since 1966 and has performed routine vegetation sampling on and around the Livermore site and Site 300 since 1971. External radiation has been monitored around the Livermore site since 1973 and around Site 300 since 1988.

Sampling for all media is conducted according to written, standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2002).

LLNL also monitors wildlife and plants at the Livermore site and Site 300, and carries out research relevant to the protection and mitigation of populations of rare plants and animals. Some monitoring programs are required by existing permits, while additional monitoring programs are designed to track the distribution and abundance of rare species. In addition, baseline surveys are conducted to determine distribution of special status species on LLNL property. Monitoring and research of biota on LLNL property is included to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and the California Native Plant Protection Act as they pertain to endangered or threatened species and other special status species, their habitats, and designated critical habitats that exist at the LLNL sites.

Soil and Sediment Monitoring

There are 6 soil and 6 sediment sampling locations on LLNL's Livermore site (**Figure 5-1**); 13 soil sampling locations in the Livermore Valley, including 6 at the Livermore Water Reclamation Plant (LWRP) (**Figure 5-2**); and 14 soil sampling locations at or near Site 300 (**Figure 5-3**). 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 LWRP and areas around explosives tests areas at Site 300, are also sampled.

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas at and around the Livermore site; these locations (**Figure 5-1**) largely coincide with selected storm water sampling locations (see Chapter 4). Soils in the vadose zone (the region below the land surface where the soil pores are only partially filled with water) are collected in arroyo channels at the Livermore site as part of the Ground Water Protection Management Program. Infiltration of natural runoff through arroyo channels is a significant source of groundwater recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley groundwater basin (Thorpe et al. 1990). The collocation of sampling for these media facilitates comparison of analytical results.

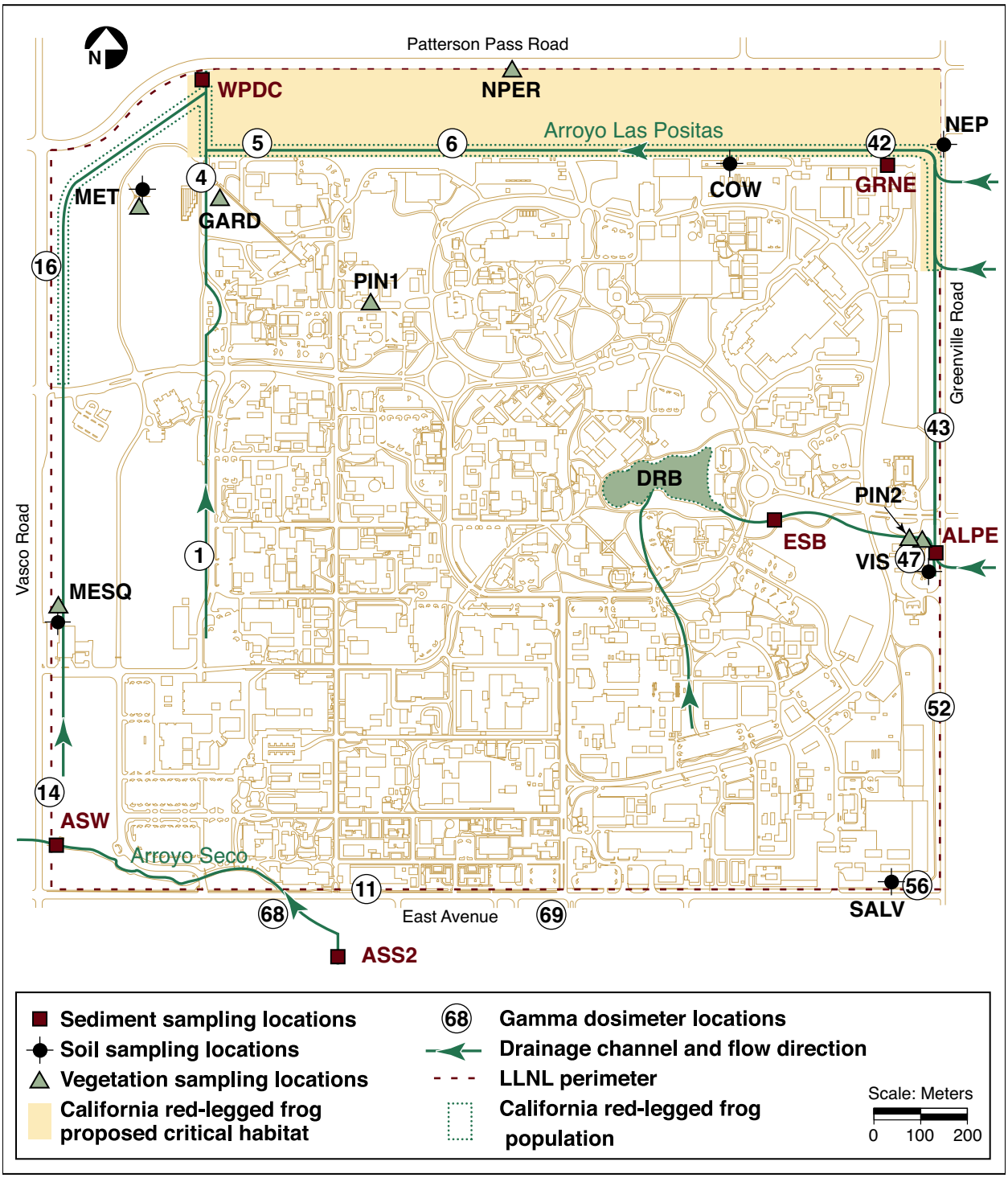


Figure 5-1. Sampling locations, Livermore site, 2003

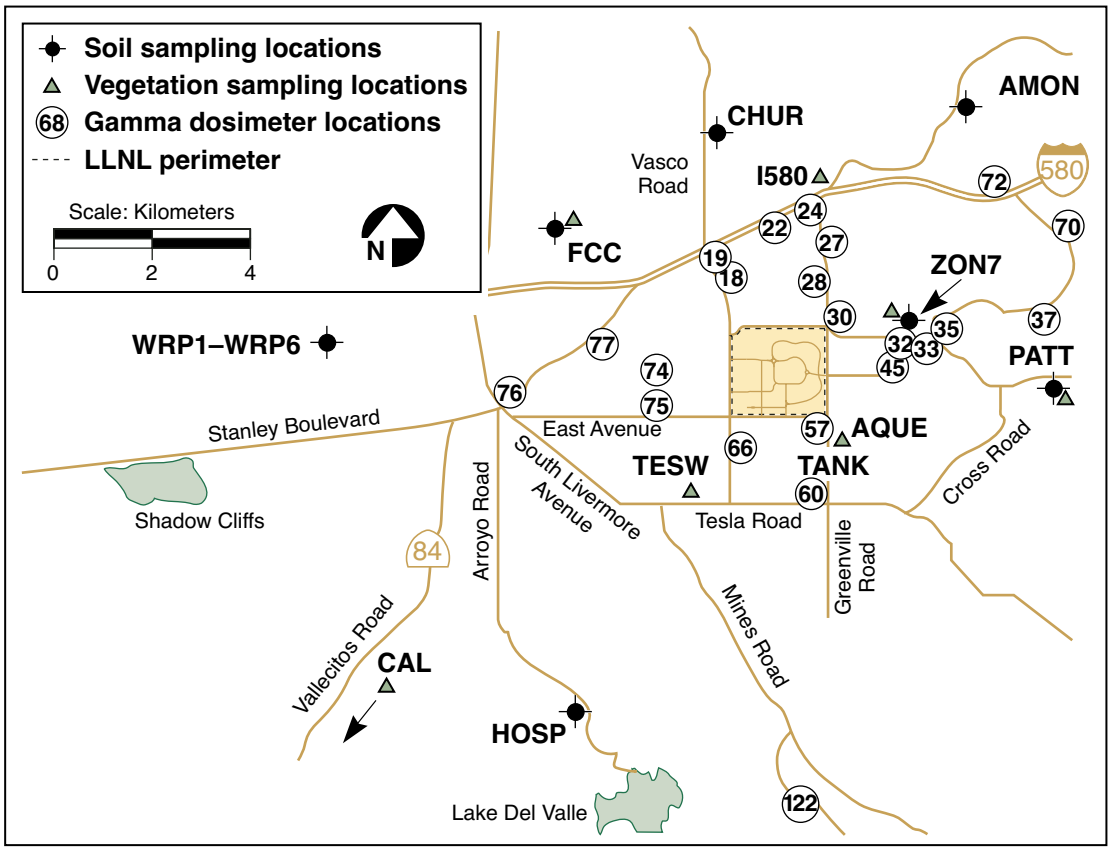


Figure 5-2. Sampling locations, Livermore Valley, 2003

Surface soil samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-m squares are chosen from which to collect the sample. Each sample is a composite consisting of 10 subsamples that are collected with an 8.25 cm diameter stainless steel core sampler at the corners and the center of each square. All subsamples are collected from the top 5 cm of soil. Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along a transect of the arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is acquired for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample. A hand auger is used to collect a 30- to 45-cm deep sample for metals analysis, and an electric drive coring device is used to collect a sample 45- to 65-cm deep for analysis for soluble volatile organic compounds and for polychlorinated biphenyls (PCBs).

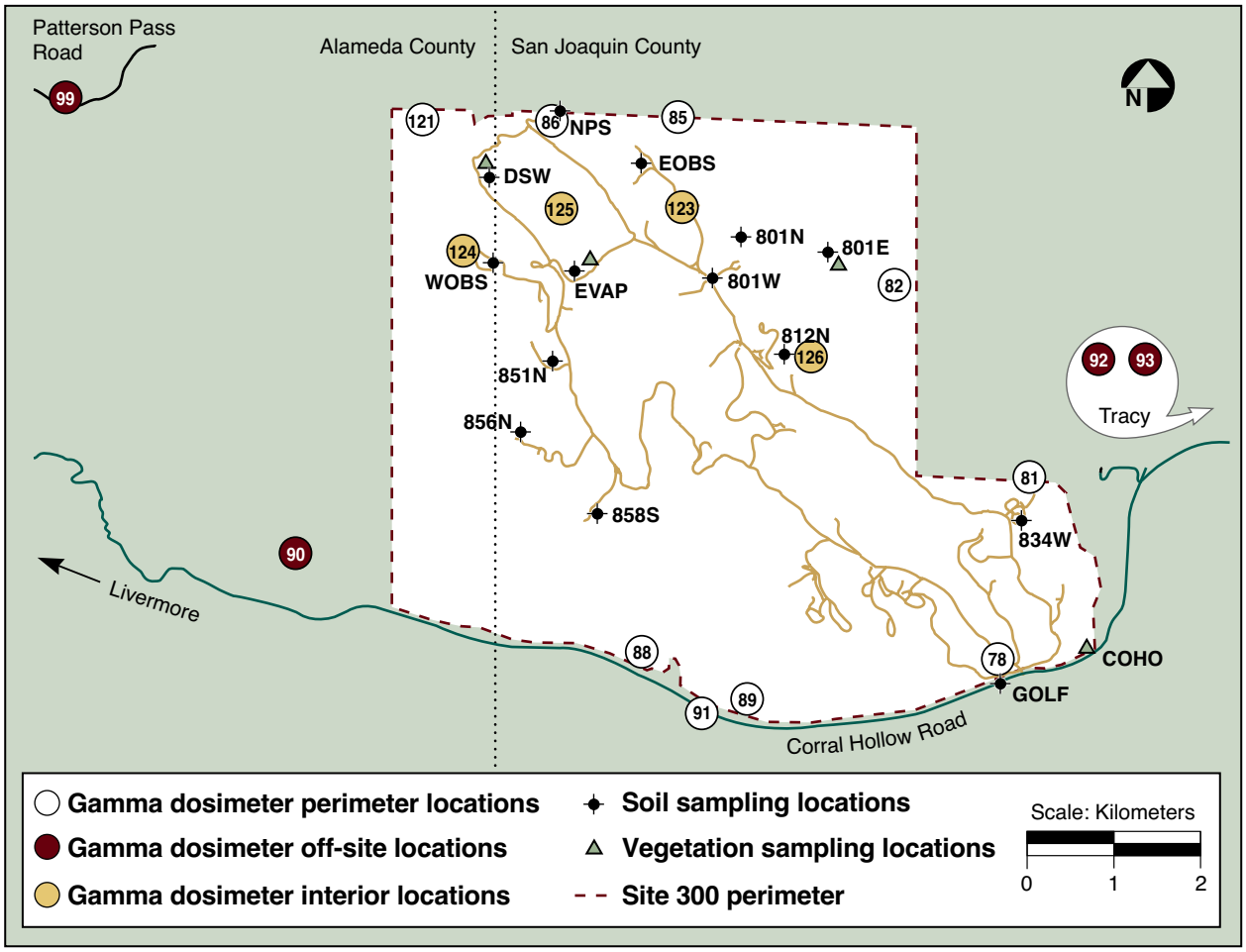


Figure 5-3. Sampling locations at Site 300 and off-site, 2003

In 2003, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Annual sediment samples collected at the Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were analyzed for total and soluble metals, and for soluble volatile organic compounds; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are dried, ground, sieved, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectroscopy. Other sample aliquots (300-g) are analyzed by gamma spectroscopy using a high-purity germanium (HPGe) detector for 47 radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. The 10-g subsamples for beryllium analyses are analyzed by atomic emission spectrometry.

Vadose zone soil samples are analyzed by standard EPA methods. In 2003, as in the previous three years, a vadose zone soil sample from location ESB (**Figure 5-1**) was also analyzed for PCBs.

Radiological Monitoring Results

Tables 5-1 through **5-3** present data on the concentrations of plutonium-238 and plutonium-239+240 in the Livermore Valley surface soils and sediments; data for americium-241, which is only detected at LWRP; and for tritium, which is only measured in surface sediments. Data for cesium-137, potassium-40, thorium-232, uranium-235, and uranium-238 in surface soils from the Livermore Valley sampling locations are included in the file "Ch5 Soil" provided on the report CD.

Table 5-1. Plutonium activity concentrations in Livermore Valley soil, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.0027 ± 0.0019	0.054 ± 0.0089
L-CHUR-SO	0.0057 ± 0.0026	0.14 ± 0.017
L-COW-SO	0.0019 ± 0.0028	0.020 ± 0.0062
L-FCC-SO	0.0028 ± 0.0016	0.089 ± 0.011
L-HOSP-SO	0.0037 ± 0.0026	0.068 ± 0.010
L-MESQ-SO	0.0012 ± 0.0019	0.034 ± 0.0065
L-MET-SO	0.00037 ± 0.0012	0.044 ± 0.0074
L-NEP-SO	0.0033 ± 0.0017	0.052 ± 0.0075
L-PATT-SO	–0.00010 ± 0.0012	0.024 ± 0.0048
L-SALV-SO	0.019 ± 0.0038	0.18 ± 0.019
L-TANK-SO	0.0044 ± 0.0020	0.13 ± 0.014
L-VIS-SO	0.020 ± 0.0041	0.35 ± 0.035
L-ZON7-SO	0.0026 ± 0.0016	0.031 ± 0.0055
Median	**0.0028**	**0.054**
IQR[a]	**0.0025**	**0.096**
Maximum	**0.02**	**0.35**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

Table 5-2. Plutonium and americium activity concentrations in LWRP soil, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.48 ± 0.048	11 ± 1.1	4.9 ± 1.8
L-WRP2-SO	0.26 ± 0.029	4.7 ± 0.44	3.8 ± 3.0
L-WRP3-SO	0.056 ± 0.0087	0.97 ± 0.095	<0.41
L-WRP4-SO	0.023 ± 0.0083	0.36 ± 0.047	<0.4
L-WRP5-SO	0.082 ± 0.014	14 ± 0.14	<0.41
L-WRP6-SO	0.026 ± 0.0058	0.41 ± 0.043	<0.8
Median	**0.069**	**2.8**	**<0.61**
IQR[a]	**0.18**	**8.9**	**Not calculated[b]**
Maximum	**0.48**	**14**	**4.9**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

b Interquartile range not calculated because of high incidence of nondetections.

Table 5-3. Plutonium and tritium activity concentrations in surface sediment, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.00080 ± 0.0016	0.012 ± 0.0033	13 ± 2.4
L-ASS2-SD	–0.00017 ± 0.00059	0.0071 ± 0.0021	12 ± 2.6
L-ASW-SD	0.0024 ± 0.0018	0.038 ± 0.0077	2.9 ± 2.0
L-ESB-SD	0.18 ± 0.019	1.9 ± 0.17	27 ± 2.9
L-GRNE-SD	0.0076 ± 0.0033	0.17 ± 0.021	4.6 ± 2.1
L-WPDC-SD	0.00030 ± 0.00098	0.015 ± 0.0038	2.1 ± 2.0
Median	**0.0016**	**0.027**	**8.3**
IQR[a]	**0.0059**	**0.12**	**9.4**
Maximum	**0.18**	**1.9**	**27**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

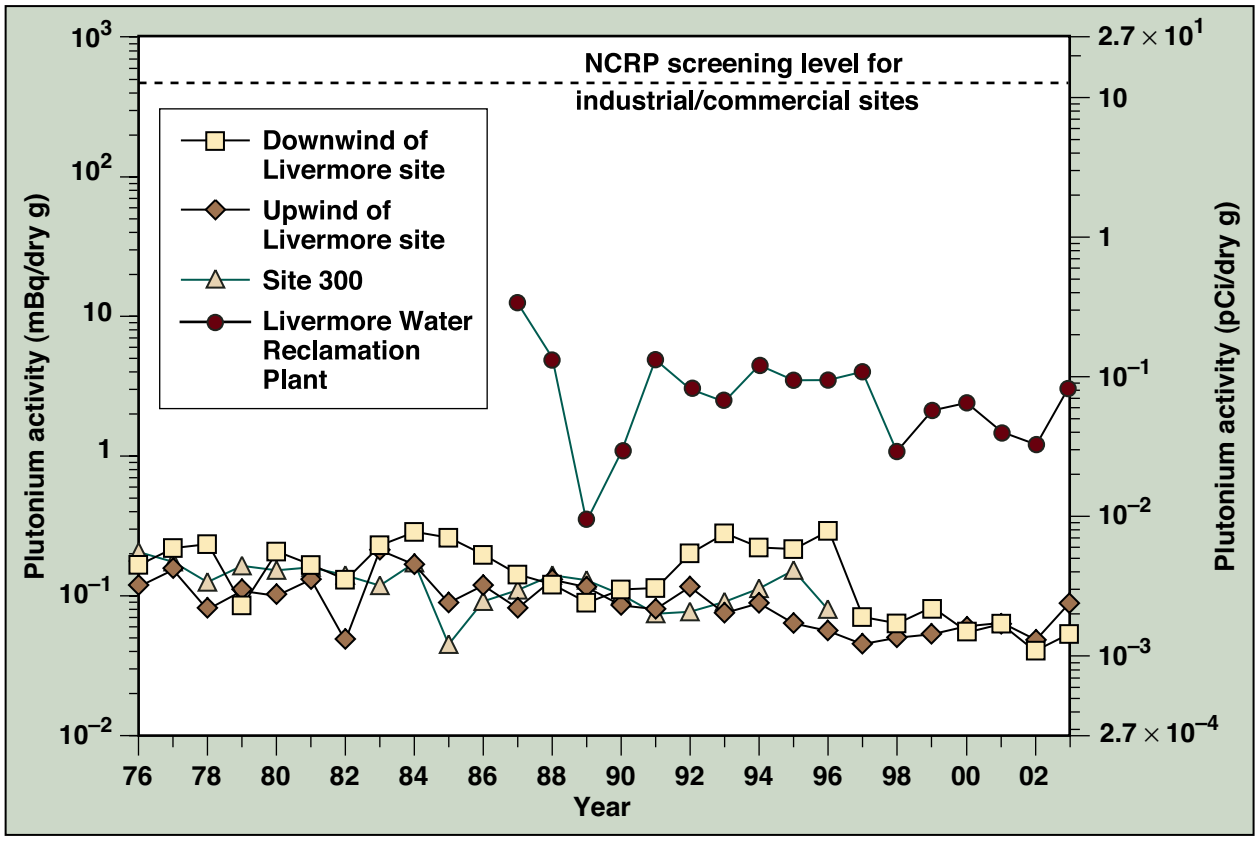
The concentrations and distributions of all observed radionuclides in soil for 2003 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Plutonium has, in the past, been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2003, the measured plutonium-239+240 value for VIS was 0.35 mBq/dry g (9.4×10^{-3} pCi/dry g), a value that is less than the 95% upper confidence level for the 95th percentile calculated for background data, i.e., 0.48 mBq/dry g (1.3×10^{-2} pCi/dry g) (LLNL 1998, Appendix D). The slightly higher values at and near the Livermore site have been attributed to historic operations, including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant (Silver et al. 1974). LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste. Nonetheless, plutonium-239+240, from historic operations, can be carried off site by resuspension of soil by wind.

A sediment sampling location, ESB, also shows the effects of historic operation of the solar evaporators; it is in the drainage area for the southeast quadrant at LLNL. The measured value for plutonium-239 at this location for 2003 was 1.9 mBq/dry g (5.0×10^{-2} pCi/dry g). The highest detected value for tritium, 27 Bq/L (740 pCi/L), was at location ESB, which is also downwind of the Tritium Facility. All tritium concentrations were within the range of previous data. Tritium in sediments will continue to be evaluated as long as the measured values remain above the detection limits of the liquid scintillation analytical method.

Elevated levels of plutonium-239+240 (resulting from an estimated 1.2×10^{9} Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases) were again detected at LWRP sampling locations. In addition, americium-241 was detected in two LWRP samples; it is most likely caused by the natural decay of the trace concentrations of plutonium-241 that were present in the releases to the sewer.

Historical median plutonium-239+240 concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site and at LWRP are shown in **Figure 5-4**. Livermore Valley upwind concentrations have remained relatively constant since monitoring began and generally are indicative of worldwide fallout. Greater variation can be noted in the downwind concentration data, which in 2003 included sampling locations VIS, PATT, NEP, COW, AMON, SALV, and ZON7, compared with the upwind data. Notable variability in plutonium-239+240 is also seen in samples from LWRP. Because the plutonium-239+240 is likely to be present in discrete particles, the random presence or absence of the particles dominates the measured plutonium-239+240 in any given sample.

Table 5-4 presents data on the concentrations of uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; 2003 soils data for Site 300 for cesium-137, potassium-40, and thorium-232 are included in the file "Ch5 Soil" provided on the report CD. The concentrations and the distributions of all observed radionuclides in Site 300 soil for 2003 lie within the ranges reported in all years since monitoring began. The ratio of uranium-235 to uranium-238 generally reflects the natural ratio of 0.7%. There is significant uncertainty in calculating the ratio, however,



Note: Upwind and downwind designations are relative to the center of the Livermore site.
NCRP = National Council on Radiation Protection and Measurements

Figure 5-4. Median plutonium-239+240 activities in surface soils, 1976–2003

due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured value for 2003 occurred at 812N, a location where explosives tests have been conducted. The uranium-235 to uranium-238 ratio in this sample equals that ratio for depleted uranium, i.e., 0.002. Such values at Site 300 result from the use of depleted uranium in explosive experiments.

Nonradiological Monitoring Results

Analytical results for organic compounds found in vadose zone soil samples are compared with de minimus concentrations developed by LLNL and approved by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) (Folks 1997; Marshack 2003). Analytical results for metals are compared with natural background concentrations for metals developed by LLNL. (See the file "Ch5 Soil" provided on the report CD for de minimus concentration levels of organic compounds and background concentrations of metals.)

Table 5-4. Uranium and beryllium concentrations in Site 300 soil, 2003

Location	Uranium-235[a] (μg/dry g)	Uranium-238[b] (μg/dry g)	U235/U238 ratio	Beryllium (mg/kg)
3-801E-SO	0.023 ± 0.011	2.1 ± 0.94	0.011 ± 0.0072	1
3-801N-SO	0.035 ± 0.012	9.9 ± 2.8	0.0035 ± 0.0016	0.6
3-801W-SO	0.026 ± 0.014	4.2 ± 1.4	0.0062 ± 0.0039	<0.5
3-812N-SO	0.24 ± 0.018	110 ± 7.4	0.0022 ± 0.00022	110
3-834W-SO	0.019 ± 0.012	2.2 ± 1.7	0.0086 ± 0.0086	0.6
3-851N-SO	0.031 ± 0.012	3.7 ± 1.5	0.0084 ± 0.0047	0.6
3-856N-SO	0.022 ± 0.0095	2.5 ± 1.1	0.0088 ± 0.0054	<0.5
3-858S-SO	0.017 ± 0.0086	2.1 ± 0.94	0.0081 ± 0.0055	<0.5
3-DSW-SO	0.027 ± 0.011	3.1 ± 1.5	0.0087 ± 0.0055	<0.5
3-EOBS-SO	0.020 ± 0.014	1.6 ± 1.3	0.013 ± 0.013	<0.5
3-EVAP-SO	0.030 ± 0.010	5.0 ± 1.6	0.0060 ± 0.0028	<0.5
3-GOLF-SO	0.022 ± 0.014	2.4 ± 1.4	0.0092 ± 0.0079	<0.5
3-NPS-SO	0.022 ± 0.011	2.4 ± 1.2	0.0092 ± 0.0065	<0.5
3-WOBS-SO	0.023 ± 0.011	4.5 ± 1.2	0.0051 ± 0.0028	<0.5
Median	**0.023**	**2.8**	**0.0085**	**<0.5**
IQR[c]	**0.0073**	**2.2**	**0.0031**	**—[d]**
Maximum	**0.24**	**110**	**0.013**	**110**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in μg/dry g by specific activity of uranium-235, i.e., 0.080 Bq/μg or 2.15 pCi/μg.

b Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in μg/dry g by specific activity of uranium-238, i.e., 0.01245 Bq/μg or 0.3367 pCi/μg.

c IQR = Interquartile range

d Interquartile range not calculated because of high incidence of nondetections.

All analytical results for soluble VOCs were below detection limits. Unfortunately, detection limits were elevated for all compounds due to matrix interferences. All total metals concentrations were within site background. See the file "Ch5 Soil" provided on the report CD for analytical results for VOCs and metals. Since 2000, Aroclor 1260 (a PCB) has been detected at location ESB. In 2003, it was again detected at location ESB at a concentration of 0.7 mg/kg. The presence of PCBs suggests that this sample represents residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see Chapter 4). The detected concentrations are below the federal and state hazardous waste limits.

Beryllium results for soils at Site 300 were within the ranges reported since sampling began. The highest value, 110 mg/kg, was found at B812, which is an area that has been used for explosives testing. The QA duplicate was collected at this location; the result for beryllium was 6.0 mg/kg. These differing results reflect the particulate nature of the contamination.

Environmental Impact on Soil and Sediment

Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2003 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts, or could not be measured above detection limits.

The highest value of 11 mBq/dry g (0.31 pCi/dry g) for plutonium-239+240 measured at LWRP is 2.3% of the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999). Regression analysis of the annual medians of the upwind and downwind data groups shows a slight decrease in plutonium-239+240 values with time.

Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Table 5-5**. These studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern.

Site 300

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occur near active and inactive firing tables at Buildings 801 and 812. They result from the fraction of the firing table operations that disperse depleted uranium. The uranium-238 concentrations are below the NCRP recommended screening level for commercial sites of 313 µg/g (3.9 Bq/g or 105 pCi/g). Historically, some measured concentrations of uranium-238 near Building 812 have been greater than the screening level. A CERCLA remedial investigation is underway at the Building 812 firing table area to define the nature and extent of contamination. Depleted uranium has been detected in soil and groundwater in the area. The Site 300 CERCLA activities are discussed in more detail in Chapter 7.

Table 5-5. Special soil and sediment studies

Year	Subject[a]	Reference
1971-1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1976	Evaluation of the Use of Sludge Containing Plutonium as a Soil Conditioner for Food Crops	Myers et al. 1976
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999
2000	Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling	ATSDR 2000
2002	Livermore Big Trees Park:1998 Results	MacQueen et al. 2002
2003	ATSDR Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community	ATSDR 2003

a See Acronyms and Abbreviations for list of acronyms.

Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (**Figure 5-1**) and in the Livermore Valley (**Figure 5-2**) are divided into four groups (Near, Intermediate, Far, and PIN1) for statistical evaluation. Tritium from LLNL operations should be detected at the Near and Intermediate locations depending upon wind direction and the magnitude of the releases. Near locations (AQUE, GARD, MESQ, NPER, MET, PIN2, and VIS) are onsite or within 1 km of the LLNL site perimeter; Intermediate locations in the Livermore Valley (I580, PATT, TESW, and ZON7) are greater than 1 and less than 5 km from the LLNL perimeter. Far locations are unlikely to be affected by LLNL operations; one background location (CAL) is more than 25 km distant, and the other (FCC) is about 5 km from the Livermore site but generally upwind. The PIN1 location is a pine tree rooted in an area of known tritium groundwater contamination on the Livermore site.

There are four monitoring locations for vegetation at Site 300 (**Figure 5-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to uptake of contaminated groundwater by roots. At the two other locations, 801E and COHO, the only potential source of tritium uptake is the atmosphere.

Wines for the 2003 sampling were purchased from supermarkets and wine merchants in Livermore except for one bottle purchased in southern California. Wines represent the Livermore Valley, six regions of California, and three countries in Europe.

Water is extracted from vegetation by freeze-drying and counted for tritiated water (HTO) using liquid scintillation techniques. Both HTO and organically bound tritium (OBT) are detected in wine using helium-3 mass spectrometry, but the relative fractions of each are not determined.

Vegetation Monitoring Results

All concentrations of tritium in Livermore vegetation for 2003 are shown in **Table 5-6**. The highest mean and maximum concentrations in vegetation for 2003 were at the Intermediate location ZON7, but concentrations at the Near location VIS were similar. Given normal dispersion, concentrations of tritium are expected to be higher at VIS than at ZON7, because ZON7 is 1.5 km farther away from tritium sources. As well, ZON7 is in the same downwind direction as VIS from the Tritium Facility. However, ZON7 and VIS do not lie in the same wind direction from the diffuse source of tritium at the B612 yard, and samples are not collocated in time. When winds shift, tritium concentrations in plants rapidly approach equilibrium with air moisture. Thus it is not too surprising that concentrations in vegetation at ZON7 can occasionally be greater than at VIS.

Median values for each set of sampling locations are graphed in **Figure 5-5** to show the trend in tritium concentrations in vegetation since 1972. For the past six years, median concentrations for vegetation collected from the Intermediate and Far locations have been below detection limits, and even the median Near concentration for 2003 is at the detection limit. Only one (Games and Howell 1976) of several statistical tests determined that the Near and Far locations are different at the 5% significance level.

The concentration of HTO extracted from vegetation is basically that of the tritium in air moisture to which the plant was exposed for at most the two hours prior to sampling. Thus, quarterly sampling is not necessarily expected to be representative of the air seen by the vegetation for an entire year. For 2003, the mean or median concentrations of the vegetation samples do not reflect the increase in total tritium released from LLNL compared with 2002, but the samples taken in early May 2003 (second quarter) did detect increased emissions.

As in the past, concentrations in PIN1, because of the contaminated groundwater source, were higher than those in other vegetation. However, because of the higher tritium concentrations in air during the second quarter sampling and somewhat lower concentrations in PIN1 in 2003 compared with 2002, there is no statistical difference between PIN1 and PIN2 at the 5% significance level in 2003.

Table 5-6. Quarterly concentrations of tritium in plant water (Bq/L) and mean annual ingestion doses, 2003

	First quarter	Second quarter	Third quarter	Fourth quarter	Median	Mean	Mean dose[a] (nSv/y)
Sampling locations within 1 km of the Livermore site perimeter							
AQUE	3.7 ± 2.1	0.58 ± 2.0	2.6 ± 1.5	2.1 ± 1.5	2.4	2.2	11
GARD	0.013 ± 1.9	1.9 ± 2.1	0.30 ± 1.4	1.5 ± 1.4	0.9	0.93	< 10[b]
MESQ	0.66 ± 2.0	1.7 ± 2.1	–0.50 ± 1.4	1.5 ± 1.4	1.1	0.84	< 10[b]
MET	–0.061 ± 2.0	1.3 ± 2.1	–0.52 ± 1.4	–0.40 ± 1.3	–0.23	0.08	< 10[b]
NPER	4.2 ± 2.1	2.6 ± 2.1	4.4 ± 1.6	0.42 ± 1.4	3.4	2.9	14
PIN2	3.8 ± 2.1	31 ± 3.1	3.8 ± 1.6	3.4 ± 1.5	3.8	10	__[c]
VIS	4.4 ± 2.1	22 ± 2.8	1.8 ± 1.5	0.77 ± 1.4	3.1	7.2	35
PIN1[d]	31 ± 3.1	45 ± 3.5	94 ± 4.2	15 ± 2.1	38	46	__[e]
Sampling locations from 1 to less than 5 km from the Livermore site perimeter							
I580	1.8 ± 2.0	2.8 ± 2.1	–0.38 ± 1.4	1.4 ± 1.4	1.6	1.4	< 10[b]
PATT	1.1 ± 2.0	–0.93 ± 2.0	–0.65 ± 1.4	–0.62 ± 1.3	–0.64	–0.28	< 10[b]
TESW	2.8 ± 2.1	1.0 ± 2.0	–0.87 ± 1.3	2.0 ± 1.4	1.5	1.2	< 10[b]
ZON7	4.6 ± 2.1	23 ± 2.9	1.2 ± 1.5	1.0 ± 1.4	2.9	7.5	37
Sampling locations more than 5 km from the Livermore site perimeter							
CAL	1.8 ± 2.0	0.00026 ± 2.0	–1.8 ± 1.3	–0.49 ± 1.3	–0.24	–0.12	< 10[b]
FCC	0.16 ± 1.9	–1.1 ± 2.0	–0.37 ± 1.4	1.5 ± 1.4	–0.11	0.047	< 10[b]
Sampling locations at Site 300							
COHO	0.71 ± 2.0	–0.41 ± 2.0	–0.49 ± 1.4	0.20 ± 1.3	–0.1	0.0025	< 10[b]
801E	–0.45 ± 2.0	–0.32 ± 2.0	0.45 ± 1.4	0.36 ± 1.3	0.02	0.01	< 10[b]
DSW[d]	19 ± 2.7	33 ± 3.2	2100 ± 19	24 ± 2.4	29	540	2600
EVAP[d]	74 ± 4.1	0.90 ± 2.1	230 ± 6.5	42 ± 3.0	58	87	430

Note: Radioactivities are reported as the measured concentration and an uncertainty ($\pm 2\sigma$ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See Chapter 8.

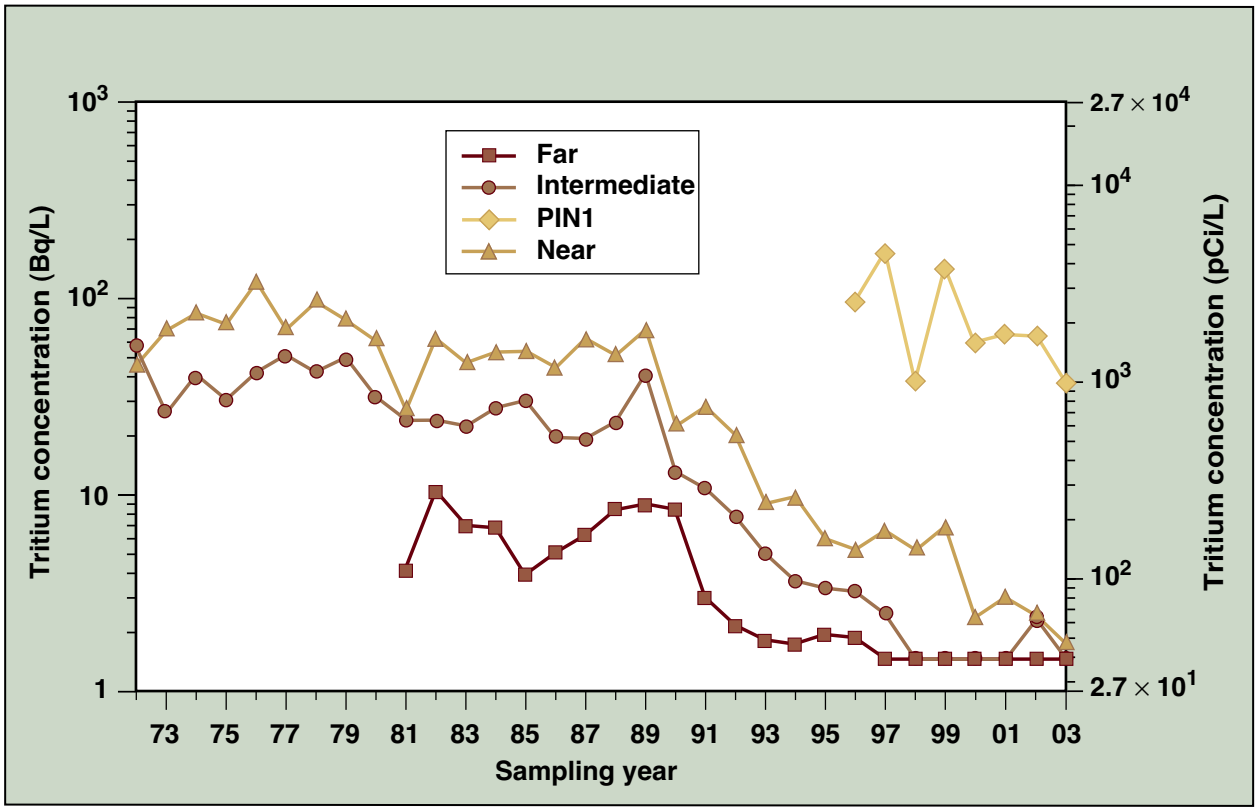
a Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-6**.

b When concentrations are less than the detection limit (about 2.1 Bq/L), doses can only be estimated as being less than the dose at that concentration.

c Doses were not calculated because pine trees are not ingested by human beings. Concentrations from PIN2 are included with NEAR vegetation because plant water tritium concentrations are similar among plant types.

d These plants are rooted in areas of known subsurface contamination.

e Between 1997 and 2002, PIN1 was treated as a diffuse source and a dose was calculated. Beginning in 2003, for NESHAPs compliance, ambient air monitoring at LLNL accounts for small diffuse sources, so a dose was not calculated.



Note: When median values are below 1.5 Bq/L (below detection limits), values are plotted as 1.5 Bq/L to eliminate meaningless variability.

Figure 5-5. Median tritium concentrations in Livermore Site and Livermore Valley plant water samples, 1972 to 2003

All samples at Site 300 locations 801E and COHO were below detection limits; median concentrations at these locations have been at or below detection limits since 1992. Tritium in vegetation at DSW and EVAP continues its erratic pattern dating from 1983, with high concentrations at times and non-detections at other times, depending upon whether or not the roots are taking up contaminated groundwater. The median concentrations at DSW and EVAP for 2003 were similar to those in 2002. The highest concentration (2100 Bq/L) was observed at DSW.

Wine Monitoring Results

The mean concentration of Livermore Valley wines sampled in 2003 reached an all-time low since sampling began (0.89 Bq/L); the mean concentration in European wines also reached the same low; California wines continue to reflect residual historical bomb fallout and cosmogenic tritium levels (**Table 5-7**). The highest concentration in a Livermore Valley wine (1.7 Bq/L) was from a wine made from grapes harvested in

Table 5-7. Tritium in retail wine (Bq/L), 2003[a]

Sample	Area of production		
	Livermore Valley	California	Europe
1	0.58 ± 0.19	0.29 ± 0.19	0.51 ± 0.19
2	0.62 ± 0.20	0.39 ± 0.19	0.66 ± 0.20
3	0.73 ± 0.20	0.39 ± 0.19	0.79 ± 0.20
4	0.74 ± 0.20	0.40 ± 0.19	1.6 ± 0.24
5	0.75 ± 0.20	0.43 ± 0.19	
6	0.79 ± 0.20	0.64 ± 0.20	
7	0.85 ± 0.20		
8	0.96 ± 0.21		
9	0.96 ± 0.21		
10	0.98 ± 0.21		
11	1.0 ± 0.21		
12	1.7 ± 0.25		
Mean ± standard deviation	0.89 ± 0.29	0.42 ± 0.12	0.89 ± 0.49
Dose (nSv/y)[b]			
Mean concentration	0.88	0.42	0.88
Maximum concentration	1.7	0.63	1.6

Note: Radioactivities are reported here as the measured concentration and an uncertainty (±2σ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See Chapter 8.

a Wines from a variety of vintages were purchased and analyzed in 2003. The concentrations reported are those at the time the bottle was opened.

b This dose is calculated based on consumption of 52 L wine per year (see Chapter 6).

1998. A 2002 European wine had a similar concentration (1.6 Bq/L); European wines sampled tend to be very variable, because some wines will come from areas of background tritium while others will come from areas with a local source of tritium.

The wines purchased in 2003 represent vintages from 1998 to 2002. Thus, to compare the effect of LLNL operations on local wines, concentrations at the time of laboratory analysis must be corrected for the radiological decay that has occurred since the approximate date of harvest. Decay-corrected concentrations of tritium in wine for the Livermore Valley, California, and Europe are shown in **Figure 5-6** for the years from 1991 to present. Concentrations in all sampled wines are shown. The concentration of tritium in rainfall at Portland, Oregon (IAEA/WHO 2001) is also shown to demonstrate the similarity between tritium concentrations in California wines and background tritium concentrations on the Pacific coast (no similar data exist for California).

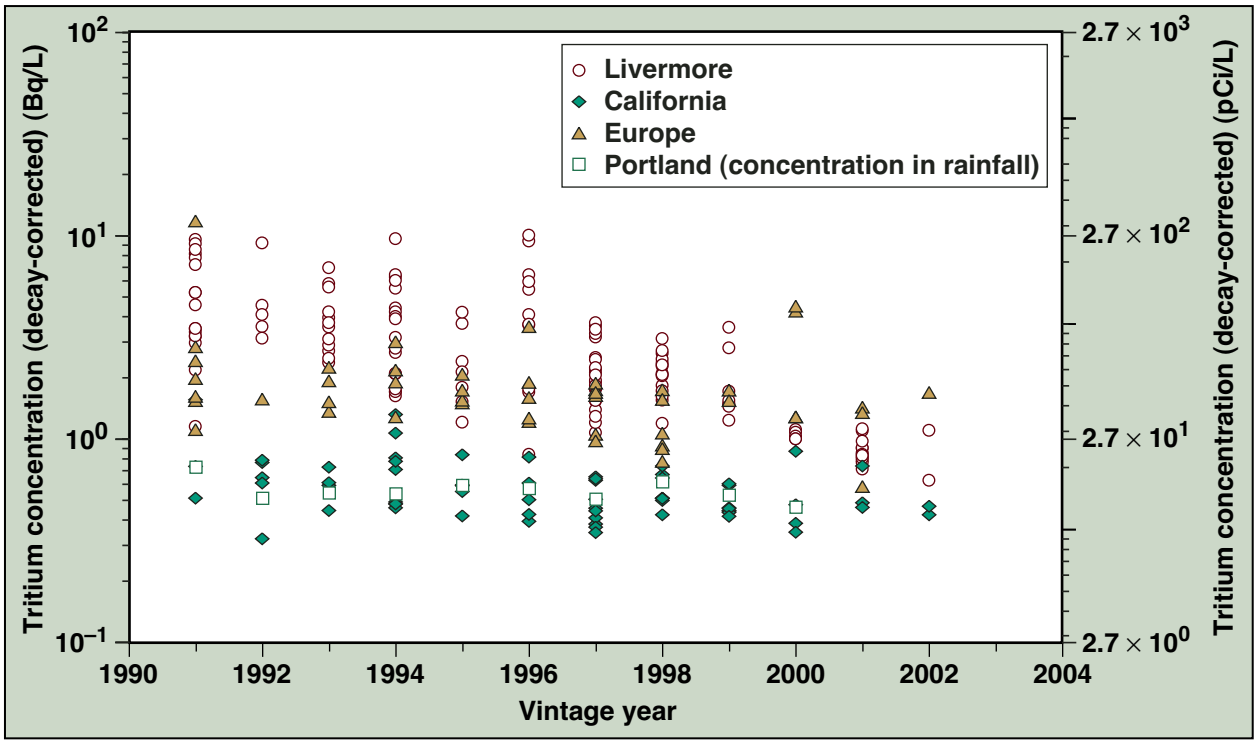


Figure 5-6. Tritium concentrations in all retail wines decay-corrected from the sampling year to the vintage year

Data for the 2003 sampling year were analyzed using Games/Howell multiple comparisons. Tritium concentrations in Livermore Valley wines were higher than California wines at the 5% significance level; using Scheffé's *F* test (Scheffé 1953) European wines were indistinguishable statistically both from Livermore Valley and from California wines. This is due to the large uncertainty on the mean of the European wines.

When regressions are calculated based on the time-dependent data in **Figure 5-6**, the correlation coefficients are very low for Europe and California; for the Livermore Valley the correlation coefficient is only 0.5. Nevertheless, for the 2003 sampling year, the half-life of tritium in Livermore Valley wines appears to be about half that of Europe or California. This demonstrates that LLNL tritium releases declined considerably between 1991 and 2002.

Environmental Impact on Vegetation and Wine

Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 5-6**. These doses were calculated using the transfer factors from **Table 6-6** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). All doses are estimated based on measured concentrations of HTO in vegetation and consequent dose from HTO ingestion.

The annual ingestion dose, based on highest observed mean HTO concentration in vegetation for 2003, is 37 nSv (3.7 µrem/y). Since 1991, the hypothetical annual ingestion dose based on the maximum observed mean has decreased by a factor of ten; since 1980, a year after LLNL started calculating ingestion dose in this manner, the hypothetical dose has decreased by a factor of 55. Doses calculated in this manner neglect the increased contribution from OBT. However, according to a conclusion by a panel of tritium experts, "the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this." (U.S. Department of Health and Human Services 2001) Thus the maximum estimated ingestion dose from LLNL operations for 2003 is at most 74 nSv (7.4 µrem/y).

To demonstrate compliance with NESHAPs, between 1997 and 2002, location PIN1 was treated as a diffuse source of tritium, and a hypothetical dose to the maximally exposed individual at the nearest perimeter location was calculated using the dispersion and dose model CAP88-PC. Mean annual doses from PIN1 have always been less than 9.0 pSv (0.9 nrem). In 2003, LLNL obtained permission from the U.S. Environmental Protection Agency (EPA) to demonstrate compliance by using monitoring data in place of modeling dose from releases from small sources. Any tritium released by PIN1 is sampled by the air tritium monitoring network. There is thus no reason to calculate a dose from PIN1 in 2003. Furthermore, sampling of PIN1 and PIN2 will be terminated in 2004 since it is no longer necessary.

LLNL operations at the Livermore site release small quantities of HTO to the immediate environs that can be measured by conventional methods in vegetation. The ingestion dose calculated based on HTO concentrations in vegetation but that also accounts for OBT (74 nSv; 7.4 mrem/y) is just 1/40,000 of the average annual background dose in the United States from all sources and just 1/1400 the dose from a typical chest x-ray (Schleien and Terpilak 1984). This dose is calculated on the assumption that all the vegetables, milk, and meat ingested have concentrations that represent the location of the sampled vegetation. This is an improbable scenario, because the average person lives farther from the Livermore site than the location of the highest vegetation concentrations and grows just a small fraction of total food ingested. Thus the likely potential dose received will be considerably smaller than this already tiny dose (see **Table 6-8**). During 2003 at Site 300, no tritium was released to the atmosphere from LLNL operations. Consequently, vegetation concentrations are below detection limits, except at

locations of contaminated groundwater (see Chapter 7, "Remediation Activities and Monitoring Results" section). The contaminated groundwater resulting from past activities does affect concentrations in vegetation at locations DSW and EVAP. The dose calculated from these elevated concentrations is entirely hypothetical, because vegetation at Site 300 is not ingested by either livestock or people. The mean dose for 2003 would be 2.6 µSv (0.26 mrem), which is very small.

Wine

For Livermore Valley wines purchased in 2003, the highest concentration of tritium (1.7 Bq/L) is just 0.22% of the Environmental Protection Agency's standard for maximal permissible levels of tritium in drinking water (740 Bq/L). A person would have to drink at least 435 liter-bottles of Livermore Valley wine a day to exceed the EPA standard. Dose from drinking 1 L per day of the Livermore Valley wine with the highest concentration purchased in 2003 would be 12 nSv/y (1.2 µrem/y). A more realistic dose estimate, based on moderate drinking (1 L per week)[1] at the mean of the Livermore Valley wine concentrations (0.89 Bq/L) is 0.88 nSv/y (0.088 µrem/y). Both doses explicitly account for the added contribution of OBT[2].

Local wineries are sufficiently distant from the Livermore site that tritium in wines can only be detected reliably using an ultra-sensitive method. The potential dose from drinking Livermore Valley wines, including the contribution of OBT, even at the high consumption rate of 1 L per day, is about 1/250,000 of the average annual background dose from naturally occurring sources of radiation.

Ambient Radiation Monitoring

Gamma radiation in the environment can come from two natural sources. The first source is from the terrestrial component of natural elements of the earth's crust (i.e., parents [uranium-238, thorium-232, and potassium-40] and daughter radiation produced in the physical decay of the uranium, thorium, and actinium series). The second source is from cosmic radiation, which induces secondary radiations from interactions with atmospheric nuclei in the upper atmosphere. These cosmic interactions result in the production of meson, neutron, gamma, and electron radiations at the surface (Eisenbud 1987).

Sampling locations for 2003 are the same as for 2002, although, in 2003, several site locations were unavailable in one quarter due to the inadvertent removal of samples during the replacement of perimeter fencing by a construction crew. Sampling locations for TLDs are divided into three groups for analysis:

1. Moderate consumption is higher than the average consumption of wine in the United States (2.01 gal/y or 7.6 L/y) (California Wine Institute 2001).
2. Dose from wine is calculated by summing the dose from HTO in the water fraction of wine and the dose from OBT in the organic fraction of wine. Dose coefficients for HTO and OBT are those of the International Commission on Radiation Protection (1996).

Livermore site locations—TLDs are positioned at 14 perimeter and near fence line locations (**Figure 5-1**). The labeling system used has been maintained for historical reference purposes.

Livermore Valley locations—The 22 Livermore valley sites (**Figure 5-2**) represent natural background for this geological area.

Site 300 and vicinity locations—9 TLDs are deployed to monitor the perimeter of Site 300, while 4 are deployed within Site 300. Two off-site TLD locations are maintained nearby Site 300, and 2 others in the city of Tracy (**Figure 5-3**).

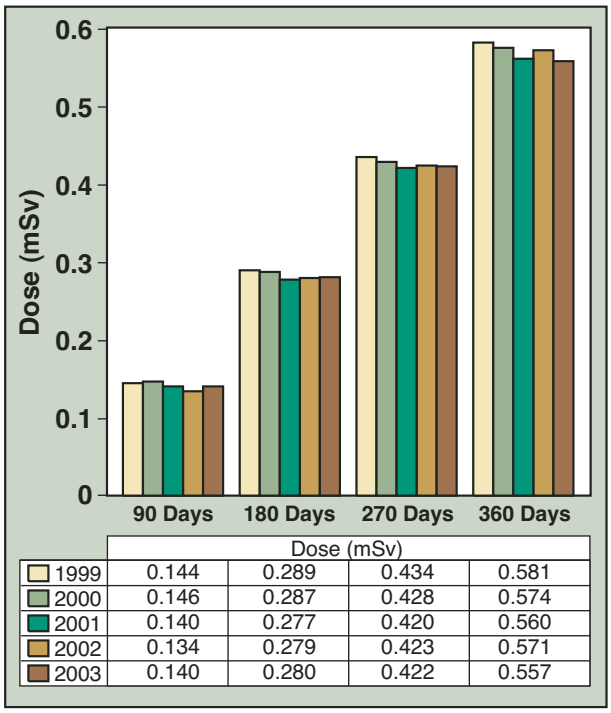
As policy, the State of California Radiological Health Branch maintains several collocated TLD sample sites around the LLNL perimeter and Livermore Valley for the purpose of independent monitoring for comparison.

LLNL uses the Panasonic UD-814AS1 TLD to passively measure gamma radiation in the environment. This TLD type contains four crystal elements. One is a $Li_2B_4O_7$ element and three are thallium-activated $CaSO_4$ elements. The $CaSO_4$ crystals absorb gamma radiation and hold this induced excitation with minimal fading until the TLD has been thermally heated to release it following deployment. This trapped energy is released in the form of emitted light. The output of the light intensity is proportional to the gamma ray that initiated the process. This value is the TLD absorbed dose in units of milliroentgen (mR) and is recorded and then corrected for reader calibration. TLDs are prepared for re-use in a process known as "annealing" (reheating the TLD to erase its memory of "absorbed energy"). Four quarterly deployment cycles are made throughout the year at the beginning of each quarter. When the TLDs are retrieved from the sites, a new quarter's deployment is made. The group retreived is then taken back for analysis. The data turnaround time is normally 2 to 3 days. Data is checked and recorded in the data base. For reporting comparisons, data is normalized to a "standard 90-day quarter." This is the dose reported in millisievert (mSv) for the field period.

Monitoring Results

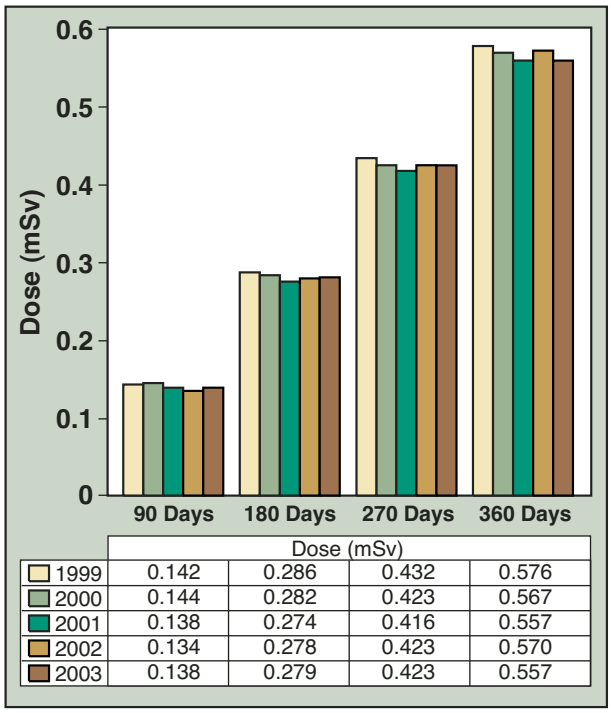
In **Figures 5-7** through **5-10**, the quarterly average cumulative doses in mSv for 2003 are presented for the Livermore site, the Livermore Valley, on-site at Site 300 and off-site at Site 300 along with quarterly doses from 1999 to 2003.

Figure 5-7 illustrates the average cumulative dose for the Livermore site perimeter for successive 90 day periods for the entire year. The graph indicates a downward trend in the site-wide annual dose as compared to previous years. Similarly, comparing the data of **Figure 5-8**, which represents the Livermore Valley, the same trend is readily observable. Likewise, when doses for Site 300 (**Figure 5-9**) are compared to the doses for the off-site locations (**Figure 5-10**), the same trends are evident.



	Dose (mSv)			
1999	0.144	0.289	0.434	0.581
2000	0.146	0.287	0.428	0.574
2001	0.140	0.277	0.420	0.560
2002	0.134	0.279	0.423	0.571
2003	0.140	0.280	0.422	0.557

Figure 5-7. Livermore site perimeter cumulative dose (mSv), 1999 through 2003



	Dose (mSv)			
1999	0.142	0.286	0.432	0.576
2000	0.144	0.282	0.423	0.567
2001	0.138	0.274	0.416	0.557
2002	0.134	0.278	0.423	0.570
2003	0.138	0.279	0.423	0.557

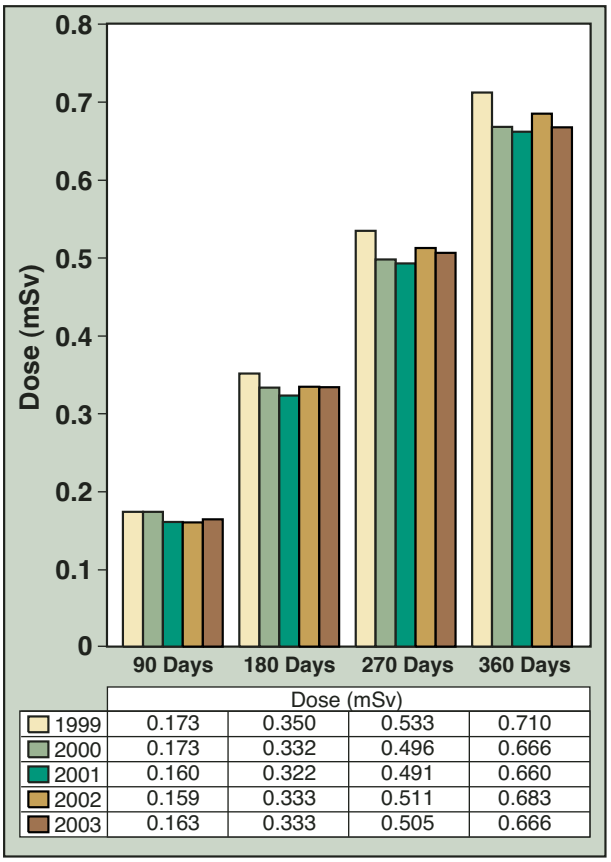
Figure 5-8. Livermore Valley cumulative dose (mSv), 1999 through 2003

Tabular data for each individual sampling location illustrate the quarterly variation (see file "Ch5 Ambient Radiation" provided on the report CD). Missing data are due to lost or damaged samples. When actual site location data are compared for the same time period of 5 years, similarities are noted. This is indicative of the local and seasonal variations that are smoothed in the site-wide averages.

From year to year, the exposure of the TLD at one sampling site changes very little. Local variation is largely due to changes in the local distribution of the radon flux as a product of decay from the uranium and thorium series on some small level and from changes in the cosmic radiation flux. For example, when the data for the Livermore site perimeter are examined for the 5 year period by location (**Figure 5-11**), the local variation is readily observed. This is due primarily to the natural soil variability. Similar variability is seen within the other location groups (**Figures 5-12** and **5-13**).

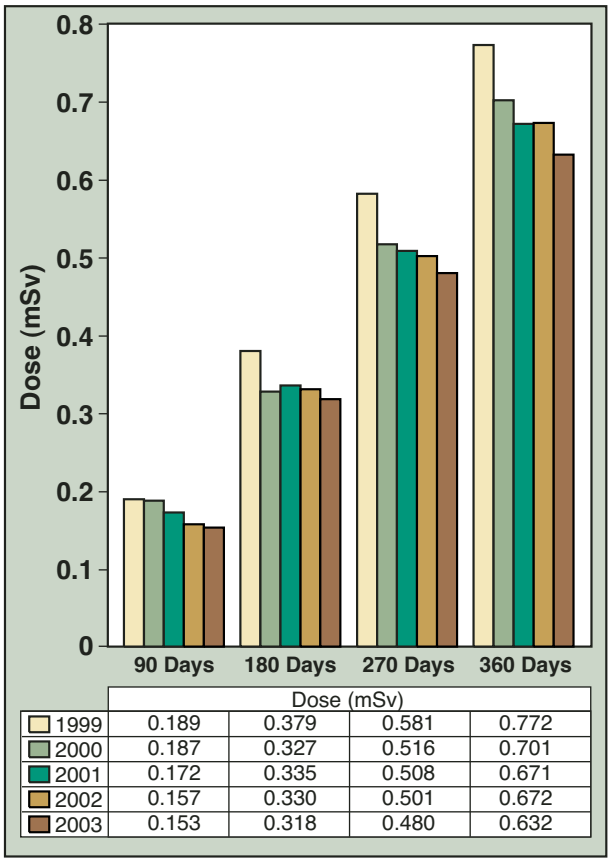
Environmental Impact on Ambient Radiation

There is no evidence to conclude that there is any environmental impact or increase in direct gamma radiation as a result of LLNL operations as measured by the TLD network for the year 2003. The radiation dose trends remain consistent with annual location average levels for each sample site. Although some locations have had anomalous annual



	Dose (mSv)			
1999	0.173	0.350	0.533	0.710
2000	0.173	0.332	0.496	0.666
2001	0.160	0.322	0.491	0.660
2002	0.159	0.333	0.511	0.683
2003	0.163	0.333	0.505	0.666

Figure 5-9. On-site at Site 300 cumulative dose (mSv), 1999 through 2003

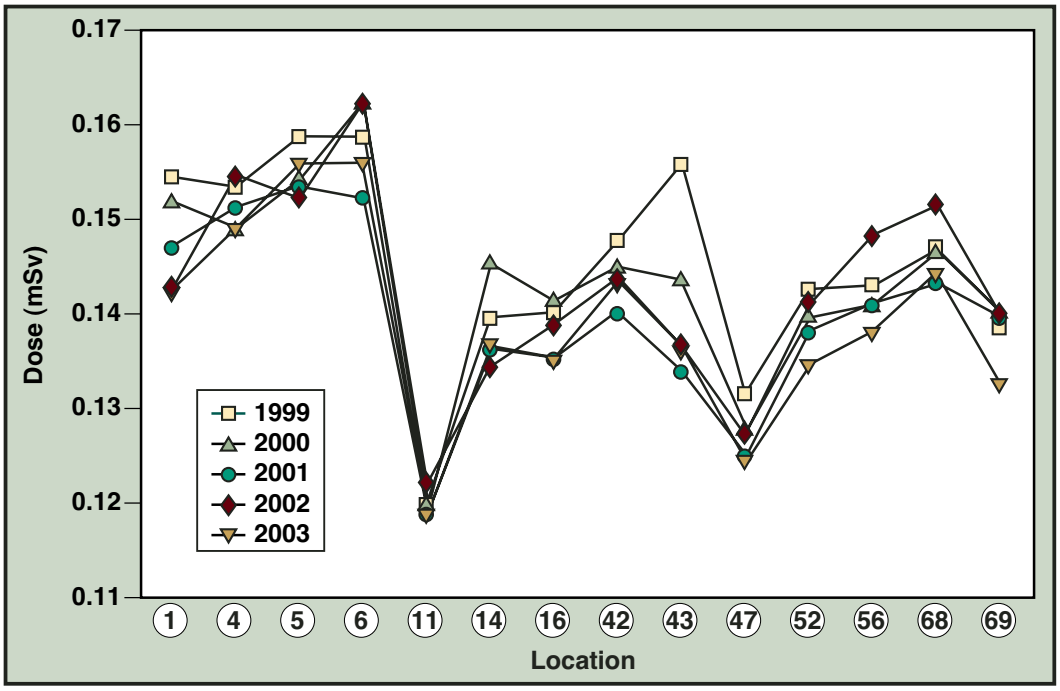


	Dose (mSv)			
1999	0.189	0.379	0.581	0.772
2000	0.187	0.327	0.516	0.701
2001	0.172	0.335	0.508	0.671
2002	0.157	0.330	0.501	0.672
2003	0.153	0.318	0.480	0.632

Figure 5-10. Site 300 environs cumulative dose (mSv), 1999 through 2003

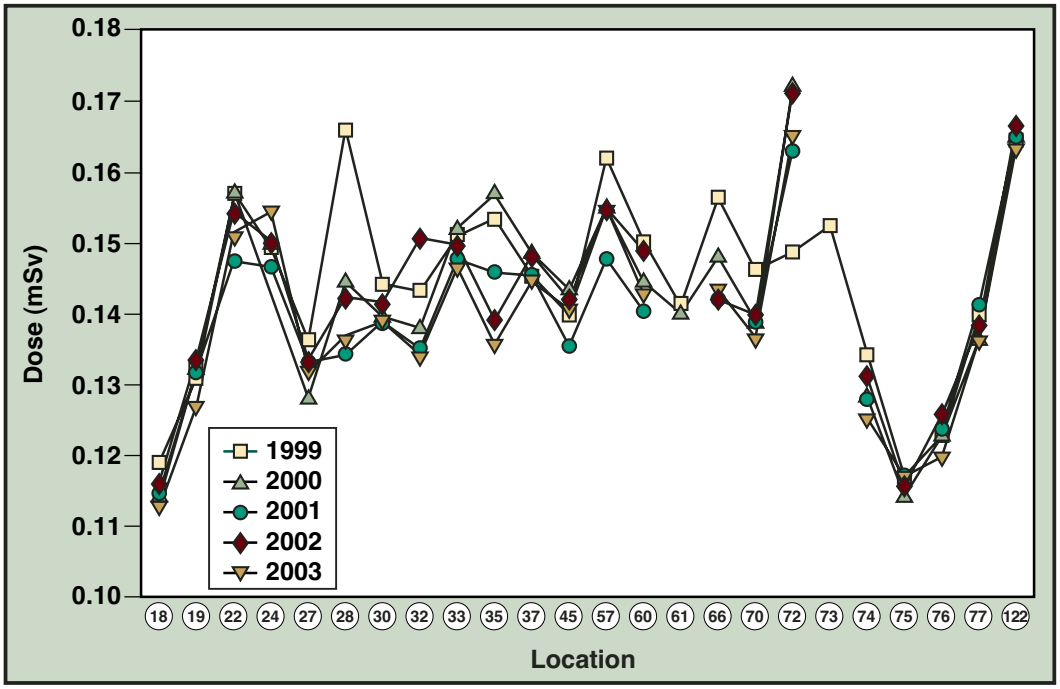
values in comparison to the long term trend for these locations, the trends would have continued at those sample sites had there been any contamination effecting the dose at that site. This is the most important reason for long term trend analysis and why these spurious excursions are not considered alarming.

As depicted in **Figure 5-14**, the annual average gamma radiation dose from 1999 to 2003 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.



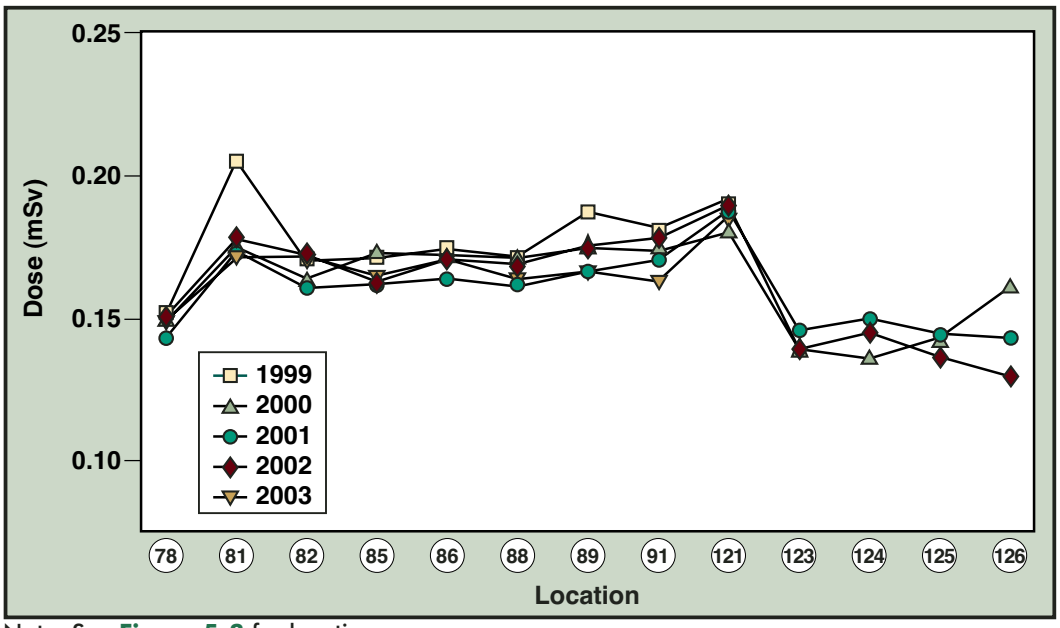
Note: See **Figure 5-1** for locations.

Figure 5-11. Livermore site perimeter annual average dose from 1999 to 2003



Note: See **Figure 5-2** for locations.

Figure 5-12. Livermore Valley annual average dose from 1999 to 2003



Note: See **Figure 5-3** for locations.

Figure 5-13. Site 300 annual average dose from 1999 to 2003

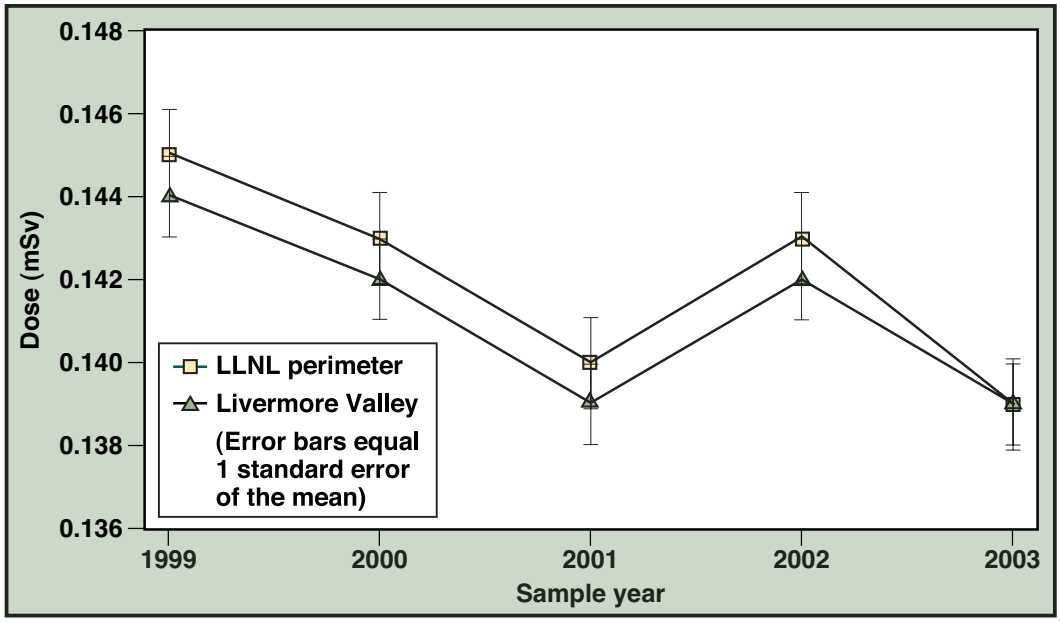


Figure 5-14. Annual average gamma radiation dose comparison for Livermore site and the Livermore Valley

Wildlife and Rare Plants

Wildlife and rare plant monitoring efforts at LLNL are focused on species and their habitats considered by Federal or California agencies and regulations to be rare, threatened, or endangered. This includes species listed under the California or Federal Endangered Species Acts; species considered of concern by the California Department of Fish and Game, and the U.S. Fish and Wildlife Services (USFWS); and species that require inclusion in NEPA and CEQA documents.

A list of species known to occur at Site 300, including state and federally listed species, is found in Appendix B. Locations of species of particular interest are shown in **Figure 5-1** for the Livermore site and **Figure 5-15** for Site 300.

Four species that are listed under the federal or California endangered species acts are known to occur at Site 300: the California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus)*, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. State threatened Swainson's Hawks (*Buteo swainsoni*) have been observed at Site 300, but Swainson's Hawk breeding habitat does not occur at Site 300. The California red-legged frog is also known to occur at the Livermore site.

In 2001, the USFWS designated critical habitat for the California red-legged frog (USFWS 2001). The North Buffer Zone and eastern edge of the Livermore site in addition to approximately half of Site 300 were included in this 2001 critical habitat designation. Most of this critical habitat designation, including all LLNL areas, was rescinded in 2002 due to a court decision. Critical habitat for the Alameda whipsnake was designated in 2000 and includes the southwest quarter of Site 300 (USFWS 2000). Similar to the California red-legged frog critical habitat designation, the Alameda whipsnake critical habitat designation was rescinded in 2003 by a court decision. A portion of Site 300 has also been designated as a critical habitat area for the large-flowered fiddleneck and as the *Amsinckia grandiflora* Reserve through a declaration by Secretary of the U.S. DOE. Activities within the reserve are conducted under a memorandum of agreement between the DOE and the USFWS.

Several other species that are considered rare or otherwise of special interest by the federal and state governments also occur at Site 300 and the Livermore site. These species include California Species of Special Concern, California Fully Protected Species, federal Species of Concern, species with respect to the federal Migratory Bird Treaty Act, and those species included in the California Native Plant Society's (CNPS's) *Inventory of Rare and Endangered Plants* (CNPS 2001). In particular, monitoring programs have

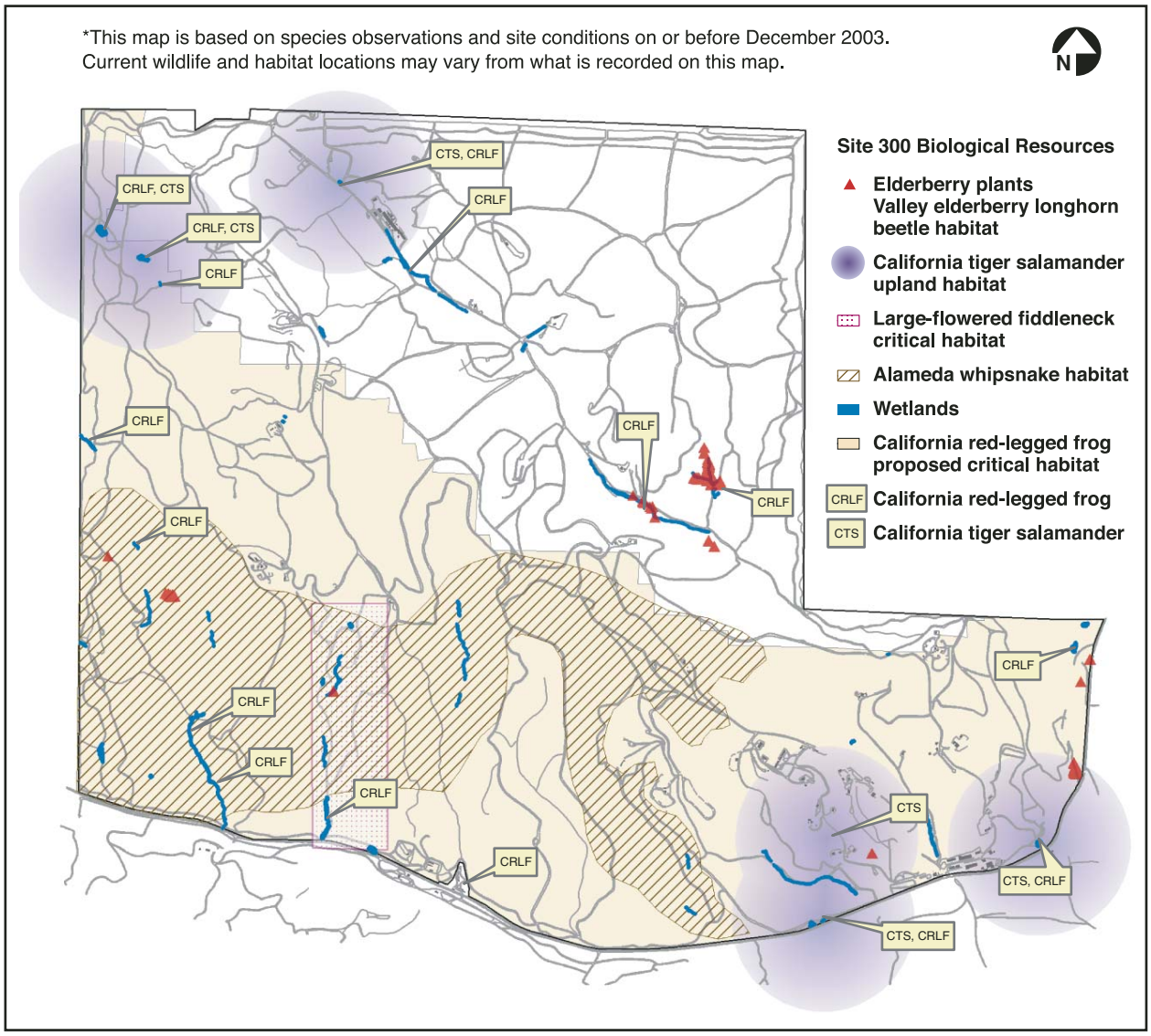


Figure 5-15. Distribution of federal and California threatened and endangered plants and wildlife, Site 300, 2003

been developed for the Tricolored Blackbird (*Agelaius tricolor*), a California species of special concern, and the White-tailed Kite (*Elanus leucurus*), a California fully protected species.

Including the federally endangered large-flowered fiddleneck, eight species of rare plants are known to occur at Site 300. Three of these species, the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), and the diamond-petaled poppy (*Eschscholzia rhombipetala*), are included in the CNPS List 1B (CNPS 2001). These species are considered rare and endangered throughout their range. An additional species, the round-leaved filaree is currently

included on CNPS List 2 (CNPS 2001). This list includes species that are rare or endangered in California and elsewhere. The four remaining rare plant species, the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*), are all included on the CNPS List 4 (CNPS 2001). List 4 plants are uncommon enough to warrant monitoring, but are not considered rare. No rare plants are known to occur at the Livermore site despite previous surveys (Preston 1997, 2002a).

The following sections describe results from LLNL wildlife and rare plant studies and surveys. For an estimate of LLNL's dose to biota, see the "Special Topics on Dose Assessment" section in Chapter 6.

Compliance Activities

California Red-Legged Frog

California red-legged frogs occur at the Livermore site and Site 300. Known locations of California red-legged frogs are shown in **Figures 5-1** and **5-15**. Livermore site populations of the California red-legged frog were monitored in accordance with the 1997 and 1998 amended USFWS Biological Opinion for the Arroyo Las Positas Maintenance Project. The 1998 Biological Opinion allows for a checkerboard pattern of Arroyo sections ranging in length from one hundred feet to three hundred feet to be managed annually for excess in-stream vegetation. No stream maintenance was conducted in Arroyo Las Positas in 2003.

California red-legged frog monitoring at the Livermore site in 2003 included egg mass surveys. Egg masses were counted, and the location of each egg mass was recorded using handheld GPS. The oviposition site (location and attachment point) was quantified to yield greater insight into microhabitat characteristics that might be important to California red-legged frog breeding ecology in the Arroyo Las Positas. The total number of California red-legged frog egg masses detected in the Arroyo Las Positas was 33 in 2003, similar to the 31 egg masses found in 2002, but the location of these egg masses shifted in 2003. In 2002, several egg masses were found in Arroyo Las Positas where it runs along the eastern edge of the site. Although few egg masses were found in the eastern portion of Arroyo Las Positas in 2003, more were found in the Arroyo near the north buffer zone. Because predation is high, the actual number of frogs produced per egg mass is unknown. Further annual surveys will help to evaluate the long-term viability of this population.

Surveys for adult frogs were conducted in various locations at Site 300 (intermittent drainages, springs, and ponds) and the Livermore Site (Arroyo Las Positas, Arroyo Seco, and portions of artificial drainage channels). These surveys consisted of walking the perimeter of the stream or pond at night between May 1 and November 1 and surveying in and around the wetland areas using a flashlight.

Alameda Whipsnake

In 2002, LLNL began participation in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on federally threatened Alameda whipsnake. In April 2002, the USFWS issued a Biological Opinion for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to Alameda whipsnakes. Through participation in this study, LLNL obtained USFWS approval to conduct prescribed burns necessary for Site 300 operation in areas that support Alameda whipsnakes. The study area consists of a control site and a burn site that are vegetated by a mosaic of coastal scrub and annual grasslands. Baseline studies were conducted in spring and fall of 2002 and spring of 2003 at Site 300 and consisted of live trapping Alameda whipsnakes, recording the location of individuals, and marking the snakes for future identification.

Thirteen Alameda whipsnakes were captured at the control and burn sites in the spring and fall of 2003. (Six of these 13 snakes were previously captured as part of this project). A total of eighteen Alameda whipsnakes were captured during baseline monitoring in 2002. A prescribed burn was conducted at the burn site in the summer of 2003, and the first season of post-burn monitoring was conducted in the fall of 2003. To date, no conclusions have been made about the effect of the Site 300 prescribed burns on Alameda whipsnakes.

Invasive Species Control Activities

Bullfrog (*Rana catesbeiana*) control activities continued in 2003 in compliance with the 1998 ammended USFWS Biological Opinion for the Arroyo Las Positas Maintenance Project. Bullfrog egg masses were removed from the Drainage Retention Basin weekly during spring and summer of 2003. Four nighttime surveys for adult bullfrogs were conducted in the summer of 2003. During these surveys, bullfrogs were identified by a qualified biologist and removed. The control program appears to be stabilizing or reducing the overall numbers of bullfrogs after the original introduction in 1999 and subsequent population explosion.

Environmental Impact Statement/Environmental Impact Report Monitoring

In implementing the mitigation monitoring requirements of the *1992 Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (U.S. DOE and UC 1992a,b) biological surveys were performed in 2003 for specific special-status species at Site 300 project construction (ground-disturbing) areas. Presence data for the San Joaquin kit fox, American badger (*Taxidea taxus*), and Western Burrowing Owl (*Speotyto cunicularia hypugaea*) were collected at each project location, and other applicable mitigation measures were implemented where appropriate.

A branchiopod survey was conducted in the 2001/ 2002 and 2002/2003 rainy seasons to determine the distribution of federally listed branchiopods at Site 300 (Weber 2002). 2003 was the final year of branchiopod surveys that were initiated to obtain baseline information for the new *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Imact Statement*. These surveys were conducted according to the USFWS interim survey guidelines for listed vernal pool branchiopods (USFWS 1996). These guidelines require that the survey protocol be conducted during two consecutive wet seasons. At Site 300, potential habitat for branchiopods currently on the federal endangered species list exists in the two vernal pools located in the northwest corner of the site, nine relatively large pools in roadbeds, and three ephemeral pools in intermittent drainages. Surveys consisted of sampling these pools at the water surface, throughout the water column, along the pool margins and at the bottom using a fine-meshed aquarium net. Specimens were identified using a 10x hand lens.

Two branchiopod species that are not federal or California endangered species, California fairy shrimp (*Linderiella occidentalis*) and California clam shrimp (*Cyzicus californicus*), were found during the 2002 and 2003 surveys. Although not listed as threatened or endangered, the California fairy shrimp is a Federal Species of Concern. No listed branchiopods were observed at Site 300.

Surveillance Monitoring

Wildlife

Nesting Bird Surveys

NLLNL conducts nesting bird surveys, which complies with the Migratory Bird Treaty Act. A nest searching technique was used in 2003 to determine the distribution and productivity of the Elk Ravine (Site 300) Tricolored Blackbird colony. The Tricolored Blackbird is not known to nest at the Livermore site. The nests were located in late summer after Tricolored Blackbirds had fledged, and the location of each nest was recorded using a handheld global positioning system (GPS). 577 nests were located and productivity was estimated for the colony at 1731 to 2308 fledglings (clutch size 3 to 4) or more conservatively estimated at 577 to 1731 fledglings (clutch size 1 to 3), representing the largest overall concentration of vertebrate special status species at Site 300. The number of nests found in 2003 is less than the number of nests found during 2002 surveys, which was over 800. Information gathered from the Tricolored Blackbird colony will be used for planning and management in addition to improving regional understanding of the distribution and abundance of this declining species.

White-tailed Kites annually nest in the trees located along the north, east and south perimeters of the Livermore site. LLNL surveyed potential White-tailed Kite nesting sites using binoculars or a spotting scope during the spring of 2003; two pairs of White-tailed Kites successfully fledged a total of five young. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide kite surveys were not conducted at Site 300 in 2003.

Avian Monitoring Program

An avian monitoring program was initiated in 2001 to obtain background information for the draft *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (see Chapter 2 for more information on the draft environmental impact statement). This avian monitoring program continued in 2003 with variable circular plot point count stations systematically distributed through Site 300. Each point was surveyed in the morning on calm dry days between sunrise and 9 a.m. during March, April, and May of 2003. Each site was surveyed once during this time period. Surveys included recording all bird species identified visually using binoculars or by their vocalization in 10 minutes. A constant effort mist netting station was also established spanning Elk Ravine and Gooseberry Canyon at Site 300. Birds were captured using ten standard passerine mist nets once every ten days throughout the breeding season (May through August 2003). Birds captured in the mist nets were identified to species, banded, aged, sexed, measured, and weighed before being released.

All of the species identified in these surveys are listed in Appendix B. Willow Flycatchers (*Empidonax traillii*) were captured during mist netting in Elk Ravine in 2003. This is of particular interest because the Willow Flycatcher is endangered under the California Endangered Species Act and was not previously known to occur at Site 300.

Rare Plants

LLNL conducted restoration and/or monitoring activities in 2003 for four of the eight rare plant species known to occur at Site 300: the large-flowered fiddleneck, the big tarplant, the diamond-petaled poppy, and the round-leaved filaree (*Erodium macrophyllum*). The results of this work are described in more detail in an annual progress report (Carlsen et al. 2003b).

Large-Flowered Fiddleneck

LLNL established an experimental population of large-flowered fiddleneck at Site 300 within the *Amsinckia grandiflora* Reserve and is working with the USFWS and the U.S. Bureau of Reclamation on continued monitoring of native and experimental large-flowered fiddleneck populations, and further developing habitat restoration and maintenance techniques. This experimental population is divided into two smaller subpopulations: the flashing subpopulation (the original experimental population) and the fire frequency subpopulation. One extant native population of large-flowered fiddleneck is also found at Site 300. The experimental and native populations were censused during March 2003. During the 2003 spring census, the location and size of each large-flowered fiddleneck plant was recorded in addition to information about the vegetation community in which large-flowered fiddleneck occurs.

The number of large-flowered fiddleneck plants in all experimental and native populations has remained extremely low for the past five years. Fewer than 50 large-flowered fiddleneck plants were observed in the native population between 1999 and 2003, and only four plants were observed in 2003. The experimental large-flowered fiddleneck

population has also had low numbers in recent years. There have been fewer than 70 large-flowered fiddlenecks in the flashing portion of the experimental population each year since 1998, and this subpopulation dropped to a low of 10 plants in 2001. The fire frequency subpopulation contained 148 large-flowered fiddleneck plants in 2000, 257 in 2001, 57 in 2002, and 50 in 2003.

The experimental population was expanded in 2000 to investigate more fully the use of fire as a management tool. This portion of the experimental population is referred to as the fire frequency subpopulation. Vegetation monitoring after the 2001 and 2002 prescribed burns show that these burns are beneficial in the restoration of native bunch grasses.

Because of the low population numbers in native and experimental populations, LLNL obtained funding from the U.S. Bureau of Land Management to enhance the seed bank of the flashing subpopulation at Site 300 and a second experimental population at Lougher Ridge in Black Diamond Mines Regional Park. A total of 2400 large-flowered fiddleneck seeds from the LLNL-maintained seed bank were planted at the Site 300 experimental population in the fall of 2002. The 2002 seeding did not result in a large increase in population numbers (69 large-flowered fiddleneck were observed in the flashing subpopulation in 2003) probably due to unusual rainfall during the winter of 2002/2003. Seeding was repeated in the fall/winter 2003.

Seed predation is a factor potentially attributing to the low population number of large-flowered fiddleneck. The amount of seed predation by small mammal populations in the Site 300 experimental population was studied in 2003. Detailed monitoring of populations located in areas undergoing controlled burning is also being conducted to determine the impacts of fire on the population dynamics of this species. Seed predation in 2003 was slightly lower than in 2002 and 2001 and much lower than the extremely high predation rate observed in 1998 and 1999.

Big Tarplant

The distribution of big tarplant was mapped using a handheld GPS in October and November 2003. This distribution was compared, using a GIS (Geographic Information System), to the distribution of prescribed burns conducted at Site 300 in 2003 and in previous years.

The big tarplant remained widespread throughout Site 300 in 2003. Data show the plants do not survive direct contact with the burn but do benefit from reduced competition resulting from a burn. This suggests an intermittent burn frequency in some areas may further increase populations of this species.

Diamond-Petaled California Poppy

In 2003, two populations of diamond-petaled California poppy were known to occur near the western boundary of Site 300. Although this species is not listed under the federal or California endangered species acts, it is extremely rare and is only currently known to occur at Site 300 and one additional location. A census of the two Site 300 populations was conducted in March 2003, during which LLNL recorded the size and location for each diamond-petaled poppy plant, and the vegetation community in which this species occurs.

A total of 10 diamond-petaled poppy plants were observed in the original site (identified in 2001) in 2003; this is down considerably from 285 in 2002 and 189 plants observed in 2001. The majority of these plants produced seed-bearing pods. The second population identified during the 2002 special status plant surveys (Preston 2002a) contained a total of 76 plants in 2002 and only two plants in 2003.

Round-Leaved Filaree

One population of round-leaved filaree was located at Site 300 during a site-wide botanical survey conducted in 2002 (Preston 2002), and a second population was located in 2003 during surveys of the fire trail system. 2003 was the first year of monitoring round-leaved filaree at Site 300. During the spring of 2003, the extent of these two populations was mapped using a handheld GPS and the survivorship of round-leaved filaree was measured and compared to the survivorship of the related exotic species red-stem filaree (*Erodium cicutarium*). Survivorship to flowering for round-leaved filaree was high, 93%, compared to red-stem filaree, which had a 66% survivorship to flowering.

Environmental Impacts on Wildlife and Rare Plants

The Livermore site population of California red-legged frogs in 2003 appeared to be stable compared to 2002. The location of reproduction in Arroyo Las Positas shifted in 2003. This shift is probably the result of dredging conducted in 2002 that changed the water depth and vegetation of the dredged reaches of Arroyo Las Positas. In spite of the location shift, reproduction rates appear to be similar in 2003 compared to 2002. At Site 300, 2003 surveys indicate that the existing small populations of California red-legged frogs continue to persist.

The bullfrog control program continued at the Livermore site in an effort to reduce competitive pressures of this invasive species of the California red-legged frogs. The control program appears to be stabilizing or reducing the overall numbers of bullfrogs after the original introduction and subsequent population explosion.

LLNL was also able to avoid impacting the nesting of tricolored blackbird and white-tailed kites by monitoring the timing and location of their nesting. LLNL's avian monitoring program also detected one California Endangered Species, the Willow Flycatcher, previously not known to occur at Site 300.

The decline in populations of large-flowered fiddleneck observed over the past several years at Site 300 has been observed in other existing natural and experimental populations of the large-flowered fiddleneck throughout its existing range. These low numbers are probably the result of environmental factors and not related to Site 300 activities. Potential factors contributing to the decline of the large-flowered fiddleneck include encroachment of bush lupine (*Lupinus albifrons*), seed predation, and increase in annual grass density in large-flowered fiddleneck populations. Research continues to help determine what factors are contributing to the decline of this species and what management strategies will be beneficial to this species.

Site 300 as a whole is a place where rare plants flourish. Big tarplant is abundant throughout a large portion of Site 300 despite being very rare throughout California. The diamond-petaled poppy and large-flowered fiddleneck both occur in remote areas of Site 300 and are limited to only one or two other known locations.

6 Radiological Dose Assessment

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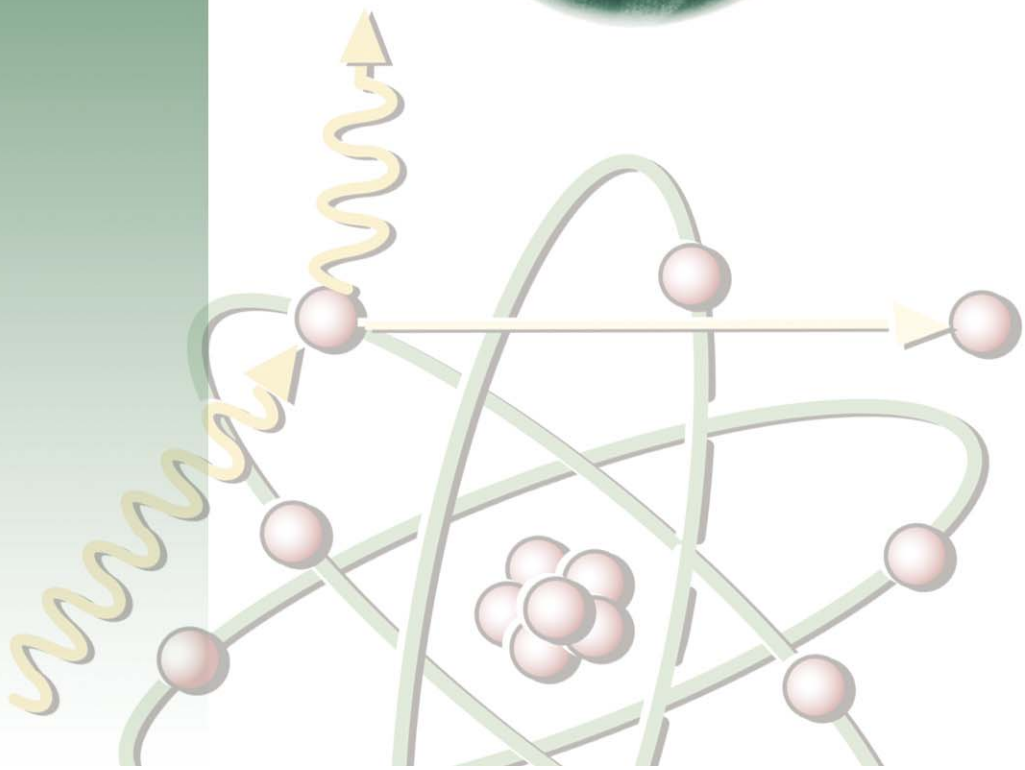

Introduction

LLNL assesses potential radiological doses to the public and biota from its operations, in order to demonstrate compliance with regulatory standards that protect the public and environment. This chapter describes the releases of radioactivity, pathways of exposure, applicable standards, assessment methods and key data and concepts. It summarizes the radiological dose determinations, identifying trends over time and placing them in perspective with natural background and other sources of radiation exposure.

Releases of Radioactivity from LLNL Operations

Releases of radioactive material to air, for example in the form of air effluent dispersed from stacks, are by far the major source of public radiological exposures from LLNL operations. In contrast, releases to groundwater, surface water, and sanitary sewer water are not sources of direct public exposures because these waters are not directly consumed or used by the public. Consequently, measurements and modeling of radiological releases to air determine LLNL's dose to the public.

Data on radiological releases to air are gathered by three principal means: continuous monitoring of stack effluent at selected facilities at the Livermore site (described in Chapter 3); routine surveillance ambient air monitoring for radioactive particles and gases, both on and off LLNL property (also described in Chapter 3); and radioactive material usage inventories. The inventory process is described in LLNL's National Emission Standards for Hazardous Air Pollutants (NESHAPs) annual reports, showing LLNL's compliance with NESHAPs (Harrach et al. 2004). Of these three approaches, stack monitoring provides the most definitive characterization. The extent of reliance on usage inventories declined in 2003, in favor of increased utilization of ambient air monitoring data (see the "Compliance Demonstration for Minor Sources" section below).

Despite the emphasis on radiological releases to air and monitoring of the ambient air, it should be noted that LLNL's extensive environmental monitoring program, in place since the early 1970s, encompasses a variety of media. In addition to ambient and effluent air monitoring and the three categories of water monitoring already mentioned, LLNL samples rain water, soil, vegetation, and wine, and measures environmental (gamma) radiation. The monitoring program also includes a wide range of potential contaminants; it is not limited to radioactive ones.

Radiation Protection Standards

The release of radionuclides from operations at LLNL and the resultant radiological impact to the public are regulated by both the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

The primary DOE radiation standards for protection of the public are 1 millisievert per year (1 mSv/y) or 100 millirem per year (100 mrem/y) whole-body effective dose equivalent (EDE) for prolonged exposure of a maximally exposed individual in an uncontrolled area and 5 mSv/y (500 mrem/y) EDE for occasional exposure of this individual. (EDEs and other technical terms are discussed in *Supplementary Topics on Radiological Dose* [available on report CD] and defined in the glossary of this report.) These limits pertain to the sum of the EDE from external radiation and the committed 50-year EDE from radioactive materials ingested or inhaled during a particular year that may remain in the body for many years.

The EPA's radiation dose standard for air emissions limits the EDE to members of the public to 100 µSv/y (10 mrem/y). EPA regulations specify not only the allowed levels, but also the approved methods by which airborne emissions and their impacts must be evaluated. With respect to all new or modified projects, NESHAPs compliance obligations define the requirements to install continuous air-effluent monitoring and to obtain EPA approval before the startup of new operations. NESHAPs regulations require that any operation with the potential to produce an annual-averaged off-site dose greater than or equal to 1 µSv/y (0.1 mrem/y), taking full credit for emission-abatement devices such as high-efficiency particulate air (HEPA) filters, must obtain EPA approval prior to the startup of operations. This same calculation, but without taking any credit for emission abatement devices, determines whether or not continuous monitoring of emissions to air from this project is required. These requirements are spelled out in LLNL's online *Environment, Safety, and Health (ES&H) Manual*, Document 31.1, "Air Quality Compliance."

Air Dispersion and Dose Models

Computational models are needed to describe the transport and dispersion in air of contaminants and the doses to exposed persons via all pathways. The computer codes used at LLNL to model air releases and their impacts feature idealized, Gaussian-shaped plumes and can be run on personal computers. The CAP88-PC code incorporates dosimetric and health effects data and equations that are mandated by EPA to be used in compliance assessments (Parks 1992). The code evaluates the four principal pathways of exposure from air releases—internal exposures from inhalation of air and ingestion of foodstuff and drinking water, and external exposures through irradiation from contaminated ground and immersion in contaminated air. CAP88-PC accommodates site-specific input data files to characterize meteorological conditions and population distributions for both individual and collective dose evaluations, and the code is relatively easy to use and understand. For these reasons, CAP88-PC has been the "workhorse"

modeling tool for LLNL's regulatory compliance assessments since its availability in March 1992, particularly as applied to chronic releases of radioactivity to air occurring in the course of routine operations. In addition, an LLNL-modified version of CAP88-PC that contains an improved tritium model (NEWTRIT) has been used the past several years for purposes of comparison (Peterson and Davis 2002).

Identification of Key Receptors

When assessing probable off-site impacts, LLNL pays particular attention to doses received by three hypothetical receptors. First is the dose to the site-wide maximally exposed individual (SW-MEI; defined below) member of the public. Second is the dose to the maximally exposed individual (MEI) member of the public from a given source point. Third is the collective or "population" dose received by people residing within 80 km of either of the two LLNL sites.

The SW-MEI is defined as the hypothetical member of the public at a single, publicly accessible location (where members of the public reside or abide) who receives the greatest LLNL-induced EDE from all sources at a site. For LLNL to comply with the NESHAPs regulations, the LLNL SW-MEI cannot receive an EDE as great or greater than 100 µSv/y (10 mrem/y) from releases of radioactive material to air. Public facilities that could be the location of the SW-MEI include schools, churches, businesses, and residences. This hypothetical person is assumed to remain at this location 24 hours per day, 365 days per year, continuously breathing air having the radionuclide concentration, and consuming a specified fraction of food and drinking water that is affected by the releases of radioactivity from the site. Thus, the SW-MEI dose is not received by any actual individual and is a conservative estimate of the highest possible dose to any member of the public. The location of the SW-MEI can change from one year to the next; it is sensitive to the frequency distribution of wind speeds and directions, as well as locations of key sources on the site.

At the Livermore site, the SW-MEI in 2003 was located at the UNCLE Credit Union, about 10 m outside the controlled eastern perimeter of the site. This location lies 957 m from the Tritium Facility (Building 331), in an east-northeast direction (the typical prevailing wind direction). At Site 300, the SW-MEI occupied a position on the south-central boundary of the site bordering the Carnegie State Vehicular Recreation Area, approximately 3170 m south-southeast of the firing table at Building 851. These SW-MEI locations are depicted in **Figure 6-1**.

While the SW-MEI location is determined by all sources at a site and coincides with an actual publicly accessible facility, the location of the MEI is any point of unrestricted public access receiving the largest potential dose from a given source and is generally different for each emission point. Such a point typically occurs at the site perimeter, and is often referred to as the maximum "fence line" dose. However, the off-site maximum dose could occur some distance beyond the perimeter (e.g., when a stack is close to the perimeter).

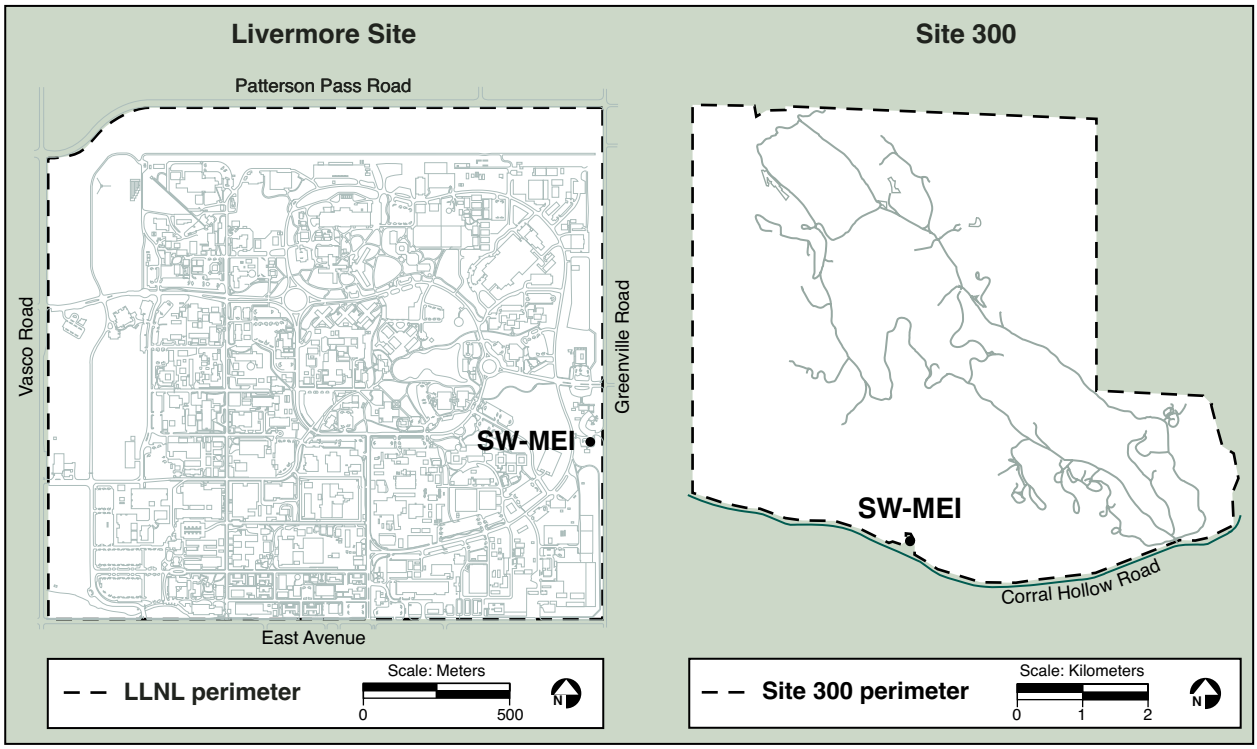

Figure 6-1. Location of the site-wide maximally exposed individual (SW-MEI) at the Livermore site and Site 300, 2003.

All new or modified LLNL projects in which releases of radioactivity to the environment may occur are reviewed for joint compliance with NESHAPs and the National Environmental Policy Act (NEPA). Dose to the MEI is used to evaluate whether continuous monitoring of the emissions from a given project is required, and whether it is necessary to petition the EPA for permission to start up the activity.

Results of 2003 Radiological Dose Assessment

This section summarizes the doses to the most-exposed public individuals from LLNL operations in 2003, shows the temporal trends by comparison to previous years, presents the potential doses to the populations residing within 80 km of either the Livermore site or Site 300, and places the potential doses from LLNL operations in perspective with doses from other sources.

Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2003 was 0.44 µSv/y (0.044 mrem/y). Of this, the dose attributed to diffuse emissions totaled 0.20 µSv (0.020 mrem) or 45%; the dose due to point sources was 0.24 µSv (0.024 mrem) or 55% of the total. The point source dose includes Tritium Facility elemental tritium gas (HT) emissions modeled as tritiated water (HTO), as directed by EPA Region IX. Using NEWTRIT to calculate the dose for tritium emissions reduced the tritium component of the total dose from 0.41 µSv (0.041 mrem) to 0.30 µSv (0.030 mrem).

The total dose to the Site 300 SW-MEI from operations in 2003 was 0.17 µSv (0.017 mrem). Point source emissions from firing table explosives experiments accounted for 98% of this total, while 0.0034 µSv (0.00034 mrem), or about 2%, was contributed by diffuse sources.

Table 6-1 shows the facilities or sources that accounted for more than 90% of the doses to the SW-MEI for the Livermore site and Site 300 in 2003. Although LLNL has nearly 150 sources with potential for releasing radioactive material to air according to NESHAPs prescriptions, most are very minor. Nearly the entire radiological dose to the public each year from LLNL operations comes from no more than a dozen sources. In April 2003, EPA granted LLNL permission to use surveillance monitoring in place of

Table 6-1. List of facilities or sources whose combined emissions accounted for more than 90% of the SW-MEI doses for the Livermore site and Site 300 in 2003

Facility (source category)	CAP88-PC dose (µSv/y)	CAP88-PC percentage contribution to total dose
Livermore site		
Building 331 stacks (point source)	0.22[a]	50
Building 612 Yard (diffuse source)	0.13[a]	30
Building 331 outside (diffuse source)	0.059[a]	13
Building 612, R102 (point source)	0.014	3.2
Site 300		
Building 851 Firing Table (point source)	0.17	98
Soil resuspension (diffuse source)	0.0034	2

a When LLNL's NEWTRIT model is used in CAP88-PC in place of CAP88-PC's default tritium model, the doses for Building 612 yard, Building 331 stacks, and Building 331 outside are reduced to 75% of the values shown, and that for the Building 331 stacks are reduced to 73% of the value shown.

inventory-based modeling to account for dose contributions from the numerous minor sources; see attachment in last year's *NESHAPs Annual Report* (Harrach et al. 2003). This procedure was implemented for the first time in assessing 2003 operations, as reported here and in this year's *NESHAPs Annual Report* (Harrach et al. 2004).

Dominant radionuclides at the two sites were the same as in recent years. Tritium accounted for about 93% of the Livermore site's calculated dose. At Site 300, practically the entire calculated dose was due to the isotopes uranium-238, uranium-235, and uranium-234 in depleted uranium. Regarding pathways of exposure, the relative significance of inhalation and ingestion depends on the assumptions made about the origin of food consumed. The assumption when assessing individual LLNL doses that milk is imported while the remainder of the food is produced locally results in ingestion dose exceeding inhalation dose in the case of tritium, approximately 80% to 20%, respectively. For uranium, these numbers are nearly reversed: 17% by the ingestion pathway versus 83% via inhalation. LLNL doses from air immersion and ground irradiation are negligible for both tritium and uranium.

The trends in dose to the SW-MEI from emissions at the Livermore site and Site 300 over the last 14 years are shown in **Table 6-2**. The general pattern, particularly over the last decade, shows year-to-year fluctuations around a low dose level, staying at or below about 1% of the federal standard. The SW-MEI dose estimates are intentionally conservative, predicting potential doses that are generally higher than actually would be experienced by any member of the public.

Table 6-3 shows the Site 300 SW-MEI dose values attributed to firing table experiments for 1990 through 2003; the table also shows the total amounts of depleted uranium and the total quantity of high explosives used each year in the experiments. (Only explosives experiments that included depleted uranium are considered here; most have none.)

Doses from Unplanned Releases

There were no unplanned atmospheric releases of radionuclides at the Livermore site or Site 300 in 2003.

Population Doses

Population doses, or collective EDEs, for both LLNL sites were calculated out to a distance of 80 km in all directions from the site centers using CAP88-PC. As noted earlier, CAP88-PC evaluates the four principal exposure pathways: ingestion through food and water consumption, inhalation, air immersion, and irradiation by contaminated ground surface.

Table 6-2. Doses (μSv) calculated for the sitewide maximally exposed individual (SW-MEI) for the Livermore site and Site 300, 1990 to 2003

Year	Total dose	Point source dose	Diffuse source dose
Livermore site			
2003	0.44[a]	0.24[a]	0.20
2002	0.23[a]	0.10[a]	0.13
2001	0.17[a]	0.057[a]	0.11
2000	0.38[a]	0.17[a]	0.21
1999	1.2[a]	0.94[a]	0.28
1998	0.55[a]	0.31[a]	0.24
1997	0.97	0.78	0.19
1996	0.93	0.48	0.45
1995	0.41	0.19	0.22
1994	0.65	0.42	0.23
1993	0.66	0.40	0.26
1992	0.79	0.69	0.10
1991	2.34	—[b]	—[b]
1990	2.40	—[b]	—[b]
Site 300			
2003	0.17	0.17	0.0034
2002	0.21	0.18	0.033
2001	0.54	0.50	0.037
2000	0.19	0.15	0.037
1999	0.35	0.34	0.012
1998	0.24	0.19	0.053
1997	0.20	0.11	0.088
1996	0.33	0.33	0.0045
1995	0.23	0.20	0.03
1994	0.81	0.49	0.32
1993	0.37	0.11	0.26
1992	0.21	0.21	—[c]
1991	0.44	0.44	—[c]
1990	0.57	0.57	—[c]

a The dose includes HT emissions modeled as HTO as directed by EPA Region IX. EPA Region IX acknowledges that such modeling results in an overestimation of the dose. This methodology is used for purposes of compliance.

b Diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991.

c No diffuse emissions were evaluated and reported at Site 300 before 1993.

Table 6-3. Annual dose to the SW-MEI from explosives experiments on firing tables at Site 300, 1990 to 2003, related to the total quantity of depleted uranium used in the experiments and the total quantity of high explosives driving the detonations

Year	Annual dose to SW-MEI		Total depleted uranium used in experiments (kg)	Total quantity of high explosive used in depleted uranium experiments (kg)
	μSv	mrem		
2003	0.17	0.017	62	48
2002	0.18	0.018	45	77
2001	0.50	0.050	187	104
2000	0.15	0.015	43	34
1999	0.34	0.034	216	168
1998	0.19	0.019	230	192
1997	0.11	0.011	163	122
1996	0.33	0.033	272	112
1995	0.20	0.020	165	199
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

Population centers affected by LLNL emissions include the relatively nearby communities of Livermore and Tracy, the more distant metropolitan areas of Oakland, San Francisco, and San Jose, and the San Joaquin Valley communities of Modesto and Stockton. Within the 80 km outer distance specified by DOE, there are 7.1 million residents included for the Livermore site population dose determination, and 6.2 million for Site 300. Population data files (distribution of population with distance and direction) used for the present report were updated for the 2003 modeling effort. These population distributions are based on the LandSpan Global Population 2001 Database (Dobson et al. 2000).

The CAP88-PC result for potential population dose attributed to 2003 Livermore-site operations was 0.016 person-Sv (1.6 person-rem); the corresponding collective EDE from Site 300 operations was 0.032 person-Sv (3.2 person-rem). These values are both within the normal range of variation seen from year to year.

Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of these LLNL doses, **Table 6-4** compares them to average doses received in the United States from exposure to natural background radiation and medical tests. Population doses from LLNL operations in 2003 are about 400,000 times smaller than ones from natural background radiation. The estimated maximum potential doses to individual members of the public from operations at the two LLNL sites (combined) in 2003 are nearly 5000 times smaller than ones received from background radiation in the natural environment.

Table 6-4. Comparison of background (natural and man-made) and LLNL radiation doses, 2003

Location/source	Individual dose[a]		Population dose[b]	
	(μSv)	(mrem)	(person-Sv)	(person-rem)
Livermore site sources				
Atmospheric emissions	0.44	0.044	0.016	1.6
Site 300 sources				
Atmospheric emissions	0.17	0.017	0.032	3.2
Other sources[c]				
Natural radioactivity[d,e]				
Cosmic radiation	300	30	1,900	190,000
Terrestrial radiation	300	30	1,900	190,000
Internal (food consumption)	400	40	2,500	250,000
Radon	2,000	200	12,500	1,250,000
Medical radiation (diagnostic procedures)[e]	530	53	3,300	330,000
Weapons test fallout[e]	10	1.0	68	6,800
Nuclear fuel cycle	4	0.4	25	2,500

a For LLNL sources, this dose represents that experienced by the SW-MEI member of the public.

b The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of LLNL (approximately 7.1 million people for the Livermore site and 6.2 million for Site 300), calculated with respect to distance and direction from each site.

c From National Council on Radiation Protection and Measurements (NCRP 1987a,b)

d These values vary with location.

e This dose is an average over the U.S. population.

Special Topics on Dose Assessment

Compliance Demonstration for Minor Sources

Since 1991, LLNL has demonstrated compliance for minor sources through a labor-intensive inventory and modeling process. The dose consequences to the public for these sources were 8 to 20 orders of magnitude below the regulatory standard of 10 mrem/y and did not justify the level of effort expended in accounting for them. To better allocate resources, LLNL made a request, pursuant to the NESHAPs regulations, to use existing ambient air monitoring to demonstrate compliance for minor emissions sources. This request was made in March 2003 and granted in April 2003. For this calendar year 2003 compliance report, LLNL is, for the first time, demonstrating NESHAPs compliance for minor sources by comparing measured ambient air concentrations at the location of the SW-MEI to concentrations limits set by the EPA in Table 2, Appendix E of 40 CFR 61. The radionuclides for which the comparison is made are tritium and plutonium-239+240 for the Livermore site SW-MEI and uranium-238 for the Site 300 SW-MEI. At the Livermore site, the average of the monitoring results for locations L-VIS and L-CRED represent the SW-MEI. At Site 300, the minor source that has the potential to have a measurable effect is the resuspension of depleted-uranium-contaminated soil. Because this is a diffuse source, the average of the results for all monitoring locations at the site are used to represent the SW-MEI.

The Table 2, Appendix E of 40 CFR 61 standards and the measured concentrations at the SW-MEI are presented in **Table 6-5**. As demonstrated by the calculation of the fraction of the standard, LLNL measured concentrations for tritium and plutonium-239+240, and uranium-238 in air are 0.003 or less than the health protective standard for these radionuclides.

Estimate of Dose to Biota

Although mankind is protected from excess radiation dose by the methods outlined in this chapter, biota is not necessarily protected because of different exposure pathways (e.g., dose to a ground squirrel burrowing in contaminated soil). Thus LLNL calculates potential dose to biota from LLNL operations using the DOE guidance document, "DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (U.S. DOE 2002), and the RAD-BCG (Biota Concentration Guides) Calculator (Version 2) in an Excel spreadsheet. Limits on absorbed dose to biota are 10 mGy/d (1 rad/d) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial animals.

Table 6-5. Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2003

Location	Nuclide	EPA concentration standard (Ci/m^3)	Mean measured concentration (Ci/m^3)	Measured concentration as a fraction of the standard	Detection limit (approximate) (Ci/m^3)
Livermore SW-MEI	Tritium	1.5×10^{-9}	5.0×10^{-12} [a]	3.3×10^{-3}	1×10^{-12}
Livermore SW-MEI	Plutonium-239	2.0×10^{-15}	1.3×10^{-19} [b]	6.5×10^{-5}	5×10^{-19}
Site 300 SW-MEI	Uranium -238	8.3×10^{-15}	7.0×10^{-18} [c]	8.4×10^{-4}	3×10^{-20}

a The tritium value includes contribution of emissions from the Tritium Facility, estimated at 3.8×10^{-12} Ci/m^3.

b Note that the mean measured concentration for plutonium is less than the detection limit; only 3 of the 24 values comprising the mean were measured detections.

c The mean ratio for uranium-235/uranium-238 for 2003 is 0.00708, which is only slightly less than 0.00726, the ratio of these isotopes for naturally occurring uranium. This indicates that approximately 96% of the measured quantities of uranium-238 were caused by resuspension of soil containing naturally occurring uranium.

In the RAD-BCG Calculator, each radionuclide in each medium (soil, sediment, surface water) is assigned a derived concentration limit. For each concentration entered in the spreadsheet, a fraction of the derived concentration limit for that radionuclide is automatically calculated; the fractions are summed for each medium. For aquatic and riparian environments, if a concentration for water is entered, the calculator automatically assigns an expected concentration to the sediment, and vice versa.

For aquatic and riparian animals, the sum of the fractions for water exposure are added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), the site has passed the screening analysis, and the biota are assumed to be protected.

In the LLNL assessment, the maximum concentration of each radionuclide measured in soils, sediments, and surface waters during 2003, no matter where measured, was entered into the screening calculation. This approach may result in an assessment that is unrealistically conservative, given that the maximum concentrations in the media are spread over a very large area, and no animal could possibly be exposed to them all. Other assumptions increase the possibility that the estimated dose will be conservative. For example, while only gross alpha and gross beta are measured in water, it is assumed that gross alpha is represented by plutonium-239 and gross beta by strontium-90 to assure maximum dose. Furthermore, although biota would most likely live in and near permanent bodies of water (i.e., surface water), measurements of storm water runoff were used for the assessment because they had higher concentrations than surface waters. Finally, when measurements were available for both runoff and sediment, the value that gave the highest fraction of the BCG was used.

Radionuclides measured by LLNL in 2003 that might have been contributed by LLNL operations were americium-241, cesium-137, tritium, plutonium-239, thorium-232, uranium-235, and uranium-238; in addition, gross beta is represented by strontium-90. For LLNL, the sum of the fractions for the aquatic system was 0.19, and the sum for the terrestrial system was 0.032, both well below the screening level. These results are similar to those in 2001 and 2002.

A less artificial assessment of dose to aquatic biota from LLNL operations can be made using surface water concentrations from the Drainage Retention Basin (DRB) combined with sediment concentrations from the East Settling Basin (ESB). Sediment samples are not taken in the DRB, and water is ephemeral at the ESB. Nevertheless, concentrations may be expected to be similar given that water drains through the ESB to the DRB. Using these concentrations in the RAD-BCG Calculator, the sum of the fractions for aquatic exposure is 0.13, which is about two-thirds of the fraction from the ultra-conservative approach. It is clear that dose to biota from LLNL operations are below the level of regulatory concern.

Modeling Dose from Tritium — Comparison of Approaches

Since tritium has been and continues to be the principal radionuclide released to air in Livermore site operations (from a public dose standpoint), a comparison was made in 2003 of the approaches used at LLNL to model its dose impacts.

Since 1986, LLNL has calculated dose from releases of HTO (or total tritium modeled as HTO) to the atmosphere using the regulatory model CAP88-PC (since 1992) or its predecessor, AIRDOS-EPA. The dose calculated with AIRDOS-EPA or CAP88-PC uses source terms that represent the principal tritium sources at the site. As well, since 1979, using bulk transfer factors (**Table 6-6**) derived from equations in the Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.109 (U.S. NRC 1977), LLNL has calculated potential ingestion doses from measured concentrations in vegetation (Chapter 5), as well as doses from inhalation (Chapter 3) and drinking water (Chapter 4). Both CAP88-PC and Regulatory Guide 1.109 only account for dose from HTO. In the last few years, it has been learned that doses that neglect the contribution of organically bound tritium (OBT) may underestimate dose, but by no more than a factor of two and in most cases by a much smaller factor (U.S. Department of Health and Human Services 2001). Recently, another model, NEWTRIT (Peterson and Davis 2002), has been used to estimate inhalation and ingestion doses from releases of both HT and HTO; the ingestion dose accounts for both HTO and OBT. NEWTRIT uses observed or predicted air concentrations as input.

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

Doses in μSv	Bulk transfer factors times observed mean concentrations
Inhalation and skin absorption	0.21 x concentration in air (Bq/m^3) (See Chapter 3)
Drinking water	0.013 x concentration in drinking water (Bq/L) (See Chapter 4)
Food Ingestion	0.0049 x concentration in vegetation (Bq/kg) (See Chapter 5); (factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk)

Note: The derivation for these bulk transfer factors may be found in Appendix C of *Environmental Report 2002* (Sanchez et al. 2003)

Hypothetical tritium doses predicted at the onsite location of the air tritium monitor, VIS (see Figure 3-1) using the three modeling approaches are compared in **Table 6-7**. All predictions were made for a hypothetical person living 100% of the time adjacent to the air tritium monitor at VIS and eating 100% locally grown food. Assumptions about the quantities of food consumed vary between the models. Because the air tritium monitor can only sample for HTO, no HT was included in the source term for CAP88-PC. Vegetation is also sampled at VIS.

The dose comparison shows about a factor of five difference between the lowest and highest dose predictions, each of which is based on a valid approach. Differences are primarily due to estimated concentrations and assumptions about intake rates and dose

Table 6-7. Comparison of hypothetical annual doses (nSv/y) at the VIS air tritium monitoring location calculated from predicted and observed concentrations of HTO in air

	CAP88-PC (from predicted air concentrations [a])	NRC R.G. 1.109 (from mean air, vegetation, and tap water[b] concentrations)	NEWTRIT (from mean air tritium concentrations)
Inhalation and skin absorption	64	38	42
Food ingestion (vegetables; milk; meat)	200; [130]; 75	7.9; 19; 7.9	110; 68; 34
Drinking water	3.7	< 29[c]	18
Food ingestion dose	270 [400]	35	210
Total dose	340 [470]	< 100	270

a Doses from CAP88-PC are based on the sum of the predicted HTO concentrations at VIS for B331 (0.13 Bq/m^3), the B612 yard (0.070 Bq/m^3), and the B331 Waste Accumulation Area (0.034 Bq/m^3). Numbers in brackets (e.g., dose from milk) are not calculated for reported LLNL doses. See *NESHAPs Report and Guidance for Radiological Dose Assessment*.

b Tap water is measured on the Livermore site but not at the VIS monitor location.

c All tap waters measured for tritium in 2003 were below the limit of detection.

coefficients (see Appendix C of *Environmental Report 2002* [Sanchez et al. 2003]). The total dose from CAP88-PC is the highest, as expected, and the NEWTRIT dose is well within a factor of two of the CAP88-PC dose. All doses are far below any level of concern.

A more realistic, but still highly conservative, set of assumptions about the lifestyle of the hypothetical member of the public residing at the VIS monitor location lowers the annual dose from tritium (**Table 6-8**) to as low as one-third of the lowest dose in **Table 6-7**, even while including tiny potential doses from other dose pathways.

Environmental Impact

The annual radiological dose from all emissions at the Livermore site and Site 300 in 2003 was found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard. This standard limits to 100 µSv/y (10 mrem/y) the EDE to any member of the public, arising as a result of releases of

Table 6-8. Doses for the tritium exposure of an individual residing at the location of the VIS air tritium monitor in 2003, based on observed HTO-in-air concentrations and using plausible but conservative assumptions (as indicated)

Source of dose	Annual dose (nSv/y)	Assumption
Inhalation	1.6	Breathes air at VIS 16 hours a day, all year
Ingesting food, including OBT	9.6	Raises and eats 25% homegrown leafy vegetables, fruit vegetables, fruits and root crops, no homegrown milk, beef, or grain but 12 kg/y homegrown chickens and 20 kg/y homegrown eggs. Assume the feed for the chickens is 50% homegrown; chickens drink water from outdoor pans at 50% air moisture.
Drinking water	[5.9][a]	Drinks 440 L/y of well water at average concentration of California groundwater
Drinking wine, including OBT	0.88	Drinks one liter bottle of Livermore Valley wine each week
Immersion	0.15	Swims in the LLNL pool 100 hours per year
All sources	27[a]	

a Drinking water dose is not included in a realistic estimate of the dose impacts of LLNL releases of tritium to the atmosphere because Livermore drinking water is unaffected by LLNL operations. Nevertheless, inclusion of a drinking water dose demonstrates that the dose attributable to LLNL is not much different than background, especially given that all doses shown include background.

radioactive material to air from DOE facilities. Using EPA-mandated computer models and actual LLNL meteorology appropriate to the two sites, the potential doses to the LLNL SW-MEI members of the public from operations in 2003 were:

- Livermore site: 0.44 µSv (0.044 mrem)—55% from point-source emissions, 45% from diffuse-source emissions. The point source emissions include gaseous tritium modeled as tritiated water vapor for compliance purposes, as directed by EPA Region IX.
- Site 300: 0.17 µSv (0.017 mrem)—98% from explosive experiments, which are classified as point-sources, 2% from diffuse-source emissions.

The major radionuclides accounting for the doses were tritium at the Livermore site and the three isotopes in depleted uranium (uranium-234, uranium-235, and uranium-238) at Site 300. The only significant exposure pathway was release of radioactive material to air, leading to doses by inhalation and ingestion.

The collective EDE or population dose attributable to LLNL operations in 2003 was estimated to be 0.016 person-Sv (1.6 person-rem) for the Livermore site and 0.032 person-Sv (3.2 person-rem) for Site 300. These doses include potentially exposed populations of 7.1 million people for the Livermore site and 6.2 million people for Site 300 living within a distance of 80 km from the site centers.

The doses to the SW-MEI members of the public resulting from Livermore site and Site 300 operations in 2003 were below one-half of one percent (0.5%) of the federal standard and were nearly 5000 times smaller than the dose from background radiation. The population doses from LLNL operations in 2003 were more than 400,000 times smaller than those caused by natural radioactivity in the environment.

Potential doses to aquatic and terrestrial biota from LLNL operations were assessed and found to be well below DOE allowable dose limits.

In conclusion, potential radiological doses from LLNL operations were well below regulatory standards and were very small compared with doses normally received by these populations from natural background radiation sources, even though highly conservative assumptions were used in the determinations of LLNL doses. These maximum credible doses to the public indicate that LLNL's use of radionuclides had no significant impact on public health during 2003.

7

Groundwater Investigation and Remediation

Richard G. Blake
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During 2003, groundwater investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. The sites are similar in that the contamination is, for the most part, confined to the site. The sites differ in that Site 300, with an area of 30.3 km^2 (11.8 mi^2), is much larger than the Livermore site and has been divided into eight operable units based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.08 km^2 (1.3 m^2) is effectively one operable unit.

Livermore Site Ground Water Project

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s when the site was the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons, metals, and tritium to the groundwater and unsaturated sediment in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency National Priorities List in 1987.

An analysis of all environmental media showed that groundwater and unsaturated sediment are the only media that require remediation (Thorpe et al. 1990). The identified compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards, or maximum contaminant levels (MCLs), are trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene, chloroform, 1, 2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, trichlorotrifluoroethane (Freon 113), trichlorofluoromethane (Freon 11), and carbon tetrachloride.

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley groundwater system is a sequence of semiconfined aquifers in which groundwater moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, groundwater has historically flowed south into the Sunol Valley Groundwater Basin.

The largest quantities of groundwater are pumped from the central and western portions of the Livermore Valley, where the valley fill sediment is thickest. These sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing formation within the valley.

Hydrogeology of the Livermore Site

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on the dominant particle type. Groundwater flow beneath the site is primarily in alluvial sand bodies, gravel lenses, and channels, bounded by the less permeable clay and silt. The alluvial sediments have been mapped into nine hydrostratigraphic units (HSUs) beneath the Livermore site, using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper member of the Livermore Formation (see **Figure 7-1**). HSUs 1B, 2, 3A, 3B, 4, and 5 contain contaminants that are primarily solvents (Blake et al. 1995; Hoffman et al. 1998).

Remediation Activities and Monitoring Results

In 2003, the Livermore site Ground Water Project (GWP) treated more than 1060 million liters of groundwater and removed approximately 90 kg of VOCs (**Table 7-1**). The GWP also brought new treatment facilities on line, installed wells, conducted hydraulic tests, developed groundwater models, published required documents, and maintained close contact with regulatory agencies and the community.

LLNL removes contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site through a system of 28 treatment facilities located throughout the 6 HSUs containing contaminants of concern. Extraction wells are used to extract groundwater for each facility, which is then treated to remove VOCs. Treatment usually consists of removing VOCs with an air-stripping system, after which any VOCs present in the stripper's effluent air are removed with granular activated carbon filters.

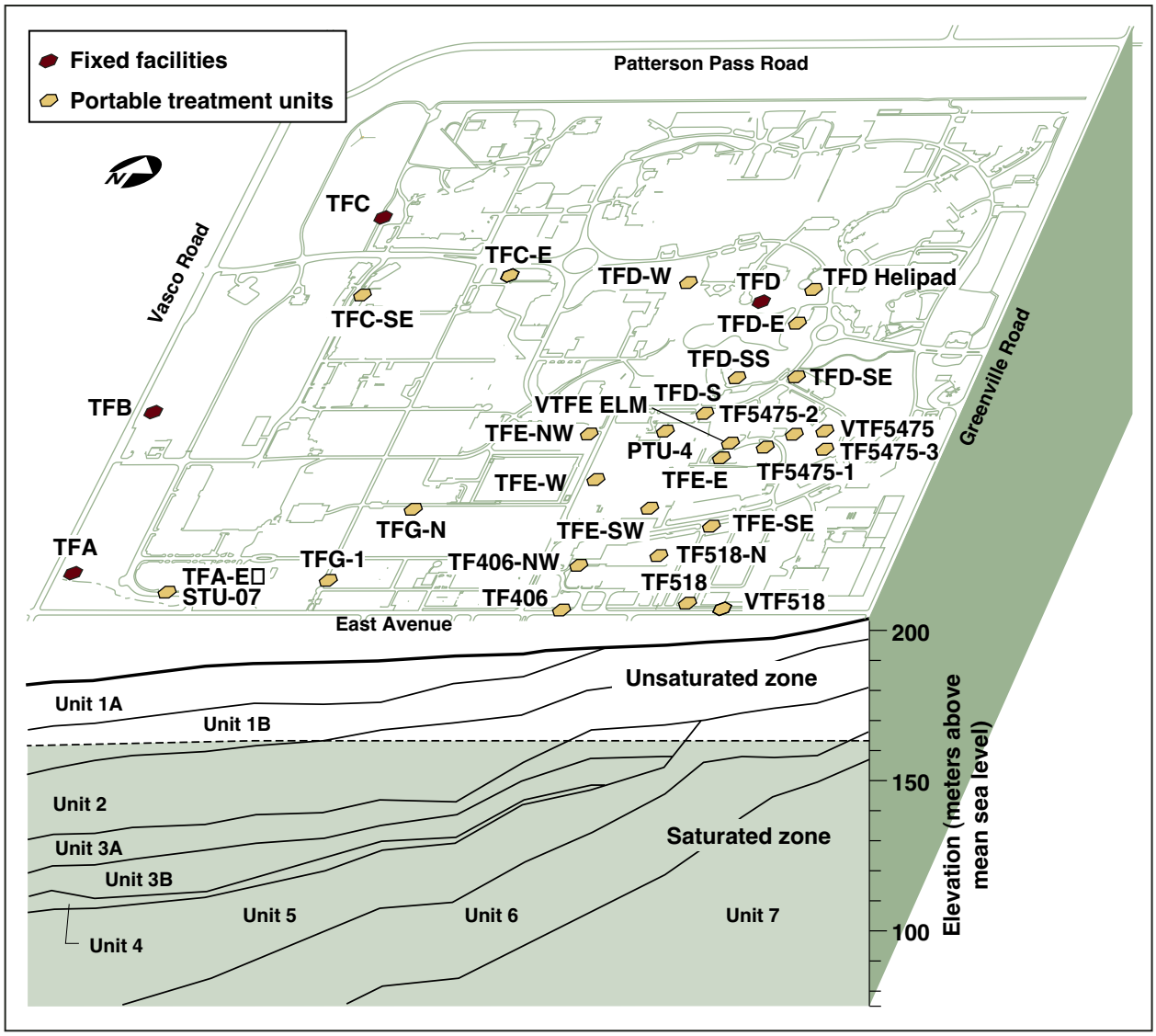

Figure 7-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment facilities

Of the 28 treatment facilities in operation in 2003, 26 are groundwater treatment facilities and 2 are a vapor treatment facilities (VTFs). A total of 78 groundwater extraction wells and 3 soil vapor extraction wells operated in 2003. Since operations began in 1989, approximately 8471 million liters of groundwater and approximately 1.4 billion m^3 of vapor have been treated, and more than 1554 kg of VOCs have been removed. **Table 7-1** shows both the 2003 totals and the cumulative totals of groundwater and soil vapor treated at the facilities and the estimated VOCs removed from the subsurface. A graph of VOC mass removal at the Livermore site since 1989 is presented in **Figure 7-2**.

Table 7-1. Volatile organic compounds removed from groundwater and soil at the Livermore site

Groundwater treatment facility[a]	Startup date	2003		Cumulative total	
		Water treated (ML)[b]	VOCs removed (kg)	Water treated (ML)	VOCs removed (kg)
TFA	9/89	371.7	8.4	4030	163
TFB	10/90	124.9	5.0	912	59.2
TFC	10/93	121.1	6.6	717	60.5
TFD	9/94	265.0	53.6	1770	553
TFE	11/96	98.4	12.8	642	151
TFG	4/96	21.2	1.2	92.6	4.9
TF406	8/96	51.5	1.4	263	9.0
TF518	1/98	5.3	0.5	42.4	4.8
TF5475	9/98	0.38	0.5	2.65	5.4
Total[c]		1060	90	8471	1011
Vapor treatment facility		**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**
VTF518	9/95	0	0	425	153
VTF5475	1/99	242	33.9	899	340
VTFE ELM	9/03	93.1	50.4	93.1	50.4
Total[c]		335	84	1418	543

a Includes fixed and portable units

b ML = million liters

c Totals rounded to nearest whole number

GWP activities, such as the types of treatment used at the different facilities and total VOC isoconcentration maps for each HSUs, are further described in the *Ground Water Project 2003 Annual Report* (Karachewski et al. 2004).

In 2003, concentrations continued to decrease in most Livermore site VOC plumes. The decline in VOC concentrations is primarily attributed to active remediation and reflects the 90 kg of VOCs removed by the groundwater extraction wells during 2003 (**Table 7-1**). Notable trends and results of VOC analyses of groundwater received from the fourth quarter 2002 to the third quarter 2003 are discussed below.

VOC concentrations on the western margin of the site either declined or remained unchanged during 2003, indicating continued effective hydraulic control of the boundary plumes in the Treatment Facility (TF) A, TFB, and TFC areas. VOC concentrations in the TFA, TFB, and TFC source areas remained unchanged as well. The offsite HSU 1B VOC plumes were below MCLs for all VOCs of concern except at one

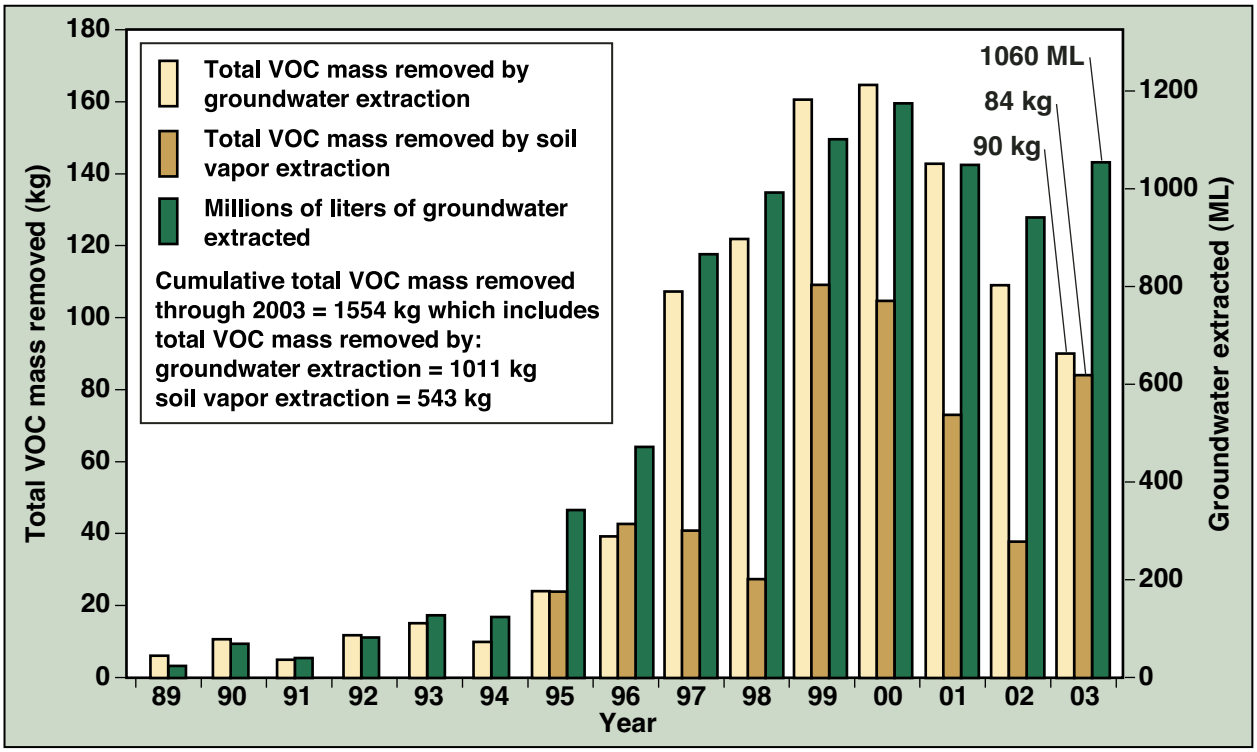

Figure 7-2. Total VOC mass removed and groundwater extracted from the subsurface of the Livermore site, 1989–2003

well where it was slightly above the MCL. PCE was detected at 5.4 µg/L at well W-506 in October 2003. The entire off-site and on-site TFA HSU 2 plume was below 50 µg/L total VOCs for the first time. All offsite TFA HSU 3A wells remained below MCLs for all VOCs of concern.

VOC concentrations in a mobile HSU 2 plume located in the western TFE area continued to decline in 2003. The 100 µg/L total VOC contour within the plume shrank 168 meters toward TFE West extraction well W-305, and total VOCs in well SIP-331-001 in the south-central part of the site declined from 101 µg/L in 2002 to 80 µg/L in 2003. Concentrations further downgradient to the west increased slightly, probably in response to activation of TFG North extraction well W-1807, located at the leading edge of the plume. Total VOC concentrations in the Old Salvage Yard in the southeastern part of the site, also known as the TFE Hotspot source area, remained elevated in 2003 (e.g., 1584 µg/L total VOCs at SIP-ETS-601). Source area cleanup at the TFE Hotspot source area is scheduled to begin in 2005.

HSU 3A total VOC concentrations continued to decline in the TF5475 area in 2003 due to a combination of soil vapor extraction at VTF5475 and regional dewatering of HSU 3A. VOCs also declined in the east-central TFD area in response to pumping at

TFD Southshore. TCE concentrations in well W-361 declined from 1000 µg/L in 2002 to 140 µg/L in 2003. Elsewhere in HSU 3A, concentrations remained largely unchanged during 2003.

In HSU 3B, a significant TCE concentration increase observed near TFD South suggests that VOCs within HSU 3B may be migrating out of the TFD Southeast area toward the TFD South area. TCE in well W-1511 increased from 62 µg/L in 2002 to 750 µg/L in 2003. Hydraulic containment of the HSU 3B source area will be addressed as part of 2004 milestones. Elsewhere in HSU 3B, VOC concentrations remained largely unchanged during 2003.

A significant total VOC concentration increase was also observed in HSU 4 at the TFD Helipad area, where concentrations in well W-1253 increased from 212 µg/L in 2002 to 3403 µg/L in 2003. Hydraulic containment of the HSU 4 source area at the TFD Helipad area will be addressed as part of the 2004 milestones. Elsewhere, concentrations in HSU 4 remained largely unchanged during 2003.

VOC concentrations in HSU 5 continue to slowly decline in the TFE East area due to pumping at extraction well W-566. Total VOC concentrations at downgradient well W-1210 decreased from 56 µg/L in 2002 to 47 µg/L in 2003. VOC concentrations on DOE property administered by Sandia National Laboratories south of East Avenue remained low during 2003, suggesting that the Treatment Facility 406 South facility proposed for 2006 may not be needed to achieve timely cleanup. The highest TCE concentrations were observed in well W-509, which declined from 20 µg/L in 2002 to 15 µg/L in 2003. HSU 5 VOC concentrations in other areas of the Livermore site remained largely unchanged during 2003.

During 2003, tritium activities in groundwater from all wells in the TF5475 area remained below the 741 Bq/L (20,000 pCi/L) MCL and continued to decrease by natural decay. Similarly, tritium activities in the Building 292 area declined below the MCL in 2003.

Groundwater Flow and Transport Modeling

Flow and contaminant transport models are used at the Livermore site to optimize the design and operation of remediation systems; to support ongoing subsurface characterization activities; and to improve our ability to forecast, monitor, and interpret the progress of the remediation program. In 2003, LLNL continued development of the three-dimensional (3-D) basin-scale groundwater flow and transport model initiated in 2002. The model was updated by incorporating remediation system improvements and hydrogeologic information from new wells. LLNL is currently improving the calibration of the 3-D model flow field to simulate the extensive extraction well field and the resultant dewatering observed on the eastern portion of the site. In parallel with the basin-scale model, LLNL developed several local-scale models to evaluate the effectiveness of potential groundwater injection wells to mitigate dewatering, as well as their long-term effect on the remediation system.

In addition to groundwater flow and transport models, LLNL also developed semi-analytical and numerical modeling tools to simulate dual extraction and SVE for remediation of source areas. LLNL utilized these quantitative tools in the design, operation, and performance evaluation of the TFE ELM, Trailer 5475, and TFD Helipad source areas. The semi-analytical models were initially calibrated with the data obtained from SVE tests conducted at these source areas. The models were then used to select extraction well locations and treatment facility design parameters such as optimal vapor extraction flow rates. Currently, LLNL is refining source area remedial modeling capabilities and developing approaches to integrate them with the regional-scale models for determining realistic estimates of cleanup time for the Livermore site.

Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA site in 1990, when it was placed on the National Priorities List. The CERCLA environmental restoration operable units (OUs) are shown in **Figure 7-3**. All characterized contaminant release sites have been assigned to one of eight OUs based on the nature, extent, and sources of contamination, and topographic and hydrologic considerations. The major contaminants of concern for each OU are listed in **Table 7-2**. Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). Key milestone and deliverable due dates for 2003 are listed in **Table 7-3**. All milestone and deliverable due dates were met during 2003.

Geology of Site 300

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 7-4**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semi-lithified sediments, mainly of continental origin
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks)

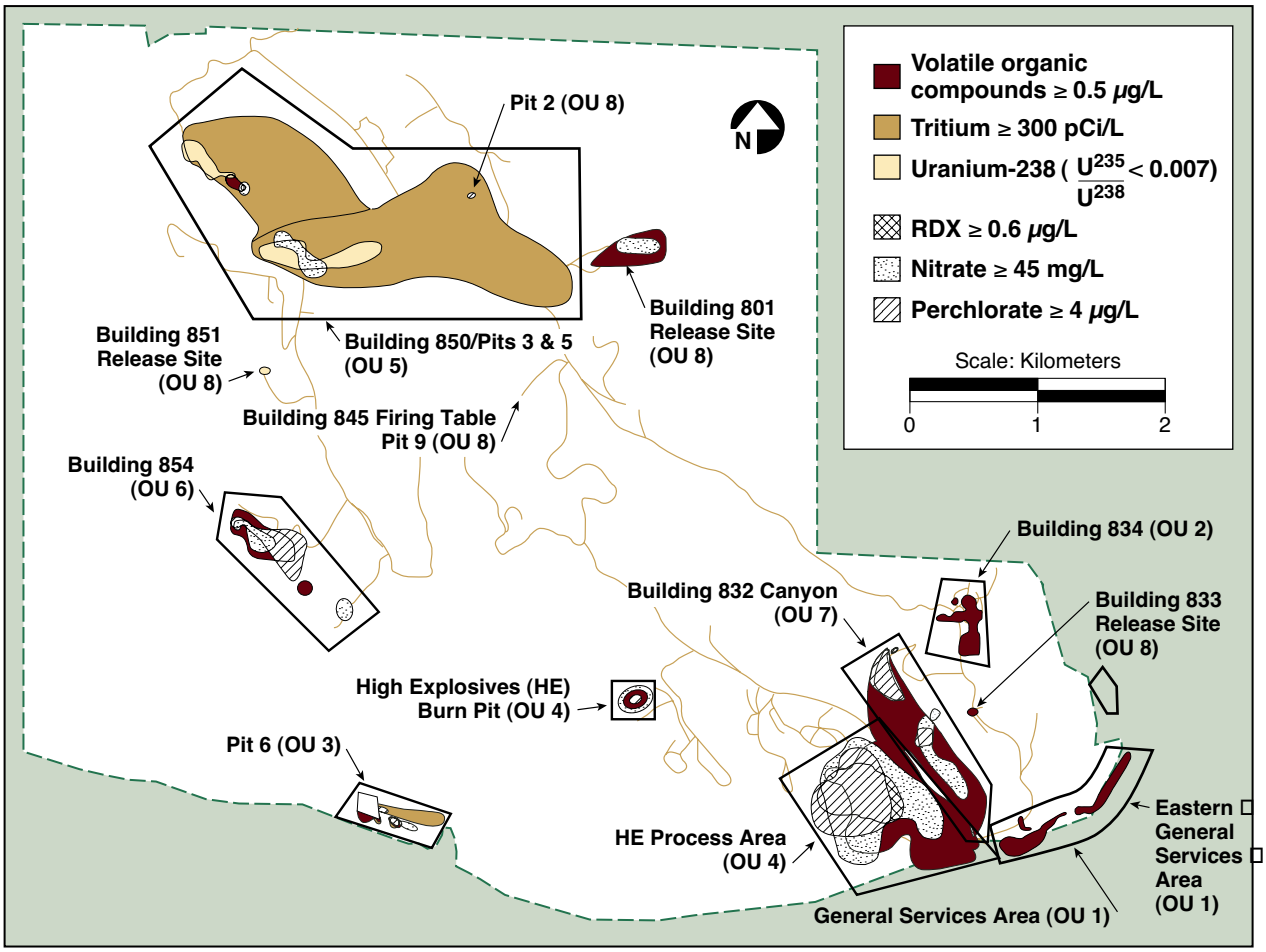

Figure 7-3. Environmental restoration operable units and contaminants of concern

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath Site 300. It is the principal hydrologic unit within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the High Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble-bearing terrace gravel derived from sources to the south, with lenses and local coverings of sandy silt and silty clay.

Table 7-2. Major contaminants of concern found in soil, rock, and groundwater at Site 300

Operable Unit (OU)	Contaminant of concern[a]
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), organosilicate oil, nitrate
Pit 6 (OU3)	VOCs (primarily TCE), tritium, nitrate, perchlorate
High Explosives Process Area (OU4)	VOCs (primarily TCE), HE (primarily RDX), nitrate, perchlorate
Building 850/Pits 3 & 5 (OU5)	Tritium, depleted uranium, VOCs (primarily TCE), nitrate, perchlorate, metals, PCBs
Building 854 (OU6)	VOCs (primarily TCE), nitrate, perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), nitrate, perchlorate
Site-Wide Operable Unit (OU8)	VOCs (primarily TCE and Freon 113), nitrate, perchlorate, depleted uranium, tritium, metals, RDX, HMX

a See Acronyms and Abbreviations for list of acronyms.

Table 7-3. Calendar year 2003 deliverable and milestone dates for Site 300 environmental restoration activities[a]

Deliverable/Milestone[b]	Due Date
Construct B830-SRC groundwater and soil vapor extraction and treatment facility in the Building 832 Canyon OU	February 28, 2003
Building 854 Draft Interim Remedial Design report	July 1, 2003
Construct B817-SRC groundwater extraction and treatment facility in the HE Process Area OU	September 29, 2003
Install monitor wells for Building 812 and conduct surface soil sampling	September 30, 2003
Complete remedial investigation for the Pit 7 Complex	September 30, 2003
Building 854 Draft Final Interim Remedial Design report	November 14, 2003
Building 854 Final Interim Remedial Design report	December 15, 2003

a Deliverables and milestones are outlined in the Site 300 Federal Facility Agreement and other agreements. See Chapter 2.

b See Acronyms and Abbreviations for list of acronyms.

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, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

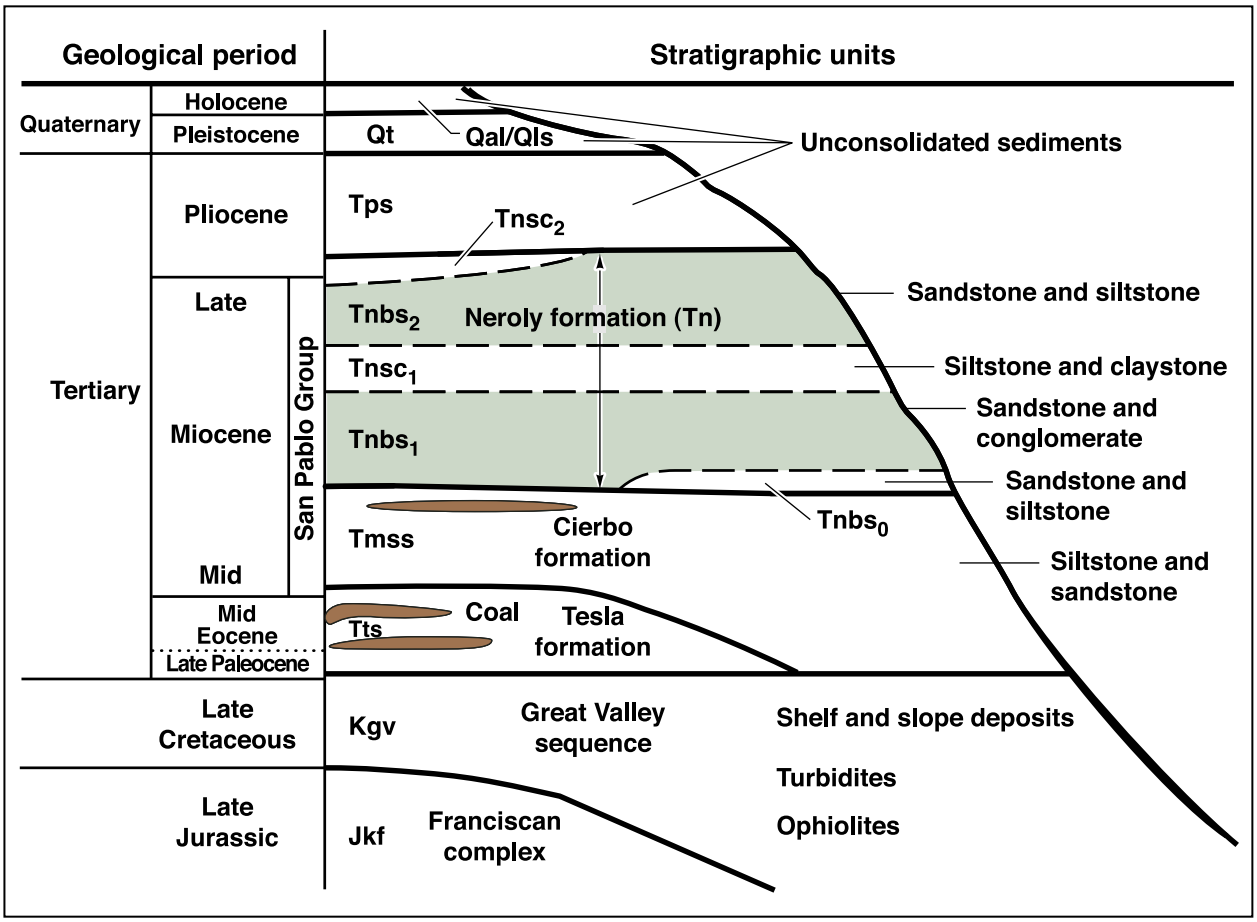

Figure 7-4. Site 300 stratigraphy

Hydrogeology of Site 300

Site 300 is semiarid, with an average annual rainfall of 27 cm. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones (see **Figure 7-4**). Groundwater primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation (Tmss). Saturated conditions also exist in two units that occur at the base of the Neroly Formation in the Building 854 and Pits 3 and 5 areas, respectively ($Tnsc_0$ and $Tnbs_0$). Groundwater can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season.

Some groundwater is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Building 833 and Building 834 areas and in

the High Explosives Process Area. An extensive perched water-bearing zone also occurs in $Tnbs_0$ sandstones in the northwestern portion of the East and West Firing Area. Fine-grained siltstone and claystone interbeds in $Tnbs_1$ and Tmss act as aquitards, confining layers, or perching horizons. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the groundwater flow occurs in fractures as well as in pores. Bedrock-hosted groundwater is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. **Figure 7-5** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which principally occurs in the Neroly lower blue sandstone aquifer ($Tnbs_1$) and $Tnbs_0$.

Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched waterbearing zones in the Building 832, Building 834, Building 854, and Building 829/High Explosives Burn Pit areas. Low rainfall and high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

Groundwater flow in the bedrock follows the inclination, or dip, of the rock layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock generally dips east-northeast. South of the anticline, bedrock dips south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 and Building 854 areas, and the southern part of the East Firing Area. The Tmss unit is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas. The thickness of the Cierbo Formation is not well known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. The continuity of saturation in the Tmss between the north-west and southeast areas of Site 300 is undetermined. Groundwater in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, groundwater is typically perched, discontinuous, and ephemeral. The exception to this condition exists in the High Explosives Process Area, where the extent of saturation in Tps sediments is significant. Groundwater in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300 but is perennially saturated only in the Corral Hollow Creek stream channel, in Doall Ravine, and in southern Elk Ravine in the vicinity of Building 812. Qal in the Pits 3 and 5 area is only saturated during rainy seasons and for extended periods of higher than normal rainfall. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, in the GSA, and in the Building 832 Canyon area; some of these groundwater occurrences are ephemeral. Small quantities of groundwater are present in some local landslide (Qls) deposits.

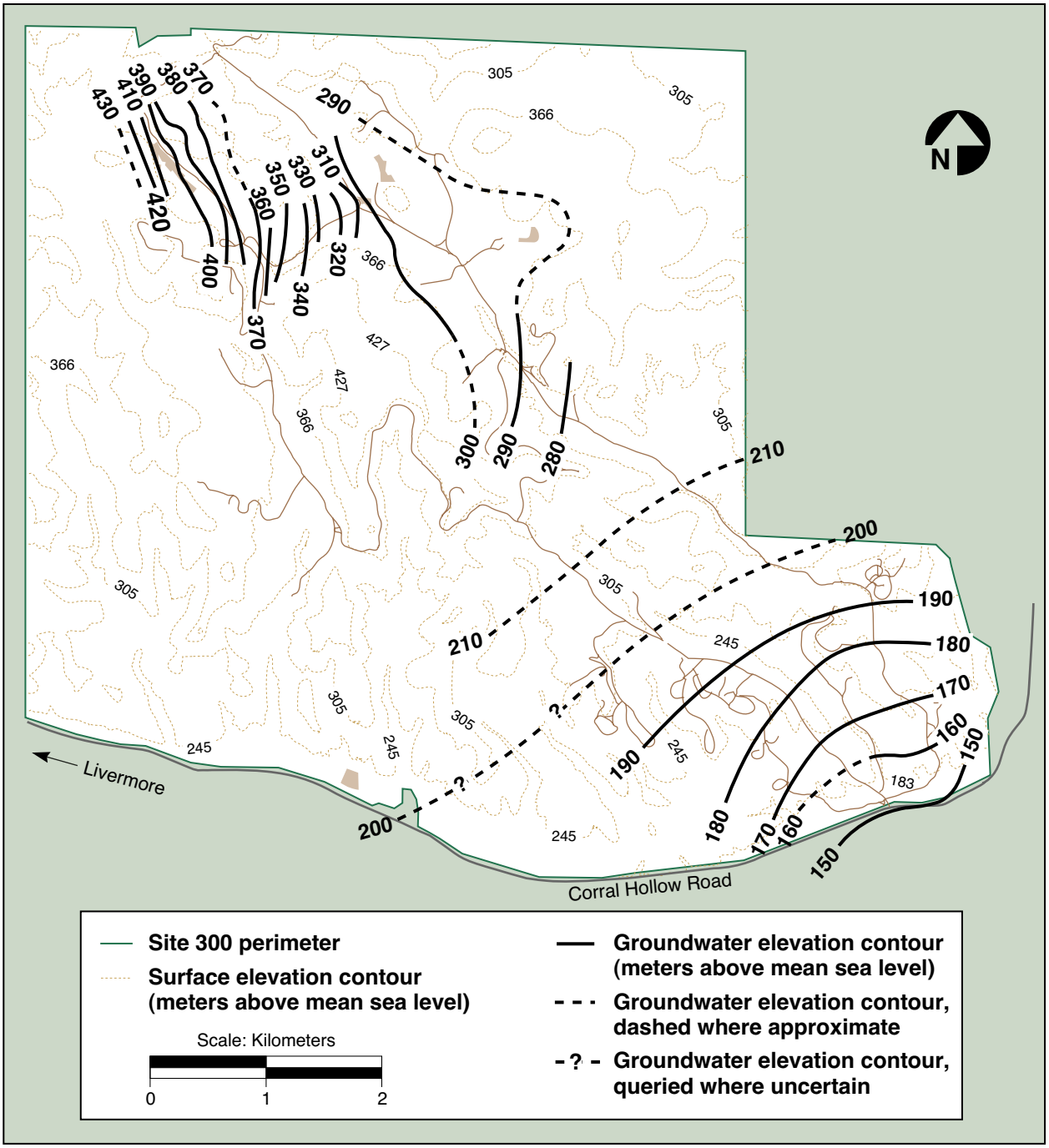

Figure 7-5. Approximate groundwater elevations in the principal continuous water-bearing zone at Site 300

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediments (Qal, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown in **Figure 7-3**.

Remediation Activities and Monitoring Results

This section presents a summary of monitoring and remediation results for contaminant release sites at Site 300. Detailed monitoring and remediation results for the central GSA, Building 834, High Explosives Process Area, Building 850, Building 854, Pit 6, Building 832 Canyon, and Site-Wide OUs are presented in the *2003 Annual Compliance Monitoring Program (CMP) Report* (Dibley et al. 2004) which is included as an attachment to this SAER report. The eastern GSA treatment system is not included in the CMP report; it operates under a separate National Pollution Elimination System permit and results are presented quarterly (Lamarre 2003a,b,c; Steenhoven 2004). The results of ongoing and planned investigations at the Pit 7 Complex, Building 865, Building 812, and Sandia Test Site are also not a part of the CMP report. Current information for each of these portions of Site 300 is presented at the end of this section.

At Site 300, there are three dedicated (non-potable) groundwater and two soil vapor extraction and treatment facilities at the eastern GSA, central GSA, and Building 834 areas. Due to treatment system modifications and construction activities, the Building 834 treatment facility did not operate during 2003. There are also 10 portable treatment facilities at Site 300, all of which operated during 2003. Thus, 13 treatment facilities that remove VOCs operated during 2003. Twenty-three wells that extract only groundwater, 8 wells that extract only soil vapor and 13 wells that extract both groundwater and soil vapor were pumped and fed into treatment systems during 2003. In 2003, the 23 wells that extract only groundwater and the 13 wells that extract both groundwater and soil vapor yielded about 108.9 million L of groundwater. During the year, the 13 wells that extract both vapor and groundwater and the 8 wells that extract only vapor removed 332,320 m^3 of vapor. In 2003, the Site 300 treatment facilities removed approximately 2.87 kg of VOCs. Since remediation efforts began in 1990, more than 977.2 million L of groundwater and approximately 4.26 million m^3 of vapor have been treated, yielding about 234 kg of removed VOCs. **Table 7-4** summarizes 2003 and cumulative totals of volumes and masses of contaminants removed from groundwater and soil vapor at each Site 300 OU.

The central GSA, eastern GSA, and B830-Distal South (B830-DISS) treatment facilities discharge to surface drainage courses. The B854-Proximal (B854-PRX) solar treatment unit/containerized wetland, B815-Distal (B815-DIS) aqueous phase granular activated carbon, and B830-Proximal North (B830-PRXN) granular activated carbon treatment systems discharge to an infiltration trench. The other seven treatment systems discharge to air by misting.

Table 7-4. Volatile organic compounds removed from groundwater and soil at Site 300

Operable Unit	Startup date	2003		Cumulative total	
		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
Eastern GSA	1991	89.3	0.20	895.9	6.39
Central GSA	1993	5.4	0.36	34.56	11.0
Building 834	1995	0	0	0	31.84
High Explosives Process Area	1999	8.4	0.17	18.16	0.26
Building 854	1999	2.8	0.60	15.05	6.74
Pit 6	1998	—[b]	—[b]	0.268	0.0014
Buildings 830 and 832	1999	2.94	0.23	13.12	0.67
Total		108.9	1.56	977.2	56.9
		Soil vapor treated ($10^3 m^3$)	VOCs removed (kg)	Soil vapor treated ($10^3 m^3$)	VOCs (kg)
Central GSA	1994	277.33	1.15	2265.00	67.31
Building 834	1998	0	0	1657.56	108.26
Building 832	1999	54.99	0.16	337.55	1.55
Total		332.32	1.31	4260.11	177.12

a ML = 1 million liters

b Groundwater treatment is not routine at Pit 6. A hydraulic pump test with a portable treatment unit for TCE removal was conducted there in 1998.

The eastern and central GSA contain maintenance and shop facilities and released contaminants to groundwater due to dry well and liquid storage activities. Groundwater influent TCE concentrations to the eastern GSA OU were reduced from 64 µg/L in January 1992 to 2.0 µg/L in December 2003. No longer do any off-site wells in the eastern GSA yield groundwater containing TCE concentrations in excess of the cleanup standard of 5 µg/L. LLNL estimates that 5 to 10 more years of groundwater extraction and treatment will be required to achieve and maintain groundwater VOC concentrations below the cleanup standard at the eastern GSA. TCE concentrations in shallow groundwater beneath the eastern GSA are shown on **Figure 7-6**.

TCE concentrations in the central GSA OU groundwater influent have been reduced from 9400 µg/L in 1993 to 49 µg/L in October 2003. From 1994 through the end of 2003, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 mg/L to 1.9 mg/L. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced. Total VOC concentrations in groundwater beneath the central GSA are shown on Figure 2.1-3 of the *2003 Annual CMP Report*.

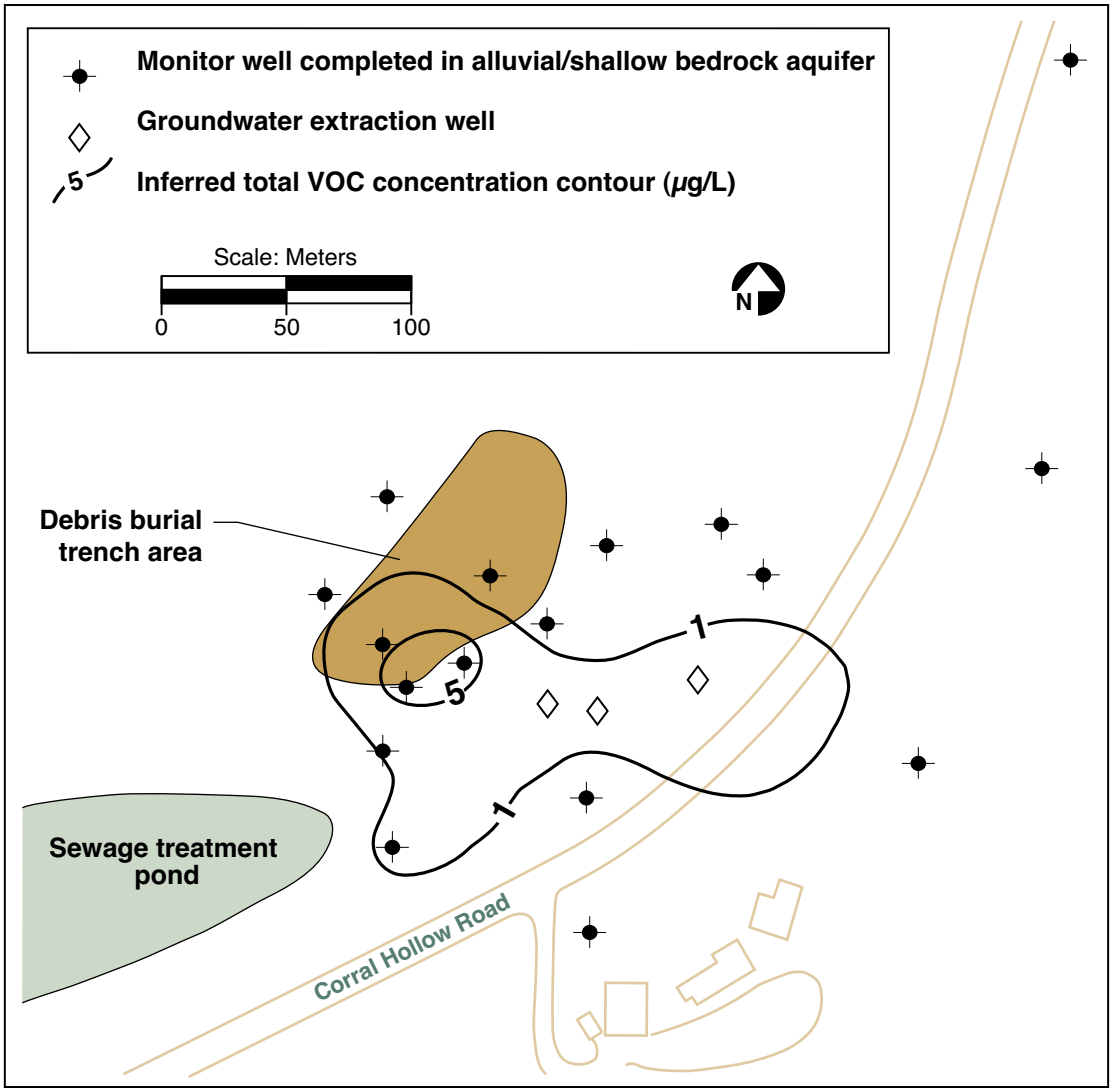

Figure 7-6. Total VOC concentrations in groundwater in the eastern GSA and vicinity (4th quarter 2003)

At Building 834, prototype weapons components were subjected to a variety of environmental stresses including heat and pressure. TCE was used as a heat-exchange fluid and was circulated in piping that leaked. The maximum 2003 total VOC concentration at Building 834 was 200,000 µg/L. Total VOC concentrations in groundwater beneath the Building 834 area are shown on Figure 2.2-3 of the *2003 Annual CMP Report.* Although the Building 834 extraction and treatment system did not operate during 2003 due to treatment facility modifications and construction activities, some VOC mass was destroyed by in situ bioremediation. This mass was not quantified. With the completion of treatment facility upgrades and construction, groundwater and soil vapor extraction and treatment at Building 834 will resume in 2004.

At the High Explosives Process Area OU, where high explosives are pressed and formed, LLNL proceeded to implement the next phase of the remedial strategy by completing construction and beginning operation of the B817-SRC facility. Three other groundwater extraction and treatment systems (B815-SRC, B815-PRX, and B815-DIS) are also operating to reduce contaminant mass in the High Explosives Process Area. Total VOC concentrations in groundwater beneath the High Explosives Process Area are shown on Figure 2.4-3 of the *2003 Annual CMP Report*. Maximum 2003 total VOC concentrations (49 µg/L) were detected in the $Tnbs_2$ aquifer. The total VOC concentrations in source area wells have been reduced by 20 to 40% since remediation began in 1999.

Building 850 is an explosives firing table. During 2003, the maximum detected tritium activity in groundwater at the Building 850 OU was 2880 Bq/L (77,700 pCi/L). Tritium activities in groundwater beneath the Building 850 OU are shown on Figure 2.5-3 of the *2003 Annual CMP Report*. Monitored natural attenuation (MNA) is the selected remedy for the remediation of tritium in groundwater emanating from the Building 850 area. MNA continues to be effective for tritium in that the extent of the 741 Bq/L (20,000 pCi/L) MCL contour continues to diminish and the highest tritium activities continue to be located immediately downgradient of the firing table. The maximum 2003 total uranium activity in groundwater that contains some depleted uranium was 0.426 Bq/L (11.5 pCi/L). Total uranium activity continues to be below the 0.74 Bq/L (20 pCi/L) State MCL.

The Building 854 OU is another site where weapons components were subjected to environmental stresses and where pipes containing TCE leaked. Two groundwater extraction and treatment systems (B854-SRC and B854-PRX) operate in the OU. The 2003 maximum total VOC concentration in groundwater is 200 µg/L, down from a historic maximum detected TCE concentration of 1290 µg/L. Total VOC concentrations in groundwater beneath the Building 850 OU are shown on Figure 2.6-3. of the *2003 Annual CMP Report*.

Pit 6 is a landfill that received waste from 1964 to 1973. The landfill was capped and closed under CERCLA in 1997. MNA is the selected remedy for the remediation of VOCs in groundwater emanating from Pit 6. The maximum 2003 groundwater TCE concentration and tritium activity was 5.5 µg/L. The maximum 2003 groundwater tritium activity was 68.5 Bq/L (1850 pCi/L). Total VOC concentrations and tritium activity in groundwater at Pit 6 are shown on Figures 2.3-3 and 2.3-4, respectively, of the *2003 Annual CMP Report*.

Building 832 Canyon OU facilities were used to test the stability of weapons components under a variety of environmental stresses. Contaminants were released from Buildings 830 and 832 through piping leaks and surface spills. Four groundwater extraction and treatment systems operate in the OU: B832-SRC, B830-SRC, B830-PRXN, and B830-DISS. B832-SRC and B830-SRC extract and treat groundwater and soil vapor. The other two facilities only treat groundwater. The maximum 2003 groundwater TCE concentration was 10,000 µg/L. This maximum concentration occurred in the $Tnsc_{1b}$ hydrostratigraphic unit. The maximum detected 2003 TCE concentration of 3200 µg/L was detected in the Qal hydrostratigraphic unit. Total

2003 VOC concentrations in the$Tnsc_{1b}$ and Qal hydrostratigraphic units at the Building 832 Canyon OU are shown on Figures 2.7-5 and 2.7-4, respectively of the *2003 Annual CMP Report*.

The Site 300 Site-Wide OU is composed of release sites at which no significant groundwater contamination and no unacceptable risk to human health or the environment is present. For this reason, a monitoring-only remedy was selected for these release sites, which include Building 801 Firing Table/Pit 8, Building 833, Building 845 Firing Table/Pit 9, Pit 2, and Building 851 Firing Table. The results of routine monitoring of these sites is included in Section 2.8 and Chapter 3 of the *2003 Annual CMP Report*. No new releases of contaminants from these sites were indicated by the 2003 analytical results.

The following sections describe the current status of investigations under way at three sites that are still under investigation and have not yet reached the Record of Decision for a final remedy to address environmental contamination: Pit 7 Complex, Building 865 and Building 812/Sandia Test Site.

Ongoing and Planned Investigations

Pit 7 Complex

The Pit 7 Complex is composed of four landfills (Pits 3, 4, 5, and 7), that received waste from explosives experiments conducted at Site 300 firing tables. Pits 3 and 5 have released tritium to groundwater. Pits 3, 5, and 7 have released depleted uranium to groundwater. The maximum tritium activity detected in groundwater in 2003 was 17,400 Bq/L (469,000 pCi/L). The maximum detected total uranium activity in groundwater that contained some depleted uranium was 4.55 Bq/L (122.9 pCi/L), 58.2% of this activity is due to added depleted uranium to the natural background uranium activity. Both the tritium and uranium maxima were detected in groundwater samples from $Tnbs_0$ bedrock. Perchlorate, TCE, and nitrate also occur in Pit 7 Complex groundwater at maximum detected concentrations of 14 µg/L, 4.3 µg/L, and 85 mg/L, respectively. **Figure 7-7** presents maps of tritium activities in groundwater in Qal alluvium and in $Tnbs_0$ bedrock.

LLNL completed the remedial investigation of the Pit 7 Complex prior to the September 30, 2003 milestone date (**Table 7-3**). Remedial investigation activities conducted during 2003 included a soil vapor tritium survey to evaluate the tritium activity remaining in the landfills and the adjacent unsaturated zone, and a water budget to define recharge, discharge, and contaminant mobilization mechanisms.

During 2003, LLNL began work on a Remedial Investigation/Feasibility Study for the Pit 7 Complex. The report will present details of the hydrogeology, nature and extent of contamination, and risk assessment and will specify remedial actions that can be applied to address the contamination.

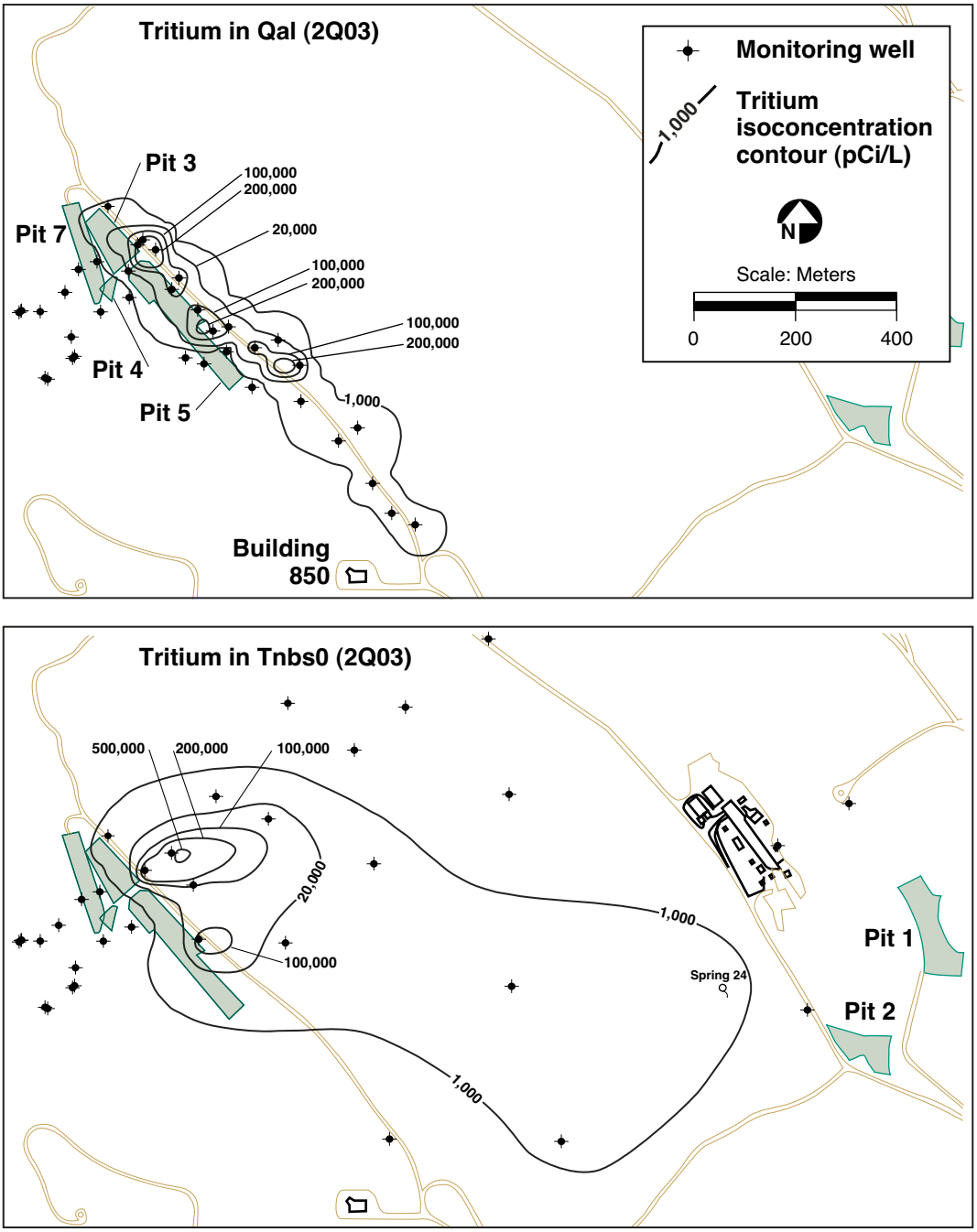

Figure 7-7. Tritium plume in Qal and $Tnbs_0$ (2nd quarter 2003)

Building 865

Building 865 is a former linear accelerator, the Advanced Testing Accelerator. Freon-113 was used as a de-greaser that was subsequently released to groundwater. The maximum Freon-113 concentration detected in groundwater during 2003 was 300 μg/L. The federal and state MCL for Freon-113 in drinking water is 1200 μg/L.

During 2003, LLNL installed five monitoring wells as a part of the remedial investigation of Building 865. LLNL will complete a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 865. This report is currently scheduled for submission to the regulatory agencies by September 30, 2006.

Building 812/Sandia Test Site

Building 812 is an explosives test firing table. A remedial investigation is in process. During 2003, a maximum detected groundwater activity of total uranium, in which some of the uranium was due to addition of depleted uranium, was 1.13 Bq/L (30.5 pCi/L). **Table 7-3** lists a milestone date of September 30, 2003 to complete monitor well installation and surface soil sampling at Builing 812. To meet this milestone, during 2003, 13 monitoring wells were completed at Building 812 and 40 surface samples were collected and submitted for uranium and thorium isotope and metals analyses. LLNL will complete a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 812. This report is currently scheduled for submission to the regulatory agencies by September 30, 2005

The Sandia Test Site was used in the past for several open air explosives experiments. No characterization activities have yet been conducted at the Sandia Test Site. LLNL will complete a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating at the site. This report is currently scheduled for submission to the regulatory agencies by September 30, 2006.

QA 8

Quality Assurance

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Donald H. MacQueen

Introduction

Quality assurance (QA) is a system of activities and processes put in place to ensure that products or services meet or exceed customer specifications. Quality control (QC) consists of activities used to verify that deliverables are of acceptable quality and meet criteria established in the quality planning process. Lawrence Livermore National Laboratory conducted environmental monitoring activities during 2003 in accordance with the Environmental Protection Department Quality Assurance Management Plan (Revision 4), which is based on DOE Order 414.1A. This order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality in DOE programs using 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 in order to maximize effectiveness and efficiency in resource use.

LLNL and commercial laboratories analyze environmental monitoring samples using U.S. Environmental Protection Agency (EPA) standard methods when available. When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. LLNL uses only State of California-certified laboratories to analyze its environmental monitoring samples. In addition, LLNL requires all analytical laboratories to maintain adequate QA programs and documentation of methods. The radiochemical methods used by LLNL laboratories are described in procedures created and maintained by the laboratory performing the analyses.

Quality Assurance Activities

Nonconformance reporting and tracking is a process used for ensuring that problems are identified, resolved, and prevented from recurring. EPD reports and tracks problems using Nonconformance Reports (NCRs) and Analytical Lab Problem Reporting Forms.

The LLNL Environmental Protection Department (EPD) generated 31 NCRs and 3 Analytical Lab Problem Reporting Forms related to environmental monitoring in 2003. Ten of the 31 NCRs generated in 2003 documented routine equipment maintenance. Of the remaining 24 problems reported, 9 were due to documentation, procedural, or sampling errors; 7 were due to problems with analytical laboratories; 7 were related to equipment malfunction; and 1 was related to sediment sampling locations that had been chronically difficult to sample (these sampling locations were eliminated based on this NCR, but will be reevaluated in the future as conditions change or new sampling methodology becomes available).

LLNL addresses internal documentation, training, and procedural errors by conducting formal and informal training. These errors generally do not result in lost samples, but may require extra work on the part of sampling and data management personnel to resolve or compensate for the errors.

LLNL addresses analytical laboratory problems with the appropriate laboratory as they arise. Many of the documented problems related to analytical laboratories concerned minor documentation or paperwork errors, which were corrected soon after they were identified. Other problems—such as missed holding times, late analytical results, and typographical errors on data reports—accounted for the remaining analytical laboratory issues. These problems were corrected by reanalysis, resampling, reissued reports, or corrected paperwork, and associated sample results were not affected.

QA staff also track and report planned environmental monitoring samples that are not collected. A summary of these lost samples appears in **Table 8-1**.

Table 8-1. Sampling completeness in 2003 for the Livermore site and Site 300

Environmental medium	Number of analyses planned	Number of analyses completed	Completeness (%)	Reason(s) for lost samples
Air particulate				
Radiological parameters (Livermore site)	1188	1161	98	No power at location (21), sampler malfunction (6)
Beryllium (Livermore site)	96	96	100	
Radiological parameters (Site 300)	728	722	99	No power at location (4), access to location denied (1), cable cut (1)
Beryllium (Site 300)	48	48	100	
Air tritium				
Livermore site	536	525	98	Total flow too low (9), flow meter malfunction (2)
Site 300	29	28	97	Flow meter malfunction (1)
Soil and Sediment				
Livermore site	42	42	100	
Site 300	30	30	100	
Arroyo sediment (Livermore site only)	43	43	100	
Vegetation and Foodstuffs				
Livermore site and vicinity	64	64	100	
Site 300	20	20	100	
Wine	25	25	100	

Table 8-1. Sampling completeness in 2003 for the Livermore site and Site 300 (continued)

Environmental medium	Number of analyses planned	Number of analyses completed	Completeness (%)	Reason(s) for lost samples
Thermoluminescent dosimeters (TLDs)				
Livermore site perimeter	76	72	95	TLD missing at pickup time (4)
Livermore Valley	100	94	94	TLD missing at pickup time (6)
Site 300	64	61	95	TLD missing at pickup time (3)
Rain[a]				
Livermore site	53	53	100	
Site 300	9	4	44	Insufficient rainfall to collect sample (5)
Storm water runoff[a]				
Livermore site	390	379	97	Location inaccessible due to construction (9), sample cancelled (2)
Site 300	226	0	0	Insufficient runoff
Drainage Retention Basin				
Field measurements	229	226	99	Measurements overlooked (3)
Samples	72	72	100	
Releases	72	72	100	
Groundwater				
Livermore site	298	296	99	Samples not scheduled (2)
Livermore Valley	25	23	92	Vendor did not provide requested samples (2)
Site 300				
Building 829 network	202	188	93	Well dry (14)
Elk Ravine	169	153	91	Well dry (15), sampling error (1)
Pit 1	432	432	100	
Pit 6	289	268	93	Well dry (20), sampling error (1)
Pit 7	429	429	100	
Off-site surveillance (annual)	70	70	100	
Off-site surveillance (quarterly)	136	129	95	Sampling error (7)
Well 20	38	37	97	Sampling error (1)

Table 8-1. Sampling completeness in 2003 for the Livermore site and Site 300 (continued)

Environmental medium	Number of analyses planned	Number of analyses completed	Completeness (%)	Reason(s) for lost samples
Livermore site wastewater				
B196	925	921	99	Power cut to sampler (2), sample not collected (2)
C196	326	324	99	Automatic sampler malfunction (2)
LWRP[b] effluent	48	48	100	
Digester sludge	80	80	100	
WDR 96-248				
Surface impoundment wastewater	56	54	96	pH values not reported (2)
Surface impoundment groundwater	160	160	100	
Sewage ponds wastewater	35	34	97	Analytical laboratory error (1)
Sewage ponds groundwater	80	80	100	
Miscellaneous aqueous samples				
Other surface water (Livermore Valley only)	58	58	100	
Cooling towers (Site 300 only)	24	24	100	

a Numbers for Livermore site runoff and Site 300 rain are for the three storms that were sampled. The goal is to sample four storms per year; however, there was insufficient rainfall during routine work hours to sample four storms during 2003.

b LWRP = Livermore Water Reclamation Plant

Analytical Laboratories

LLNL continued to operate under the Blanket Service Agreements (BSAs) put into place with seven analytical laboratories in March 1999. LLNL continues to work closely with these analytical laboratories to minimize the occurrence of problems.

Analytical Laboratory Intercomparison Studies

LLNL uses the results of intercomparison program data to identify and monitor trends in performance and to solicit corrective action responses for unacceptable results. If a laboratory performs unacceptably for a particular test in two consecutive performance evaluation studies, LLNL may choose to select another laboratory to perform the affected analyses until the original laboratory can demonstrate that the problem has been corrected. If an off-site laboratory continues to perform unacceptably or fails to prepare and implement acceptable corrective action responses, the LLNL Procurement Department will formally notify the laboratory of its unsatisfactory performance. If the problem persists, the off-site laboratory's BSA could be terminated. If an on-site laboratory continues to perform unacceptably, use of that laboratory could be suspended until the problem is corrected.

Two laboratories at Lawrence Livermore National Laboratory participated in the annual Environmental Monitoring Laboratory (EML) intercomparison studies program sponsored by the U.S. Department of Energy (DOE). The two LLNL laboratories are the Environmental Radiochemistry Environmental Monitoring Radiological Laboratory (EMRL) and the Hazards Control Department's Analytical Laboratory (HCAL).

The results of EMRL's participation in the 2003 EML studies are presented in **Table 8-2**. According to the results, 26 of 41 reported results were determined to be acceptable, 8 results were acceptable with warning, and 7 results were unacceptable, based on established control limits. Five of the unacceptable results were due to data entry errors and results were acceptable once the errors were corrected. The remaining two unacceptable results were due to differences between calibration samples and actual test samples. The root cause for the results acceptable with warning and unacceptable results were examined and procedures were put in place to prevent them from re-occurring.

The results of HCAL's participation in the 2003 EML studies (see **Table 8-3**) indicate that 6 of 10 sample results fell within the 3σ acceptance control limits, three results fell in the acceptable with warning range, and one result was unacceptable (high). The Gross Alpha as performed at the HCAL has a known positive bias because of differences between the calibration nuclide and the test nuclide.

EMRL participated in two DOE Mixed Analyte Performance Evaluation Program (MAPEP) studies in 2002. The results of these studies are presented in **Tables 8-4** and **8-5**. Nineteen of 20 analytes reported by EMRL in these studies fell within acceptable limits; the remaining value was acceptable with warning.

Although contract laboratories are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2003. See the following website for contract laboratory results: http://www.eml.doe.gov/QAP .

Table 8-2. EMRL results from the DOE EML Quality Assurance Program, 2003

Analyte	EML study	EMRL value	EML value	EMRL/ EML	Control limits[a,b]	Warning limits[a,b]	Performance[a,b]
Air filter (Bq/filter)							
Co-60	QAP 58	44.1	33.5	1.32	0.80 – 1.26	0.90 – 1.11	Not Acceptable
	QAP 59	60.0	55.1	1.09	0.80 – 1.26	0.90 – 1.11	Acceptable
Cs-137	QAP 58	136	99.7	1.36	0.80 – 1.32	0.90 – 1.17	Not Acceptable
	QAP 59	101	54.8	1.84	0.80 – 1.32	0.90 – 1.17	Not Acceptable
Gross alpha	QAP 58	1.15	1.17	0.983	0.73 – 1.43	0.84 – 1.21	Acceptable
	QAP 59	3.5	3.11	1.12	0.73 – 1.43	0.84 – 1.21	Acceptable
Gross beta	QAP 58	1.64	1.50	1.09	0.76 – 1.36	0.85 – 1.21	Acceptable
	QAP 59	4.04	3.89	1.04	0.76 – 1.36	0.85 – 1.21	Acceptable
Mn-54	QAP 58	61.1	43.8	1.40	0.80 – 1.35	0.90 – 1.19	Not Acceptable
	QAP 59	76.4	58.0	1.32	0.80 – 1.35	0.90 – 1.19	Warning
Pu-238	QAP 58	0.507	0.520	0.975	0.67 – 1.33	0.88 – 1.12	Acceptable
	QAP 59	0.249	0.229	1.09	0.67 – 1.33	0.88 – 1.12	Acceptable
Pu-239	QAP 58	0.319	0.330	0.967	0.73 – 1.26	0.88 – 1.12	Acceptable
	QAP 59	0.427	0.401	1.06	0.73 – 1.26	0.88 – 1.12	Acceptable
Soil (Bq/kg)							
Cs-137	QAP 58	1290	1450	0.89	0.80 – 1.25	0.90 – 1.16	Warning
	QAP 59	1520	1973	0.770	0.80 – 1.25	0.90 – 1.16	Not Acceptable
K-40	QAP 58	594	636	0.934	0.80 – 1.32	0.90 – 1.19	Acceptable
	QAP 59	409	488	0.838	0.80 – 1.32	0.90 – 1.19	Warning
Pu-238	QAP 58	0.891	21.9	0.041	0.59 – 2.88	0.87 – 1.49	Not Acceptable
	QAP 59	15.9	14.6	1.09	0.59 – 2.88	0.87 – 1.49	Acceptable
Pu-239	QAP 58	0.947	23.4	0.040	0.71 – 1.30	0.87 – 1.13	Not Acceptable
	QAP 59	36.1	30.4	1.19	0.71 – 1.30	0.87 – 1.13	Warning
Water (Bq/L)							
Am-241	QAP 58	2.26	2.13	1.06	0.79 – 1.41	0.90 – 1.19	Acceptable
Co-60	QAP 58	246	234	1.05	0.80 – 1.20	0.90 – 1.10	Acceptable
	QAP 59	508	513	0.990	0.80 – 1.20	0.90 – 1.10	Acceptable
Cs-134	QAP 58	24.6	30.5	0.807	0.80 – 1.30	0.90 – 1.14	Warning
	QAP 59	53.4	63.0	0.848	0.80 – 1.30	0.90 – 1.14	Warning
Cs-137	QAP 58	65.4	63.8	1.03	0.80 – 1.22	0.90 – 1.12	Acceptable
	QAP 59	84.5	50.3	1.05	0.80 – 1.22	0.90 – 1.12	Acceptable
Gross alpha	QAP 58	222	378	0.588	0.58 – 1.29	0.79 – 1.13	Warning
	QAP 59	610	622	0.981	0.58 – 1.29	0.79 – 1.13	Acceptable

Table 8-2. EMRL results from the DOE EML Quality Assurance Program, 2003(continued)

Analyte	EML study	EMRL value	EML value	EMRL/ EML	Control limits[a,b]	Warning limits[a,b]	Performance[a,b]
Gross beta	QAP 58	618	626	0.985	0.61 – 1.43	0.81 – 1.29	Acceptable
	QAP 59	1880	1948	0.965	0.61 – 1.43	0.81 – 1.29	Acceptable
H-3	QAP 58	395	390	1.01	0.78 – 2.45	0.90 – 1.32	Acceptable
	QAP 59	537	446	1.20	0.78 – 2.45	0.90 – 1.32	Acceptable
Pu-238	QAP 58	3.68	3.33	1.10	0.74 – 1.20	0.90 – 1.10	Warning
	QAP 59	2.25	2.07	1.09	0.74 – 1.20	0.90 – 1.10	Acceptable
Pu-239	QAP 58	4.26	3.92	1.09	0.79 – 1.20	0.90 – 1.10	Acceptable
	QAP 59	5.49	4.99	1.10	0.79 – 1.20	0.90 – 1.10	Acceptable
U-234	QAP 58	1.96	2.05	0.956	0.80 – 1.34	0.90 – 1.16	Acceptable
U-238	QAP 58	1.96	2.16	0.907	0.80 – 1.28	0.90 – 1.16	Acceptable

a Control and warning limits are established from historical QAP data and reported as the ratio of reported value to EML value. The criteria for acceptable performance is between the 15th and the 85th percentiles of the cumulative normalized distribution. The acceptable with warning criteria is between the 5th and the 15th percentiles and between the 85th and 95th percentiles. Values less than the 5th and greater than the 95th percentiles are not acceptable.

b The EML program was cancelled after study QAP 60 and control limits were not recalculated for QAP 59 or QAP 60. Control limits from the QAP 58 study were used to evaluate QAP 59 results.

Table 8-3. HCAL results from the DOE EML Quality Assurance Program, 2003

Analyte	EML study	HCAL value	EML value	HCAL/ EML	Control limits[a,b]	Warning limits[a,b]	Performance[a,b]
Air filter (Bq/filter)							
Gross alpha	QAP 58	1.62	1.17	1.38	0.73 – 1.43	0.84 – 1.21	Warning
	QAP 59	4.24	3.11	1.36	0.73 – 1.43	0.84 – 1.21	Warning
Gross beta	QAP 58	1.70	1.5	1.13	0.76 – 1.36	0.85 – 1.21	Acceptable
	QAP 59	4.23	3.89	1.09	N/A yet	N/A yet	Acceptable
Water (Bq/L)							
Gross Alpha	QAP 58	455	378	1.20	0.58 – 1.29	0.79 – 1.13	Warning
	QAP 59	469	446	1.05	0.58 – 1.29	0.79 – 1.13	Acceptable
Gross Beta	QAP 58	705	628	1.12	0.61 – 1.43	0.81 – 1.29	Acceptable
	QAP 59	857	622	1.38	0.61 – 1.43	0.81 – 1.29	Not Acceptable
Tritium	QAP 58	407	390	1.04	0.78 – 2.45	0.90 – 1.32	Acceptable
	QAP 59	2039	1948	1.05	N/A yet	N/A yet	Acceptable

a Control and warning limits are established from historical QAP data and reported as the ratio of reported value to EML value. The criteria for acceptable performance is between the 15th and the 85th percentiles of the cumulative normalized distribution. The acceptable with warning criteria is between the 5th and the 15th percentiles and between the 85th and 95th percentiles. Values less than the 5th and greater than the 95th percentiles are not acceptable.

b The EML program was cancelled after study QAP 60 and control limits were not recalculated for QAP 59 or AQP 60. Control limits from the QAP 58 study were used to evaluate QAP 59 results.

Table 8-4. EMRL performance in the MAPEP-02-W10 Intercomparison Program for Water

Analyte	EMRL value	Units	Reference value	Bias (%)	Acceptance range	Performance[a]
Americium-241	0.543	Bq/L	0.578	–6.1	0.40 –.075	Acceptable
Cesium-134	355	Bq/L	421	–15.7	295 – 547	Acceptable
Cesium-137	317	Bq/L	329	–3.6	230 – 428	Acceptable
Cobalt-57	57.1	Bq/L	57	0.2	39.9 – 74.1	Acceptable
Cobalt-60	39.1	Bq/L	38.2	2.4	26.7 – 49.7	Acceptable
Manganese-54	35.3	Bq/L	32.9	7.3	23.0 – 42.8	Acceptable
Plutonium-238	0.791	Bq/L	0.828	–4.5	0.58 – 1.08	Acceptable
Plutonium-239/240	0.0105	Bq/L	—	—	—	Acceptable
Uranium-234/233	1.36	Bq/L	1.54	–11.7	1.08 – 2.00	Acceptable
Uranium-238	1.38	Bq/L	1.6	–13.8	1.12 – 2.08	Acceptable
Zinc-65	555	Bq/L	516	7.6	361 – 671	Acceptable

a Acceptable results have bias ≤20%. Results acceptable with warning have basis >20% and bias ≤30%. Results with basis >30% are not acceptable..

Table 8-5. EMRL performance in the MAPEP-03-S10 Intercomparison Program for Soil

Analyte	EMRL value	Units	Reference value	Bias (%)	Acceptance range	Performance[a]
Cesium-134	188	Bq/kg	238	-21.0	167 – 309	Warning
Cesium-137	812	Bq/kg	832	-2.4	582 – 1080	Acceptable
Cobalt-57	541	Bq/kg	530	2.1	391 – 689	Acceptable
Cobalt-60	424	Bq/kg	420	1.0	294 – 546	Acceptable
Manganese-54	145	Bq/kg	137	5.8	95.9 – 178	Acceptable
Plutonium-238	65.2	Bq/kg	66.9	-2.5	46.8 – 87.0	Acceptable
Plutonium-239/240	50.4	Bq/kg	52.7	-4.4	36.9 – 68.5	Acceptable
Potassium-40	725	Bq/kg	652	11.2	456 – 848	Acceptable
Zinc-65	562	Bq/kg	490	14.7	343 – 637	Acceptable

a Acceptable results have bias ≤20%. Results acceptable with warning have basis >20% and bias ≤30%. Results with basis >30% are not acceptable.

Duplicate Analyses

Duplicate or collocated samples are distinct samples of the same matrix collected as closely to the same point in space and time as possible. Collocated samples processed and analyzed by the same laboratory provide intralaboratory information about the precision of the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples processed and analyzed by different laboratories provide interlaboratory information about the precision of the entire measurement system (U.S. EPA 1987). Collocated samples may also be used to identify errors such as mislabeled samples or data entry errors.

Tables 8-6, **8-7**, and **8-8** present statistical data for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 8-6** and **8-7** are based on data pairs in which both values are detections (see "Data Presentation"). **Table 8-8** is based on data pairs in which either or both values are nondetections.

Precision is measured by the percent relative standard deviation (%RSD); see the EPA's Data Quality Objectives for Remedial Response Activities: Development Process, Section 4.6 (U.S. EPA 1987). Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, lower values represent better precision. The results for %RSD given in **Table 8-6** are the 75th percentile of the individual precision values.

Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with a slope equal to 1 and an intercept equal to 0, as illustrated in **Figure 8-1**. Allowing for normal analytical variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be greater than 0.8. These criteria apply to pairs in which both results are above the detection limit.

When there were more than eight data pairs with both results in each pair considered detections, precision and regression analyses were performed; those results are presented in **Table 8-6**. When there were eight or fewer data pairs with both results above the detection limit, the ratios of the individual duplicate sample pairs were averaged; the mean, minimum, and maximum ratios for selected analytes are given in **Table 8-7**. The mean ratio should be between 0.7 and 1.3. When either of the results in a pair is a nondetection, then the other result should be a nondetection or less than two times the detection limit. **Table 8-8** identifies the sample media and analytes for which at least one pair failed this criterion. Media and analytes with fewer than four pairs are omitted from the table.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times or different laboratory

aliquot sizes will have different amounts of variability. Different criteria are rarely, if ever, used with collocated sample pairs in LLNL environmental monitoring sampling. Different criteria are sometimes used in special studies when more than one regulatory agency is involved.

Table 8-6. Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the detection limit

Media	Analyte	N[a]	%RSD[b]	Slope	r^2[c]	Intercept
Air	Gross alpha (variability)[d]	84	57.8	0.42	0.28	2.33×10^{-5} (Bq/m^3)
	Gross beta (variability)[d]	95	20	0.767	0.58	5.37×10^{-5} (Bq/m^3)
	Beryllium	12	11.8	1.03	0.97	–0.252 (pg/m^3)
	Uranium-235 (outliers)[e]	12	5.56	0.409	0.52	7.92×10^{-8} (μg/m^3)
	Uranium-238 (outliers)[e]	12	5.39	0.413	0.53	1.08×10^{-5} (μg/m^3)
	Tritium	28	18.8	1.05	1	0.0344 (Bq/m^3)
Dose (TLD)	90-day radiological dose	30	2.89	0.949	0.91	0.72 (mrem)
Groundwater	Gross beta	21	14.1	0.953	0.97	0.00155 (Bq/L)
	Arsenic	17	4.29	1.02	1	–0.000278 (mg/L)
	Barium	12	3.73	1.06	1	–0.00203 (mg/L)
	Bromide	9	15.7	1.02	0.84	–0.0206 (mg/L)
	Chloride	9	0.344	1	1	0.386 (mg/L)
	Nitrate (as NO3)	18	3.2	0.972	0.98	1.72 (mg/L)
	Ortho-Phosphate	10	5.18	0.895	0.94	0.0132 (mg/L)
	Potassium	24	2.26	0.99	0.98	0.361 (mg/L)
	Sulfate	9	0.369	1	1	–0.0905 (mg/L)
	Tritium	13	5.83	0.99	1	–2.47 (Bq/L)
	Uranium-234+233	13	8.81	0.835	0.99	0.0092 (Bq/L)
	Uranium-235+236	10	23.3	0.907	0.95	0.000109 (Bq/L)
	Uranium-238	13	9.03	0.903	0.99	0.00532 (Bq/L)
Sewer	Gross alpha (variability)[d]	20	39.1	0.526	0.46	8.04×10^{-5} (Bq/mL)
	Gross beta	53	8.81	0.948	0.88	6.06×10^{-5} (Bq/mL)

a Number of collocated pairs included in regression analysis

b 75th percentile of percent relative standard deviations (%RSD) where %RSD $= \left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 - x_2|}{x_1 + x_2}$ and x_1 and x_2 are the reported concentrations of each routine-duplicate pair

c Coefficient of determination

d Outside acceptable range of slope or r^2 because of variability

e Outside acceptable range of slope or r^2 because of outliers

Table 8-7. Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the detection limit

Media	Analyte	N[a]	Mean ratio	Minimum ratio	Maximum ratio
Aqueous	Gross beta	1	0.97	0.97	0.97
Drinking water	Gross beta	1	2	2	2
Groundwater	Gross alpha	7	0.95	0.56	1.8
	Radium-226	6	1.3	0.78	2
	Thorium-228	1	0.45	0.45	0.45
Runoff (from rain)	Gross alpha	2	1.1	0.92	1.2
	Gross beta	3	0.89	0.81	0.94
	Tritium	1	1.1	1.1	1.1
Soil	Cesium-137	3	0.89	0.69	1.1
	Tritium	1	2	2	2
	Tritium	1	1.9	1.9	1.9
	Potassium-40	4	1	0.97	1.1
	Plutonium-238	2	1.4	1.3	1.6
	Plutonium-239+240	3	1	0.51	1.4
	Radium-226	4	1	0.98	1
	Radium-228	4	1	0.97	1
	Thorium-228	4	0.99	0.87	1
	Uranium-235	4	1.1	0.79	1.4
	Uranium-238	4	0.91	0.75	1.1
Vegetation	Tritium	4	1.3	0.94	2

a Number of collated pairs used in ratio calculations

Table 8-8. Quality assurance collocated 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
Air	Gross beta	6	7	86
	Plutonium-238	1	12	8.3
	Plutonium-239+240	2	24	8.3
	Tritium	2	22	9.1
Groundwater	Total organic halides	1	4	25
Sewer	Gross alpha	5	33	15
	Benzene	1	6	17

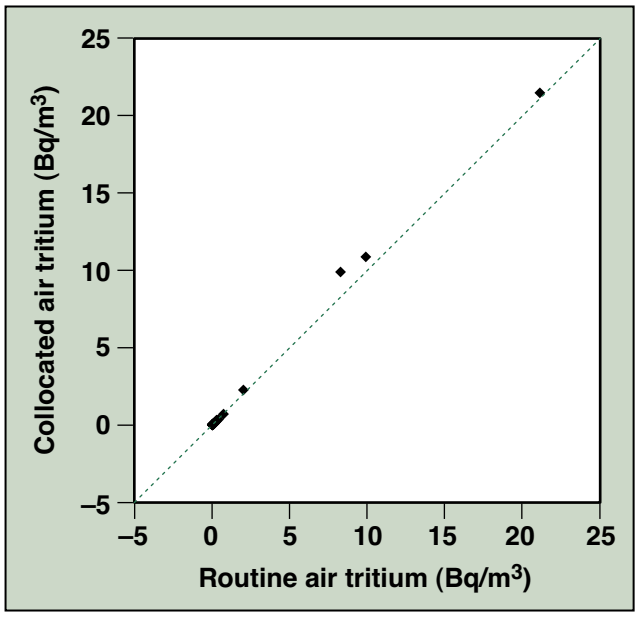

Figure 8-1. Example of data points that lie close to a line with slope equal to 1 and intercept equal to 0 using air tritium concentrations from collocated samples

Routine and collocated sample results show fairly good agreement: 90% of the pairs have a precision of 43% or better. Data sets not meeting our precision criteria fall into one of two categories. The first category, outliers, can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 22 data sets reported in **Table 8-6**, two did not meet the criterion for acceptability because of outliers. **Figure 8-2** illustrates a set of collocated pairs with one outlier.

The second category is data sets that do not meet the criterion for acceptability because results are highly variable. This tends to be typical of nondetections and measurements at extremely low concentrations, as illustrated in **Figure 8-3**. Low concentrations of radionuclides on particulates in air highlight this effect, because a small number or radionuclide-containing particles on an air filter can significantly affect results. Other causes of high variability are sampling and analytical methodology. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 22 data sets in **Table 8-7**, three show sufficient variability in results to make them fall outside the acceptable range.

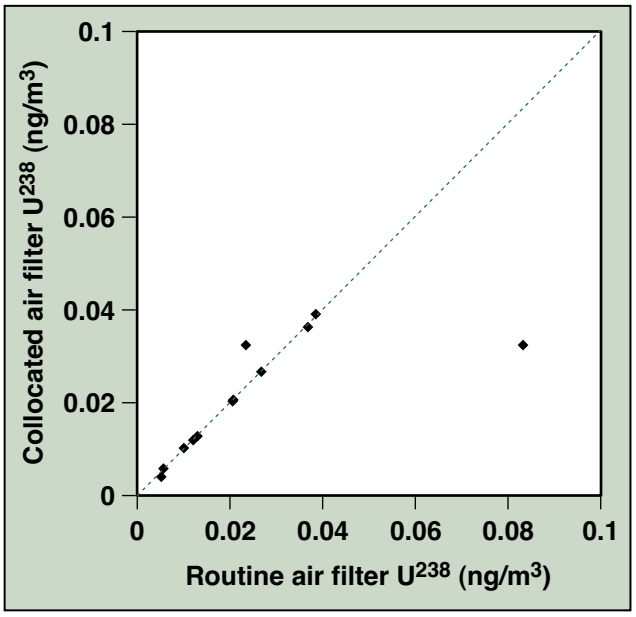

Figure 8-2. Example of data with an outlier using air filter uranium-238 concentrations from collocated samples

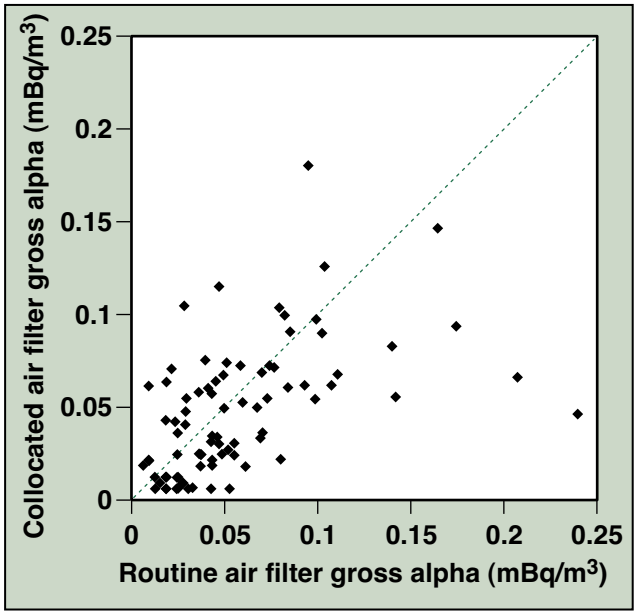

Figure 8-3. Example of variability using air filter gross alpha concentrations from collocated samples

Data Presentation

Most data tables provided in the report CD were created using computer scripts that retrieve data from the database, convert to SI units when necessary, calculate summary statistics for tables that include summary statistics, format data as appropriate, lay out the table into the desired rows and columns, and present a draft table. Final tables are included after review by the responsible analyst. Analytical laboratory data, and values calculated from analytical laboratory data, are normally displayed with two or at most three significant digits. Significant trailing zeros may be omitted.

Radiological Data

Most of the data tables display radiological data as a result plus-or-minus an associated 2σ uncertainty. The uncertainties are not used in summary statistic calculations. Any radiological result exhibiting a 2σ uncertainty greater than or equal to 100% of the result is considered to be a nondetection.

Some radiological results are derived from the number of sample counts minus the number of background counts inside the measurement apparatus. Therefore, a sample with a low concentration may have a negative value; such results are reported in the tables and used in the calculation of summary statistics and statistical comparisons.

Some data tables provide a limit-of-sensitivity value instead of an uncertainty when the radiological result is below the detection criterion. Such results are displayed with the limit-of-sensitivity value in parentheses.

Nonradiological Data

Nonradiological data reported by the analytical laboratory as being below the reporting limit are displayed in tables with a less-than symbol. The reporting limit values are used in the calculation of summary statistics, as explained below.

Statistical Comparisons and Summary Statistics

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. 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. Instead, these uses relate to the concept of practical significance and are based on professional judgment.

Summary statistics are calculated according to the *Environmental Monitoring Plan* (Woods 2002). The usual summary statistics are the median, which is a measure of central tendency, and interquartile range (IQR), which is a measure of dispersion (variability). However, some tables may present other measures, at the discretion of the responsible analyst.

The median indicates the middle of the data set. That is, half of the measured results are above the median, and half are below. The IQR is the range that encompasses the middle 50% of the data set. The IQR is calculated by subtracting the 25th percentile of the data set from the 75th percentile of the data set. When necessary, the percentiles are interpolated from the data. Different software vendors may use slightly different formulas for calculating percentiles. Radiological data sets that include values less than zero may have an IQR greater than the median. To calculate the median, we require at least four values; to calculate the IQR we require at least six values.

Summary statistics are calculated from values that, if necessary, have already been rounded (such as when units have been converted from pCi to Bq) and are then rounded to an appropriate number of significant digits. The calculation of summary statistics is also affected by the presence of nondetections. A nondetection indicates that no specific measured value is available; instead, the best information available is that the actual value is less than the reporting limit. Adjustments to the calculation of the median and IQR for data sets that include nondetections are described below.

For data sets with all measurements above the reporting limit and radiological data sets that include reported values below the reporting limit, all reported values, including any below the reporting limit, are included in the calculation of summary statistics.

For data sets that include one or more values reported as "less than the reporting limit," the reporting limit is used as an upper bound value in the calculation of summary statistics.

If the number of values is odd, the middle value (when sorted from smallest to largest) is the median. If the middle value and all larger values are detections then the middle value is reported as the median. Otherwise, the median is assigned a less-than (<) sign.

If the number of values is even, the median is halfway between the middle two values (i.e., the middle two when the values are sorted from smallest to largest). If both of the middle two values and all larger values are detections, then the median is reported. Otherwise, the median is assigned a less-than sign.

If any of the values used to calculate the 25th percentile is a nondetection, or any values larger than the 25th percentile are nondetections, then the IQR cannot be calculated and is not reported.

The median and the IQR are not calculated for data sets having no detections.

Reporting Uncertainty in Data Tables

The measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, relates to the resolution of the measuring device. For example, if an ordinary household ruler with a metric scale is used to measure the length of an object in centimeters, and the ruler has tick marks every tenth centimeter, then the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). However, an attempt to be more precise is not likely to yield reliable or reproducible results, because it requires a visual estimate of a distance between tick marks. The appropriate way to report such a measurement would be, for example, "2.1 cm." This would indicate that the "true" length of the object is nearer to 2.1 cm than to 2.0 cm or 2.2 cm (i.e., between 2.05 and 2.15 cm). This result is said to have two significant digits. Although not explicitly stated, the uncertainty is considered to be ± 0.05 cm. A more precise measuring device might

be able to measure an object to the nearest one-hundredth of a centimeter; in that case a value such as "2.12 cm" might be reported. This value would have three significant digits and the implied uncertainty would be ± 0.005 cm. A result reported as "3.0 cm" has two significant digits. That is, the trailing zero is significant, and implies that the true length is between 2.95 and 3.05 cm; closer to 3.0 than to 2.9 or 3.1 cm.

When performing calculations with measured values that have significant digits, all digits are used. The number of significant digits in the calculated result is the same as that of the measured value with the fewest number of significant digits.

Most unit conversion factors do not have significant digits. For example, the conversion from milligrams (mg) to micrograms (µg) requires multiplying by the fixed (constant) value of 1000. The value 1000 is exact; it has no uncertainty and therefore the concept of significant digits does not apply.

The other method of representing uncertainty is based on random variation. For radiological measurements, there is variation due to the random nature of radioactive decay. As a sample is measured, the number of radioactive decay events is counted, and the reported result is calculated from the number of decay events that were observed. If the sample is recounted, the number of decay events will almost always be different—because radioactive decay events occur randomly. Uncertainties of this type are reported in this volume as 2σ uncertainties. A 2σ uncertainty represents the range of results expected to occur approximately 95% of the time, if a sample were to be recounted many times. A radiological result reported as, for example, "2.6 ± 1.2 Bq/g" would indicate that with approximately 95% confidence, the "true" value is in the range 1.4 to 3.8 Bq/g (i.e., 2.6 – 1.2 = 1.4 and 2.6 + 1.2 = 3.8).

The concept of significant digits applies to both the radiological result and its uncertainty. So, for example, in a result reported as "2.6 ± 1.2", both the measurement and its uncertainty have the same number of significant digits, that is, two. When expanding an interval reported in the "±" form, for example "2.4 ± 0.44", to a range of values, the rule described above for calculations involving significant digits must be followed. For example, 2.4 – 0.44 = 1.96. However, the measurements 2.4 and 0.45 each have two significant digits, so 1.96 must be rounded to two significant digits, i.e., to 2.0. Similarly, 2.4 + 0.44 = 2.84, and this must be rounded to 2.8. Therefore, a measurement reported as "2.4 ± 0.44 Bq/g" would represent an interval of 2.0 to 2.8 Bq/g.

When rounding a value having a final digit of "5", the software that prepared the tables follows IEEE Standard 754-1985, which is "go to the even digit". For example, 2.45 would round down to 2.4, and 2.55 would round up to 2.6.

Quality Assurance Process for the Environmental Report

Unlike the preceding sections, which focused on standards of accuracy and precision in data acquisition and reporting, the following discussion deals with procedures used to ensure the content of this report maintained accuracy through the publication process. Because publication of a large, data-rich document like this site annual environmental report involves many operations and many people, the chances of introducing errors are great. At the same time, ensuring quality is more difficult because a publication is less amenable to the statistical processes used in standard quality assurance methods.

The QA procedure used for this report concentrated on the tables and figures and enlisted authors, contributors, and technicians to check the accuracy of sections other than those they had authored or contributed to. In 2003, LLNL staff checked the tables and figures in the report as well as the data tables provided in the report CD.

Checkers were assigned figures and tables and given a copy of each item they were to check along with a quality control form to fill out as they checked the item. Items to be checked included figure captions and table titles for clarity and accuracy, data accuracy and completeness, figure labels and table headings, units, significant digits, and consistency with text.

When checking numerical data, checkers randomly selected 10% of the numbers and compared them to values in the hard copy reports. If all 10% agreed with the hard copy reports, further checking was considered unnecessary. If there was disagreement, the checker compared another 10% of the data with the database values. If more errors were found, the entire table or illustration had to be checked against the data in the database. A coordinator guided the process to ensure that forms were tracked and the proper approvals were obtained. Completed quality control forms and the corrected figures or tables were returned to the report editors, who were responsible for ensuring that changes, with the agreement of the original contributor, were made.

Appendix A: EPA Methods of Environmental Water Analysis

Table A-1. Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits

Constituents of concern	Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L)		
All alkalinities	EPA 310.1	1
Aluminum	EPA 200.7 or 200.8	0.05 or 0.2
Ammonia nitrogen (as N)	EPA 350.3, 350.2, or 350.1	0.03 or 0.1
Antimony	EPA 204.2 or 200.8	0.005
Arsenic	EPA 206.2 or 200.8	0.002
Barium	EPA 200.7 or 200.8	0.025 or 0.01
Beryllium	EPA 210.2 or 200.8	0.0005 or 0.0002
Boron	EPA 200.7	0.05
Bromide	EPA 300.0	0.5
Cadmium	EPA 213.2 or 200.8	0.0005
Calcium	EPA 200.7	0.5
Chloride	EPA 300.0	1 or 0.5
Chlorine (residual)	EPA 330.1 or 330.4	0.1
Chromium	EPA 218.2 or 200.8	0.01 or 0.001
Chromium(VI)	EPA 218.4 or 7196	0.002
Cobalt	EPA 200.7 or 200.8	0.025 or 0.05
Copper	EPA 220.2, 200.7 or 200.8	0.001, 0.01 or 0.05
Cyanide	EPA 335.2	0.02
Fluoride	EPA 340.2 or 340.1	0.05
Hardness, total (as $CaCO_3$)	SM 2320B	1
Iron	EPA 200.7 or 200.8	0.1
Lead	EPA 239.2 or 200.8	0.002 or 0.005
Magnesium	EPA 200.7 or 200.8	0.5
Manganese	EPA 200.7 or 200.8	0.03
Mercury	EPA 245.2 or 245.1	0.0002
Molybdenum	EPA 200.7 or 200.8	0.025
Nickel	EPA 249.2, 200.7 or 200.8	0.002, 0.005 or 0.1
Nitrate (as NO_3)	EPA 353.2, 354.1 or 300.0	0.5

Table A-1. Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits (continued)

Constituents of concern	Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L) (continued)		
Nitrite (as NO_2)	EPA 353.2, 354.1 or 300.0	0.5
Ortho-phosphate	EPA 300.0, 365.1 or 365.2	0.05
Perchlorate	EPA 314.0	0.004
Potassium	EPA 200.7	1
Selenium	EPA 270.2 or 200.8	0.002
Silver	EPA 272.2 or 200.8	0.001 or 0.0005
Sodium	EPA 200.7	1 or 0.1
Sulfate	EPA 300.0	1
Surfactants	EPA 425.1	0.5
Thallium	EPA 279.2 or 200.8	0.001
Total dissolved solids	EPA 160.1	1
Total suspended solids	EPA 160.2	1
Total Kjeldahl nitrogen	EPA 351.2 or 351.3	0.2
Total phosphorus (as P)	EPA 365.4 or SM 4500-P	0.05
Vanadium	EPA 200.7 or 200.8	0.02 or 0.025
Zinc	EPA 200.7 or 200.8	0.02 or 0.05
General indicator parameters		
pH (pH units)	EPA 150.1	none
Biochemical oxygen demand (mg/L)	SM 5210B	2
Conductivity (μS/cm)	EPA 120.1	none
Chemical oxygen demand (mg/L)	EPA 410.4	5
Dissolved oxygen (mg/L)	EPA 360.1	0.05
Total organic carbon (mg/L)	EPA 9060 or 415.1	1
Total organic halides (mg/L)	EPA 9020	0.02
Toxicity, acute (fathead minnow)	EPA 2000	027F%
Toxicity, chronic (fathead minnow)	EPA 1000	002 NOEC
Radioactivity (Bq/L)		
Gross alpha	EPA 900	0.074
Gross beta	EPA 900	0.11
Radioisotopes (Bq/L)		
Americium-241	U-NAS-NS-3050	0.0037
Plutonium-238	U-NAS-NS-3050	0.0037

Table A-1. Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits (continued)

Constituents of concern	Analytical method	Reporting limit[a,b]
Plutonium-239+240	U-NAS-NS-3050	0.0037
Radon-222	EPA 913	3.7
Radium-226	EPA 903	0.0093
Radium-228	EPA 904	0.037
Thorium-228	U-NAS-NS-3050	0.009
Thorium-230	U-NAS-NS-3050	0.006
Thorium-232	U-NAS-NS-3050	0.006
Tritium	LLNL-RAS-011	3.7
Uranium-234	EPA 908	0.0037
Uranium-235	EPA 908	0.0037
Uranium-238	EPA 908	0.0037

a The significant figures displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, or the applicable analytical laboratory contract under which the work was performed, or both.

b These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method

Constituents of concern	Reporting limit (μg/L)[a,b]
EPA Method 413.1 or 1664	
Oil & Grease	1000
EPA Method 420.1	
Phenolics	5
EPA Method 502.2 (or 524.2)	
1,1,1,2-Tetrachloroethane	0.2
1,1,1-Trichloroethane	0.2
1,1,2,2-Tetrachloroethane	0.2
1,1,2-Trichloroethane	0.2
1,1-Dichloroethane	0.2
1,1-Dichloroethene	0.2
1,1-Dichloropropene	0.2
1,2,3-Trichlorobenzene	0.2
1,2,3-Trichloropropane	0.2
1,2,4-Trichlorobenzene	0.2
1,2,4-Trimethylbenzene	0.2
1,2-Dichlorobenzene	0.2
1,2-Dichloroethane	0.2
1,2-Dichloropropane	0.2
1,3,5-Trimethylbenzene	0.2
1,3-Dichlorobenzene	0.2
1,3-Dichloropropane	0.2
1,4-Dichlorobenzene	0.2
2,2-Dichloropropane	0.2
2-Chlorotoluene	0.2
4-Chlorotoluene	0.2
Benzene	0.2
Bromobenzene	0.2
Bromochloromethane	0.2
Bromodichloromethane	0.2
Bromoform	0.2
Bromomethane	0.2
Carbon tetrachloride	0.2
Chlorobenzene	0.2
Chloroethane	0.2
Chloroform	0.2
Chloromethane	0.2
cis-1,2-Dichloroethene	0.2
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.2
Dibromomethane	0.2
Dichlorodifluoromethane	0.2
Ethylbenzene	0.2
Freon 113	0.2
Hexachlorobutadiene	0.2
Isopropylbenzene	0.2
m- and *p*-Xylene isomers	0.2
Methylene chloride	0.2
n-Butylbenzene	0.2
n-Propylbenzene	0.2
Naphthalene	0.2
o-Xylene	0.2
Isopropyl toluene	0.2
sec-Butylbenzene	0.2
Styrene	0.2
tert-Butylbenzene	0.2
Tetrachloroethene	0.2
Toluene	0.2
trans-1,2-Dichloroethene	0.2
trans-1,3-Dichloropropene	0.2
Trichloroethene	0.2
Trichlorofluoromethane	0.2
Vinyl chloride	0.2
EPA Method 507	
Alachlor	0.5
Atraton	0.5
Atrazine	0.5
Bromacil	0.5
Butachlor	0.5
Diazinon	0.5
Dichlorvos	0.5
Ethoprop	0.5
Merphos	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Molinate	0.5
Prometon	0.5

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
Prometryn	0.5
Simazine	0.5
Terbutryn	0.5
EPA Method 524.2	
1,1,1,2-Tetrachloroethane	1
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,1-Dichloropropene	1
1,2,3-Trichlorobenzene	1
1,2,3-Trichloropropane	1
1,2,4-Trichlorobenzene	1
1,2,4-Trimethylbenzene	1
1,2-Dibromo-3-chloropropane	2
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloropropane	1
1,3,5-Trimethylbenzene	1
1,3-Dichlorobenzene	1
1,3-Dichloropropane	1
1,4-Dichlorobenzene	1
2-Chlorotoluene	1
4-Chlorotoluene	1
Benzene	1
Bromobenzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1

Constituents of concern	Reporting limit (μg/L)[a,b]
Dichlorodifluoromethane	2
Ethylbenzene	1
Ethylene dibromide	1
Freon 113	1
Hexachlorobutadiene	1
Isopropylbenzene	1
m- and *p*-Xylene isomers	1
Methylene chloride	1
n-Butylbenzene	1
n-Propylbenzene	1
Naphthalene	1
o-Xylene	1
Isopropyl toluene	1
sec-Butylbenzene	1
Styrene	1
tert-Butylbenzene	1
Tetrachloroethene	1
Toluene	1
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl chloride	2
EPA Method 525	0.5
2,4-Dinitrotoluene	0.5
2,6-Dinitrotoluene	0.5
4,4'-DDD	0.5
4,4'-DDE	0.5
4,4'-DDT	0.5
Acenaphthylene	0.5
Alachlor	0.5
Aldrin	0.5
Anthracene	0.5
Aroclor 1016 (PCB)	0.5
Aroclor 1221 (PCB)	0.5
Aroclor 1232 (PCB)	0.5
Aroclor 1242 (PCB)	0.5
Aroclor 1248 (PCB)	0.5
Aroclor 1254 (PCB)	0.5

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
Aroclor 1260 (PCB)	0.5
Atraton	0.5
Atrazine	0.5
Benzo(a)anthracene	0.5
Benzo(a)pyrene	0.5
Benzo(b)fluoranthene	0.5
Benzo(g,h,i)perylene	0.5
Benzo(k)fluoranthene	0.5
Bis(2-ethylhexyl)phthalate	0.5
Bromacil	0.5
Butachlor	0.5
Butylbenzylphthalate	0.5
Chlordane	0.5
Chloropropham	0.5
Chlorpyrifos	0.5
Chrysene	0.5
Di (2-ethylhexyl) adipate	0.5
Di-n-butylphthalate	0.5
Diazinon	0.5
Dibenzo(a,h)anthracene	0.5
Dichlorvos	0.5
Dieldrin	0.5
Diethylphthalate	0.5
Dimethylphthalate	0.5
Disulfoton	0.5
Endosulfan I	0.5
Endosulfan II	0.5
Endosulfan sulfate	0.5
Endrin	0.5
Endrin aldehyde	0.5
Ethoprop	0.5
Fluorene	0.5
Heptachlor	0.5
Heptachlor epoxide	0.5
Hexachlorobenzene	0.5
Hexachlorocyclopentadiene	0.5
Indeno(1,2,3-c,d)pyrene	0.5
Isophorone	0.5
Lindane	0.5

Constituents of concern	Reporting limit (μg/L)[a,b]
Merphos	0.5
Methoxychlor	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Pentachlorobenzene	0.5
Pentachlorophenol	0.5
Phenanthrene	0.5
Prometon	0.5
Prometryne	0.5
Propachlor	0.5
Pyrene	0.5
Simazine	0.5
Stirophos	0.5
Terbutryn	0.5
Toxaphene	
EPA Method 547	
Glyphosate	20
EPA Method 601	
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2-Dichlorobenzene	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
2-Chloroethylvinylether	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Freon 113	0.5
Methylene chloride	0.5
Tetrachloroethene	0.5
trans-1,2-Dichloroethene	0.5
trans-1,3-Dichloropropene	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl chloride	0.5
EPA Method 602	
1,2-Dichlorobenzene	0.3
1,3-Dichlorobenzene	0.3
1,4-Dichlorobenzene	0.3
Benzene	0.4
Chlorobenzene	0.3
Ethylbenzene	0.3
m-Xylene isomers	0.4
o-Xylene	0.4
p-Xylene	0.4
Toluene	0.3
Total xylene isomers	0.4
EPA Method 608	
Aldrin	0.05
BHC, alpha isomer	0.05
BHC, beta isomer	0.05
BHC, delta isomer	0.05
BHC, gamma isomer (Lindane)	0.05
Chlordane	0.2
Dieldrin	0.1
Endosulfan I	0.05
Endosulfan II	0.1
Endosulfan sulfate	0.1
Endrin	0.1
Endrin aldehyde	0.1
Heptachlor	0.05
Heptachlor epoxide	0.05

Constituents of concern	Reporting limit (μg/L)[a,b]
Methoxychlor	0.5
4,4′-DDD	0.1
4,4′-DDE	0.1
4,4′-DDT	0.1
Toxaphene	1
EPA Method 615	
2,4,5-T	0.5
2,4,5-TP (Silvex)	0.2
2,4-D	1
2,4-Dichlorophenoxy acetic acid	2
Dalapon	10
Dicamba	1
Dichloroprop	2
Dinoseb	1
MCPA	250
MCPP	250
EPA Method 624	
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloroethene (total)	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
2-Butanone	20
2-Chloroethylvinylether	20
2-Hexanone	20
4-Methyl-2-pentanone	20
Acetone	10
Benzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon disulfide	1
Carbon tetrachloride	1

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Freon 113	1
Methylene chloride	1
Styrene	1
Tetrachloroethene	1
Toluene	1
Total xylene isomers	2
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl acetate	1
Vinyl chloride	1
EPA Method 625	
1,2,4-Trichlorobenzene	5
1,2-Dichlorobenzene	5
1,3-Dichlorobenzene	5
1,4-Dichlorobenzene	5
2,4,5-Trichlorophenol	5
2,4,6-Trichlorophenol	5
2,4-Dichlorophenol	5
2,4-Dimethylphenol	5
2,4-Dinitrophenol	25
2,4-Dinitrotoluene	5
2,6-Dinitrotoluene	5
2-Chloronaphthalene	5
2-Chlorophenol	5
2-Methylphenol	5
2-Methyl-4,6-dinitrophenol	25
2-Methylnaphthalene	5

Constituents of concern	Reporting limit (μg/L)[a,b]
2-Nitroaniline	25
3,3′-Dichlorobenzidine	10
3-Nitroaniline	25
4-Bromophenylphenylether	5
4-Chloro-3-methylphenol	10
4-Chloroaniline	10
4-Chlorophenylphenylether	5
4-Nitroaniline	25
4-Nitrophenol	25
Acenaphthene	25
Acenaphthylene	5
Anthracene	5
Benzo[*a*]anthracene	5
Benzo[*a*]pyrene	5
Benzo[*b*]fluoranthene	5
Benzo[*g,h,i*]perylene	5
Benzo[*k*]fluoranthene	5
Benzoic acid	25
Benzyl alcohol	10
Bis(2-chloroethoxy)methane	5
Bis(2-chloroisopropyl)ether	5
Bis(2-ethylhexyl)phthalate	5
Butylbenzylphthalate	5
Chrysene	5
Di-*n*-butylphthalate	5
Di-*n*-octylphthalate	5
Dibenzo[*a,h*]anthracene	5
Dibenzofuran	5
Diethylphthalate	5
Dimethylphthalate	5
Fluoranthene	5
Fluorene	5
Hexachlorobenzene	5
Hexachlorobutadiene	5
Hexachlorocyclopentadiene	5
Hexachloroethane	5
Indeno[*1,2,3-c,d*]pyrene	5
Isophorone	5
m- and *p*-Cresol	5

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
N-Nitroso-di-*n*-propylamine	5
Naphthalene	5
Nitrobenzene	5
Pentachlorophenol	5
Phenanthrene	5
Phenol	5
Pyrene	5
EPA Method 632	
Diuron	0.1
EPA Method 8082	
Polychlorinated biphenyls (PCBs)	0.5
EPA Method 8140	
Bolstar	1
Chlorpyrifos	1
Coumaphos	1
Demeton	1
Diazinon	1
Dichlorvos	1
Disulfoton	1
Ethoprop	1
Fensulfothion	1
Fenthion	1
Merphos	1
Methyl Parathion	1
Mevinphos	1
Naled	1
Phorate	1
Prothiophos	1
Ronnel	1
Stirophos	1
Trichloronate	1
EPA Method 8260	
1,1,1,2-Tetrachloroethane	0.5
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2,3-Trichloropropane	0.5
1,2-Dibromo-3-chloropropane	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
2-Butanone	0.5
2-Chloroethylvinylether	0.5
2-Hexanone	0.5
4-Methyl-2-pentanone	0.5
Acetone	10
Acetonitrile	100
Acrolein	50
Acrylonitrile	50
Benzene	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon disulfide	5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5
Chloroprene	5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Ethanol	1000
Ethylbenzene	0.5
Freon 113	0.5
Methylene chloride	0.5
Styrene	0.5
Tetrachloroethene	0.5
Toluene	0.5
Total xylene isomers	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl acetate	20
Vinyl chloride	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5

Table A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method (continued)

Constituents of concern	Reporting limit (μg/L)[a,b]
trans-1,2-Dichloroethene	0.5
trans-1,3-Dichloropropene	0.5
EPA Method 8290	
1,2,3,4,6,7,8-HpCDD	0.00025
1,2,3,4,6,7,8-HpCDF	0.00025
1,2,3,4,7,8,9-HpCDF	0.00025
1,2,3,4,7,8-HxCDF	0.00025
1,2,3,6,7,8-HxCDD	0.00025
1,2,3,6,7,8-HxCDF	0.00025
1,2,3,7,8,9-HxCDD	0.00025
1,2,3,7,8,9-HxCDF	0.00025
1,2,3,7,8-PeCDD	0.0001
1,2,3,7,8-PeCDF	0.0001
2,3,4,6,7,8-HxCDF	0.00025
2,3,4,7,8-PeCDF	0.0001
2,3,7,8-TCDD	0.0001
2,3,7,8-TCDF	0.0001
OCDD	0.0005
OCDF	0.0005
EPA Method 8330	
HMX[c]	5 or 1
RDX[d]	5 or 1
TNT[e]	5

a The significant figures displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, the applicable analytical laboratory contract under which the work was performed, or both.

b These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

c HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

d RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

e TNT is 2,4,6-trinitrotoluene.

Appendix B: Wildlife Survey Results

Table B-1 includes species for which there are verified observations. It is not intended to be a complete list of Site 300 species

Table B-1. Site 300 wildlife species list

Common Name	Scientific Name	Regulatory Status[a]	Source
Mammals			
Pallid bat	*Antrozous pallidus*	CASSC	Rainey 2003
Western red bat	*Lasiurus blossevillii*		Rainey 2003
Hoary bat	*Lasiurus cinereus*		Rainey 2003
California myotis	*Myotis californicus*		Rainey 2003
Western pipistrelle	*Pipistrellus hesperus*		Rainey 2003
Brazilian free-tailed bat	*Tadarida brasiliensis*		Rainey 2003
Desert cottontail	*Sylvilagus audubonii*		LLNL 2002 Clark et al. 2002
Black-tailed jackrabbit	*Lepus californicus*		LLNL 2002 Clark et al. 2002
Heermann's kangaroo rat	*Dipodomys heermanni*		LLNL 2002 West 2002
California pocket mouse	*Chaetodipus californicus*		LLNL 2002 West 2002
San Joaquin pocket mouse	*Perognathus inornatus*	FSC	Clark et al. 2002
California ground squirrel	*Spermophilus beecheyi*		LLNL 2002
Valley pocket gopher	*Thomomys bottae*		LLNL 2002 West 2002
California vole	*Microtus californicus*		LLNL 2002 West 2002
House mouse	*Mus musculus*		LLNL 2002 West 2002
Dusky-footed woodrat	*Neotoma fuscipes*		LLNL 2002 West 2002
Brush mouse	*Peromyscus boylii*		LLNL 2002 West 2002
Deer mouse	*Peromyscus maniculatus*		LLNL 2002 West 2002
Western harvest mouse	*Reithrodontomys megalotis*		LLNL 2002 West 2002
Coyote	*Canis latrans*		LLNL 2002 Clark et al. 2002
Raccoon	*Procyon lotor*		LLNL 2002 Orloff

Table B-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Long-tailed weasel	*Mustela frenata*		LLNL 2002 Orloff
Striped skunk	*Mephitis mephitis*		LLNL 2002 Orloff
Western spotted skunk	*Spilogale gracilis*		LLNL 2002 Orloff
American badger	*Taxidea taxus*		LLNL 2002 Clark et al. 2002
Bobcat	*Lynx rufus*		LLNL 2002 Clark et al. 2002
Mountain Lion	*Felis concolor*		LLNL 2002
Mule deer	*Odocoileus hemionus*		LLNL 2002 Clark et al. 2002
Wild pig	*Sus scrofa*		LLNL 2002 Clark et al. 2002
Herpetofauna			
California red-legged frog	*Rana aurora draytonii*	FT	LLNL 2002
Pacific tree frog	*Hyla regilla*		LLNL 2002
California tiger salamander	*Ambystoma californiense*	FT, CASSC	LLNL 2002
Western spadefoot toad	*Spea hammondii*	FSC, CASSC	LLNL 2002
Western toad	*Bufo boreas*		LLNL 2002
Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT, ST	Swaim 2002
San Joaquin coachwhip	*Masticophis flagellum*	FSC, CASSC	LLNL 2002
Coast horned lizard	*Phrynosoma coronatum*	FSC, CASSC	LLNL 2002
California legless lizard	*Anniella pulchra*	FSC	Swaim 2002
Side-blotched lizard	*Uta stansburiana*		LLNL 2002 Swaim 2002
Western whiptail	*Cnemidophorus tigris*		LLNL 2002 Swaim 2002
Western fence lizard	*Sceloporus occidentalis*		LLN 2002 Swaim 2002
Western skink	*Eumeces skiltonianus*		LLN 2002 Swaim 2002
Gilbert skink	*Eumeces gilberti*		LLN 2002 Swaim 2002
Southern alligator lizard	*Gerrhonotus multicarinatus*		LLN 2002 Swaim 2002
Western yellow bellied racer	*Coluber constrictor*		LLN 2002 Swaim 2002
Pacific gopher snake	*Pituophis melanoleucus*		LLN 2002 Swaim 2002
Common kingsnake	*Lampropeltis getulus*		LLN 2002 Swaim 2002

Table B-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Western rattlesnake	*Crotalus viridis*		LLN 2002 Swaim 2002
Night snake	*Hypsiglena torquata*		LLN 2002 Swaim 2002
Glossy snake	*Arizona elegans*		LLN 2002 Swaim 2002
Long-nosed snake	*Rhinocheilus lecontei*		LLN 2002 Swaim 2002
California black-headed snake	*Tantilla planiceps*		Swaim 2002
Birds			
Cooper's Hawk	*Accipiter cooperii*	CASSC, MBTA	LLNL 2003
Sharp-shinned Hawk	*Accipiter striatus*	CASSC, MBTA	LLNL 2003
Golden Eagle	*Aquila chrysaetos*	CASSC, MBTA	LLNL 2003
Red-tailed Hawk	*Buteo jamaicensis*	MBTA	LLNL 2003
Rough-legged Hawk	*Buteo lagopus*	MBTA	LLNL 2003
Red-shouldered Hawk	*Buteo lineatus*	MBTA	LLNL 2003
Ferruginous Hawk	*Buteo regalis*	FSC, CASSC, MBTA	LLNL 2003
Swainson's Hawk	*Buteo swainsoni*	ST, MBTA	LLNL 2003
Northern Harrier	*Circus cyaneus*	CASSC, MBTA	LLNL 2003
White-tailed Kite	*Elanus leucurus*	CAFPS, MBTA	LLNL 2003
Osprey	*Pandion haliaetus*	CASSC, MBTA	LLNL 2003
Bushtit	*Psaltriparus minimus*	MBTA	LLNL 2003
Horned Lark	*Eremophila alpestris*	CASSC, MBTA	LLNL 2003
Northern Shoveler	*Anas clypeata*	MBTA	LLNL 2003
Cinnamon Teal	*Anas cuamptera*	MBTA	LLNL 2003
Mallard	*Anas platyryynchos*	MBTA	LLNL 2003
Bufflehead	*Blucephala albeola*	MBTA	LLNL 2003
Common Goldeneye	*Bucephala clangula*	MBTA	LLNL 2003
White-throated Swift	*Aeronautes saxatalis*	MBTA	LLNL 2003
Great Egret	*Ardea alba*	MBTA	LLNL 2003
Virginia Rail	*Rallus limicola*	MBTA	DOE 1992
Cedar Waxwing	*Bombycilla garrulus*	MBTA	LLNL 2003
Common Poorwill	*Phalaenoptilus nuttalii*	MBTA	LLNL 2003
Blue-grosbeak	*Guiraca caerulea*	MBTA	LLNL 2003
Black-headed Grosbeak	*Pheucticus melanocephalus*	MBTA	DOE 1992
Lazuli Bunting	*Passerina amoena*	MBTA	LLNL 2003
Turkey Vulture	*Cathartes aura*	MBTA	LLNL 2003
Killdeer	*Charadrius vociferus*	MBTA	LLNL 2003
Rock Dove	*Columba livia*		DOE 1992
Mourning Dove	*Zenaida macroura*	MBTA	LLNL 2003

Table B-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Western Scrub Jay	*Aphelocoma californica*	MBTA	LLNL 2003
American Crow	*Corvus brachyrhynchos*	MBTA	LLNL 2003
Common Raven	*Corvus corax*	MBTA	LLNL 2003
Greater Roadrunner	*Geococcyx californianus*	MBTA	LLNL 2003
Bell's Sage Sparrow	*Amphispiza belli*	FSC, MBTA	LLNL 2003
Black-throated Sparrow	*Amphispiza bilineata*	MBTA	LLNL 2003
Rufous Crowned Sparrow	*Aimophila ruficeps*	MBTA	LLNL 2003
Grasshopper Sparrow	*Ammodramus savannarum*	FSC, MBTA	LLNL 2003
Lark Sparrow	*Chondestes grammacus*	MBTA	LLNL 2003
California Towhee	*Carpodacus mexicanus*	MBTA	LLNL 2003
Oregon Junco	*Junco hyemalis*	MBTA	LLNL 2003
Lincoln's Sparrow	*Melospiza lincolnii*	MBTA	LLNL 2003
Song Sparrow	*Melospiza melodia*	MBTA	LLNL 2003
Vesper Sparrow	*Pooecetes gramineus*	MBTA	DOE 1992
Fox Sparrow	*Passerella iliaca*	MBTA	LLNL 2003
Savannah Sparrow	*Passerculus sandwichensis*	MBTA	LLNL 2003
Golden-crowned Sparrow	*Zonotrichia atricapilla*	MBTA	LLNL 2003
White-crowned Sparrow	*Zonotrichia leucophrys*	MBTA	LLNL 2003
American Kestrel	*Falco columbarius*	MBTA	LLNL 2003
Prairie Falcon	*Falca mexicanus*	CASSC, MBTA	LLNL 2003
House Finch	*Carpodacus mexicanus*	MBTA	LLNL 2003
Lesser Goldfinch	*Carduelis psaltia*	MBTA	LLNL 2003
Cliff Swallow	*Petrochelidon pyrrhonota*	MBTA	LLNL 2003
Northern Rough Winged Swallow	*Stelgidopteryx serripennis*	MBTA	LLNL 2003
Tree Swallow	*Tachycineta bicolor*	MBTA	LLNL 2003
Western Wood-pewee	*Contopus sordidulus*	MBTA	DOE 1992
Red-winged Blackbird	*Agelaius phoeniceus*	MBTA	LLNL 2003
Tricolored Blackbird	*Agelaius tricolor*	FSC, CASSC, MBTA	LLNL 2003
Brewer's Blackbird	*Euphagus cyanocephalus*	MBTA	LLNL 2003
Bullock's Oriole	*Icterus bullockii*	MBTA	LLNL 2003
Brown-headed Cowbird	*Molothrus ater*	MBTA	LLNL 2003
Western Meadowlark	*Sturnella magna*	MBTA	LLNL 2003
Loggerhead Shrike	*Lanius ludovicianus*	FSC, CASSC, MBTA	LLNL 2003
Northern Mockingbird	*Mimus polyglottos*	MBTA	LLNL 2003
California Thrasher	*Toxostoma redivivum*	FSC, MBTA	LLNL 2003
California Quail	*Callipepla californica*		LLNL 2003
Oak Titmouse	*Baeolphus inornatus*	FSC, MBTA	LLNL 2003
Yellow-rumped Warbler	*Dendroica coronata*	MBTA	LLNL 2003
Black-throated Gray Warbler	*Dendroica nigrescens*	MBTA	LLNL 2003

Table B-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Yellow Warbler	*Dendroica petechia*	CASSC, MBTA	LLNL 2003
Common Yellowthroat	*Geothlypis trichas*	CASSC, MBTA	LLNL 2003
MacGillivary's Warbler	*Oporornis tolmiei*	MBTA	LLNL 2003
Orange-crowned Warbler	*Vermivora bachmanii*	MBTA	LLNL 2003
Wilson's Warbler	*Wilsonia pusila*	MBTA	LLNL 2003
Double-crested Cormorant	*Phalacrocorax auritus*	CASSC, MBTA	LLNL 2003
Wild Turkey	*Meleagris gallopavo*		LLNL 2003
Northern Flicker	*Colaptes auratus*	MBTA	LLNL 2003
Nuttal's Woodpecker	*Picoides nuttallii*	FSC, MBTA	LLNL 2003
Acorn Woodpecker	*Melanerpes formicivorus*	MBTA	DOE 1992
Pied-billed Grebe	*Podilymbus podiceps*	MBTA	LLNL 2003
Phainopepela	*Phainopepla nitens*	MBTA	LLNL 2003
Ruby-crowned Kinglet	*Regulus calendula*	MBTA	LLNL 2003
Common Snipe	*Gallinago gallinago*	MBTA	LLNL 2003
Greater Yellowlegs	*Tringa melanoleuca*	MBTA	LLNL 2003
Burrowing Owl	*Athene cunicularia*	FSC, CASSC, MBTA	LLNL 2003
Short-eared Owl	*Asio flammeus*	FSC, CASSC, MBTA	LLNL 2003
Great horned Owl	*Bubo virginianus*	MBTA	LLNL 2003
Western Screech Owl	*Otus kennicottii*	MBTA	LLNL 2003
European Starling	*Sturnus vulgaris*		LLNL 2003
Western Tanager	*Piranga ludoviciana*	MBTA	LLNL 2003
Anna's Hummingbird	*Calypte anna*	MBTA	LLNL 2003
Costa's Hummingbird	*Calypte costae*	FSC, MBTA	LLNL 2003
Rufous Hummingbird	*Selasphorus rufus*	FSC, MBTA	LLNL 2003
Allen's Hummingbird	*Selasphorus sasin*	MBTA	DOE 1992
Rock Wren	*Salpinctes obsoletus*	MBTA	LLNL 2003
Bewick's Wren	*Thyothorus ludovicianus*	MBTA	LLNL 2003
House Wren	*Troglodytes aedon*	MBTA	LLNL 2003
Hermit Thrush	*Catharus guttatus*	MBTA	LLNL 2003
Swainson's Thrush	*Catharus ustulatus*	MBTA	LLNL 2003
Varied Thrush	*Ixoreus naevius*	MBTA	LLNL 2003
Mountain Bluebird	*Sialia currucoides*	MBTA	LLNL 2003
Western Buebird	*Sialia mexicana*	MBTA	LLNL 2003
American Robin	*Turdus migratorius*	MBTA	LLNL 2003
Pacific-slope Flycatcher	*Empidonax difficillis*	MBTA	LLNL 2003
Ash-throated Flycatcher	*Myiarchus cinerascens*	MBTA	LLNL 2003
Western Wood-pewee	*Contopus sordidulus*	MBTA	DOE 1992
Black Phoebe	*Sayornis nigricans*	MBTA	LLNL 2003
Say's Phoebe	*Sayornis saya*	MBTA	LLNL 2003

Table B-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Western Kingbird	*Tyrannus verticalis*	MBTA	LLNL 2003
Cassin's Kingbird	*Tyrannus vociferans*	MBTA	LLNL 2003
Barn Owl	*Tyto alba*	MBTA	LLNL 2003
Invertebrates			
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	FT	Arnold 2002
California fairy shrimp	*Linderiella occidentalis*	FSC	Weber 2002
California clam shrimp	*Cyzicus californicus*		Weber 2002

a CAFPS = California Department of Fish and Game Fully Protected Species (CA Dept. of Fish and Game 2001)

CASSC = California Species of Special Concern (CA Dept. of Fish and Game 2001)

FE = Endangered under the Federal Endangered Species Act

FT = Threatened under the Federal Endangered Species Act

PT = Proposed as threatened under the Federal Endangered Species Act

MBTA = Migratory Bird Treaty Act

ST = Threatened under the State Endangered Species Act

FSC = Federal Species of Concern for Alameda and San Joaquin Counties. May be endangered or threatened. Not enough biological information has been gathered to support listing at this time (U.S. Fish and Wildlife Service 1-1-03-SP-0162).

Appendix C: Errata

Protocol for Handling Errata in LLNL Environmental Reports

The primary form of publication for the LLNL site environmental annual report (SAER) is electronic, either on CD (compact disk) or on the Internet. The secondary form is hard copy, which is produced from the electronic copy. Hard copy is made available to the public at local libraries.

Because there are both publicly distributed and Internet versions of the report, the two versions must be fully equivalent, both in their original versions as first presented to the public, and as they are changed (noted as published errata) subsequent to the original publication.

In October 1998, LLNL developed a protocol for making post-publication revisions to the Internet versions of SAERs. The main criteria are that (1) the SAER home page must simply and clearly convey what revisions, if any, have been made to a particular report, and directly link to an errata information section; (2) the Internet version of the SAER must be accurately maintained; (3) each SAER accessible on the Internet at any time shall be the most current version of the report, incorporating all revisions; and (4) the content of the Internet and distributed versions of the SAER must be the same, in the sense that the published version plus its errata, if any, must provide the same information as the current (revised) Internet version.

Presently SAERs covering calendar years 1994 through 2002 can be accessed on the Internet at the address of the LLNL SAER homepage: http://www.llnl.gov/saer. Both the main volume and the data supplement volume of each individual report can be viewed in its most up-to-date form. A link to an errata section provides a complete record of post-publication changes that have been made.

Record of Changes to 2002 SAER

The following changes have been made to the Internet version of the main document.

- On page xi, the eleventh line from the bottom of the page ("Environmental Impact") was deleted.
- On page EX-2, in line 4 of the second paragraph of the right-hand column, "responsions" was changed to "resuspension".

- On page EX-3, in the label for the right-hand axis in Figure EX-1, "Bqm^3" was changed to "Bq/m^3".
- On page EX-4, in line 9 of the left-hand column, "1982" was changed to "1984".
- On page 2-4, in line 15 of the the second paragraph of the left-hand column, "895 million L" was changed to "865 million L".
- On page 2-5, in line 5 of the first paragraph in the right-hand column, "32 grams" was changed to "32 mCi (1.2×10^{-9} Bq)".
- On page 2-9, in Table 2-3, the following changes were made in the "Livermore site" column on the row titled "Air."
  - "Cold cleaners" was changed to "solvent cleaners".
  - "Ultrasonic cleaners," "degreasers," "image tube fabrication," and "plating tanks" were deleted.
- On page 8-44, in the left-hand column, the second "Environmental Impact" heading (below "Livermore Site Ground Water Project") was deleted.
- On page 12-4, in line 5 of the second paragraph in the left-hand column, "0.646 ± 0.028 mSv (64.6 ± 2.8 mrem)" was changed to 0.571 ± 0.025 mSv (57.1 ± 2.5 mrem)".
- On page 12-4, in the first paragraph of the right-hand column, the following numbers were changed.
  - "0.755 ± 0.025 mSv (75.5 ±2.3 mrem)" was changed to "0.666 ± 0.021 mSv (66.6 ± 2.1 mrem)".
  - "0.751 ± 0.068 mSv (75.1 ±6.8 mrem)" was changed to "0.672 ± 0.047 mSv (67.2 ± 4.7 mrem)".
  - "0.679 ± 0.060 mSv (67.9 ±6.0 mrem)" was changed to "0.597 ± 0.055 mSv (59.7 ± 5.5 mrem)"
- On page 12-5, the end of the second paragraph was changed to "… show a similar trend although the data does not suggest a serious impact on either health or the environment." (from "… show a similar trend. Although the data does not suggest a serious impact on either health or the environment, it falls within the action level of investigation. There are no plausible explanations at this time.")
- On page 12-6, Table 12-1 and Figure 12-4 were replaced.
- On page 12-7, Figure 12-5 was replaced.
- On page AC-1, the acronym and definition "CEI Compliance evaluation inspection" was added.

The following changes have been made to the Internet version of the Data Supplement.

- On pages 167–170, Tables 12-1 through 12-4 were replaced.

Table 12-1. Summary of dose calculations for gamma-monitoring locations (mSv)[a] at all LLNL sites, 2002

Quarter	Location				
	Livermore site	Livermore Valley	Site 300	Tracy	Near Site 300
	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]
First	0.134 ± 0.006	0.134 ± 0.005	0.152 ± 0.08	0.140 ± 0.033	0.157 ± 0.031
Second	0.145 ± 0.006	0.144 ± 0.007	0.164 ± 0.011	0.141 ± 0.035	0.173 ± 0.018
Third	0.144 ± 0.007	0.145 ± 0.008	0.178 ± 0.09	0.145 ± 0.024	0.171 ± 0.028
Fourth	0.148 ± 0.006	0.147 ± 0.006	0.172 ± 0.014	0.171 ± 0.010	0.171 ± 0.010
Annual dose[c]	0.571 ± 0.025	0.570 ± 0.013	0.666 ± 0.021	0.597 ± 0.055	0.672 ± 0.047

a 1 mSv = 100 mrem

b SE = Standard Error (standard deviation of the mean)

c Annual dose is reported as the summation of the quarterly doses. The reported error is the root mean square of the quarterly errors.

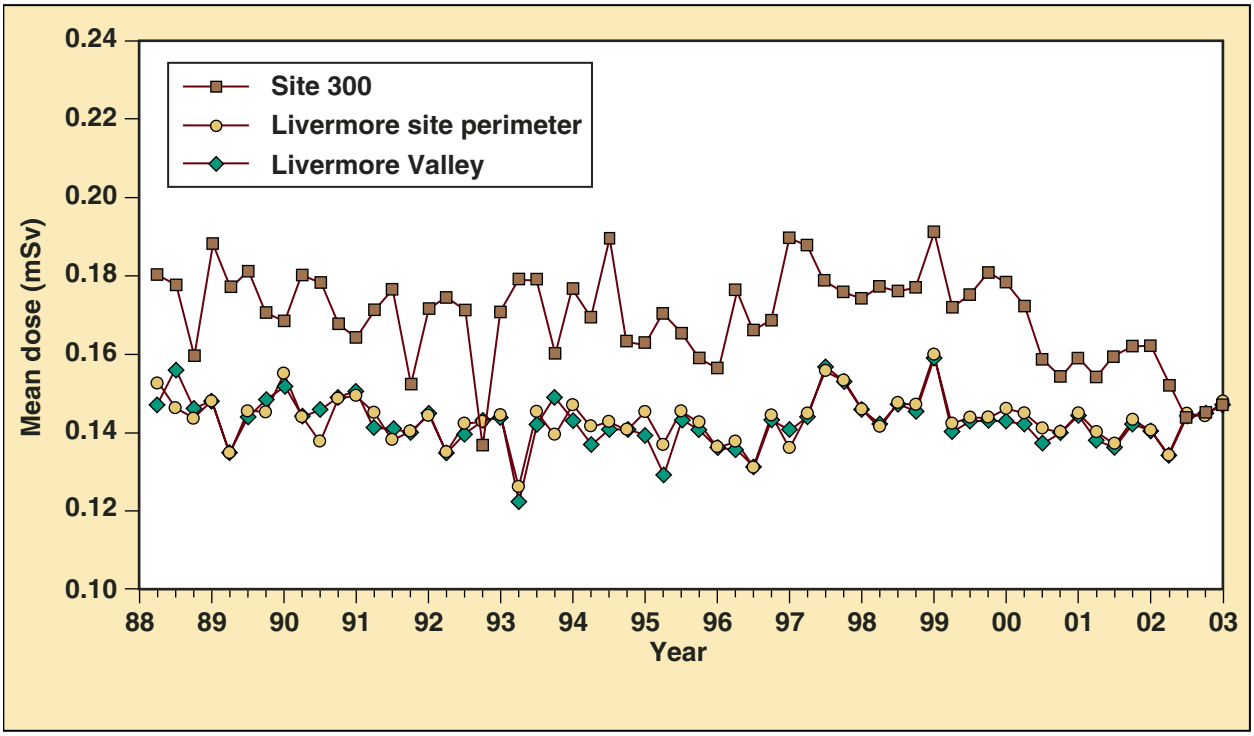

Figure 12-4. Quarterly gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1998–2002

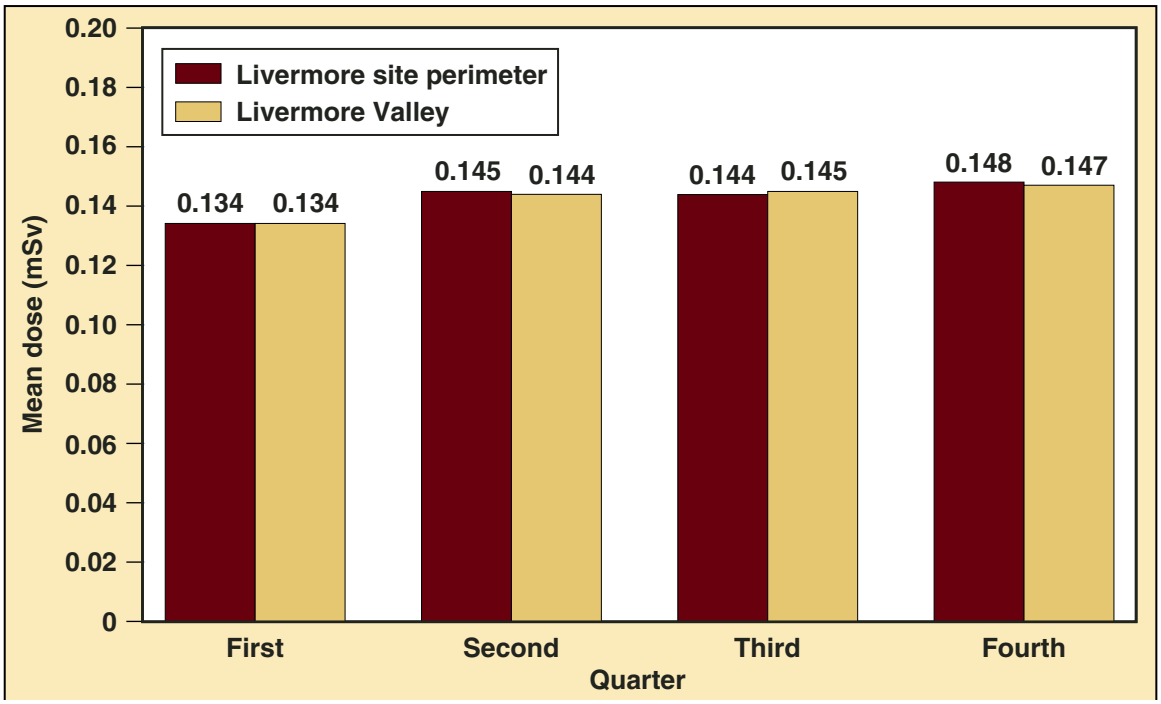

Figure 12-5. Comparison of the 2002 LLNL site perimeter and the Livermore Valley TLD quarterly mean dose (mSv)

Table 12-1. Calculated dose from TLD environmental radiation measurement, Livermore site perimeter, 2002

Location[a]	Quarterly Dose (mSv)[b]				Annual Dose[c]
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	(mSv)
L-001-TD	0.133 ± 0.013	0.154 ± 0.009	0.143 ± 0.005	0.141 ± 0.001	0.571 ± 0.017
L-004-TD	0.147 ± 0.007	0.148 ± 0.007	0.160 ± 0.003	0.163 ± 0.012	0.618 ± 0.016
L-005-TD	0.141 ± 0.008	0.155 ± 0.009	0.157 ± 0.005	0.156 ± 0.009	0.609 ± 0.016
L-006-TD	0.157 ± 0.008	0.165 ± 0.002	0.159 ± 0.004	0.168 ± 0.011	0.649 ± 0.014
L-011-TD	0.116 ± 0.004	0.128 ± 0.005	0.120 ± 0.010	0.124 ± 0.006	0.488 ± 0.013
L-014-TD	0.125 ± 0.008	0.135 ± 0.002	0.136 ± 0.003	0.142 ± 0.010	0.538 ± 0.013
L-016-TD	0.131 ± 0.008	0.138 ± 0.007	0.143 ± 0.005	0.143 ± 0.015	0.555 ± 0.019
L-042-TD	0.132 ± 0.009	0.147 ± 0.012	0.144 ± 0.006	0.152 ± 0.008	0.575 ± 0.018
L-043-TD	0.133 ± 0.010	0.140 ± 0.007	0.131 ± 0.004	0.142 ± 0.009	0.546 ± 0.016
L-047-TD	0.119 ± 0.015	0.128 ± 0.007	0.127 ± 0.012	0.135 ± 0.004	0.509 ± 0.021
L-052-TD	0.131 ± 0.008	0.146 ± 0.008	0.143 ± 0.005	0.145 ± 0.010	0.565 ± 0.016
L-056-TD	0.134 ± 0.008	0.152 ± 0.001	0.153 ± 0.005	0.154 ± 0.006	0.593 ± 0.011
L-068-TD	0.146 ± 0.013	0.148 ± 0.005	0.157 ± 0.003	0.155 ± 0.004	0.606 ± 0.015
L-069-TD	0.130 ± 0.005	0.143 ± 0.003	0.138 ± 0.004	0.149 ± 0.012	0.560 ± 0.014
Mean[d]	**0.134 ± 0.006**	**0.145 ± 0.006**	**0.144 ± 0.007**	**0.148 ± 0.006**	**0.571 ± 0.025**

Note: Measurement represents the TLD absorbed dose in mR converted to mSv.

a See Figure 12-1 in the main volume for locations.

b Measurement uncertainty is reported as ±2σ of the data.

c Uncertainty is reported as the root mean square of the quarterly means.

d Uncertainty associated with the quarterly means is reported as two standard errors of the location data.

Table 12-2. Calculated dose from TLD environmental radiation measurement, Livermore Valley, 2002

Location[a]	Quarterly Dose (mSv)[b]				Annual Dose[c]
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	(mSv)
V-018-TD	0.110 ± 0.007	0.119 ± 0.005	0.113 ± 0.004	0.121 ± 0.001	0.463 ± 0.010
V-019-TD	0.129 ± 0.004	0.135 ± 0.003	0.136 ± 0.010	0.134 ± 0.002	0.534 ± 0.011
V-022-TD	0.142 ± 0.010	0.160 ± 0.008	0.154 ± 0.019	0.160 ± 0.007	0.616 ± 0.024
V-024-TD	0.139 ± 0.003	—[d]	0.150 ± 0.008	0.161 ± 0.005	0.600 ± 0.010
V-027-TD	0.126 ± 0.009	0.133 ± 0.007	0.136 ± 0.003	0.137 ± 0.008	0.532 ± 0.014
V-028-TD	0.135 ± 0.014	0.144 ± 0.005	0.141 ± 0.010	0.149 ± 0.014	0.569 ± 0.023
V-030-TD	0.135 ± 0.008	0.142 ± 0.008	0.143 ± 0.004	0.145 ± 0.015	0.565 ± 0.019
V-032-TD	0.131 ± 0.004	0.150 ± 0.007	0.180 ± 0.127	0.142 ± 0.005	0.603 ± 0.127
V-033-TD	0.148 ± 0.012	0.150 ± 0.003	0.155 ± 0.001	0.145 ± 0.008	0.598 ± 0.015
V-035-TD	0.140 ± 0.007	0.135 ± 0.005	0.138 ± 0.008	0.143 ± 0.005	0.556 ± 0.013
V-037-TD	0.144 ± 0.013	0.147 ± 0.006	0.158 ± 0.005	0.143 ± 0.003	0.592 ± 0.015
V-045-TD	0.130 ± 0.012	0.143 ± 0.005	0.147 ± 0.005	0.147 ± 0.003	0.567 ± 0.014
V-057-TD	0.144 ± 0.002	0.154 ± 0.012	0.161 ± 0.010	0.160 ± 0.002	0.619 ± 0.016
V-060-TD	0.147 ± 0.011	0.150 ± 0.007	0.146 ± 0.008	0.152 ± 0.005	0.595 ± 0.016
V-066-TD	0.128 ± 0.009	—[d]	0.149 ± 0.003	0.149 ± 0.002	0.568 ± 0.010
V-070-TD	0.130 ± 0.006	0.141 ± 0.006	0.136 ± 0.006	0.152 ± 0.010	0.559 ± 0.014
V-072-TD	0.157 ± 0.006	0.178 ± 0.011	0.176 ± 0.029	0.174 ± 0.006	0.685 ± 0.032
V-074-TD	0.127 ± 0.007	0.142 ± 0.006	0.125 ± 0.003	—[d]	0.525 ± 0.010
V-075-TD	0.110 ± 0.007	0.117 ± 0.006	0.113 ± 0.011	0.124 ± 0.009	0.464 ± 0.017
V-076-TD	0.124 ± 0.007	0.124 ± 0.014	0.122 ± 0.002	0.133 ± 0.007	0.503 ± 0.017
V-077-TD	0.129 ± 0.005	0.135 ± 0.004	0.140 ± 0.005	0.150 ± 0.017	0.554 ± 0.019
V-122-TD	0.146 ± 0.012	0.178 ± 0.010	0.172 ± 0.008	0.170 ± 0.003	0.666 ± 0.018
Mean [e]	**0.134 ± 0.005**	**0.144 ± 0.007**	**0.145 ± 0.008**	**0.147 ± 0.006**	**0.570 ± 0.013**

Note: Measurement represents the TLD absorbed dose in mR converted to mSv.

a See Figure 12-2 in the main volume for locations.

b Measurement uncertainty is reported as $\pm 2\sigma$ of the data.

c Annual dose is reported as 4 times the available quarterly mean data. The uncertainty is reported as the root mean square of the !!quarterly errors reported.

d Data are not available due to missing or damaged TLD.

e Uncertainty associated with the quarterly means is reported as two standard errors of the location data.

Table 12-3. Calculated dose from TLD environmental radiation measurement, Site 300 perimeter, 2002

Location[a]	Quarterly Dose (mSv)[b]				Annual Dose[c]
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	(mSv)
3-078-TD	0.143 ± 0.003	0.149 ± 0.011	0.149 ± 0.010	0.160 ± 0.007	0.601 ± 0.017
3-081-TD	0.171 ± 0.006	0.181 ± 0.015	0.182 ± 0.009	—[d]	0.712 ± 0.018
3-082-TD	—[e]	0.174 ± 0.002	0.175 ± 0.003	0.168 ± 0.001	0.689 ± 0.004
3-085-TD	0.151 ± 0.010	0.167 ± 0.006	0.197 ± 0.009	0.132 ± 0.002	0.647 ± 0.015
3-086-TD	0.154 ± 0.002	0.174 ± 0.003	0.178 ± 0.014	0.175 ± 0.012	0.681 ± 0.019
3-088-TD	0.158 ± 0.007	0.166 ± 0.005	0.172 ± 0.011	0.177 ± 0.008	0.673 ± 0.016
3-089-TD	0.163 ± 0.007	0.178 ± 0.006	0.178 ± 0.006	0.179 ± 0.006	0.698 ± 0.013
3-091-TD	0.162 ± 0.006	0.172 ± 0.007	0.193 ± 0.012	0.183 ± 0.010	0.710 ± 0.018
3-121-TD	0.171 ± 0.002	0.202 ± 0.001	0.182 ± 0.006	0.202 ± 0.008	0.757 ± 0.010
3-123-TD	0.132 ± 0.004	0.145 ± 0.002	—[d]	—[d]	0.554 ± 0.004
3-124-TD	0.141 ± 0.010	0.150 ± 0.002	—[d]	—[d]	0.582 ± 0.010
3-125-TD	—[e]	0.137 ± 0.010	—[d]	—[d]	—[f] —[g]
3-126-TD	0.121 ± 0.018	0.139 ± 0.007	—[d]	—[d]	0.520 ± 0.019
Mean[h]	**0.152 ± 0.008**	**0.164 ± 0.011**	**0.178 ± 0.009**	**0.172 ± 0.014**	**0.666 ± 0.021**

Note: Measurement represents the TLD absorbed dose in mR converted to mSv.

a See Figure 12-3 in the main volume for locations.

b Measurement uncertainty is reported as ±2σ of the data.

c Annual dose is reported as 4 times the available quarterly mean data. The uncertainty is reported as the root mean square of the quarterly !!!!errors reported.

d Location removed

e Data are not available due to missing or damaged TLD.

f Insufficient number of samples to calculate annual dose.

g Insufficient number of samples to calculate standard error

h Uncertainty associated with the quarterly means is reported as two standard errors of the location data.

Table 12-4. Calculated dose from TLD environmental radiation measurement, Tracy and other off-site !locations in the vicinity of Site 300, 2002

Location[a]	Quarterly Dose (mSv)[b]				Annual Dose[c]
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	(mSv)
3-092-TD	0.156 ± 0.018	0.158 ± 0.005	0.157 ± 0.007	0.176 ± 0.008	0.647 ± 0.021
3-093-TD	0.123 ± 0.003	0.123 ± 0.010	0.133 ± 0.004	0.166 ± 0.013	0.545 ± 0.017
Mean[d]	**0.140 ± 0.033**	**0.141 ± 0.035**	**0.145 ± 0.024**	**0.171 ± 0.010**	**0.597 ± 0.055**
3-090-TD	0.172 ± 0.011	0.182 ± 0.005	0.185 ± 0.007	0.176 ± 0.008	0.715 ± 0.016
3-099-TD	0.141 ± 0.012	0.164 ± 0.010	0.157 ± 0.004	0.166 ± 0.013	0.628 ± 0.021
Mean[d]	**0.157 ± 0.031**	**0.173 ± 0.018**	**0.171 ± 0.028**	**0.171 ± 0.010**	**0.672 ± 0.047**

Note: Measurement represents the TLD absorbed dose in mR converted to mSv.

a See Figure 12-3 in the main volume for locations.

b Measurement uncertainty is reported as ±2σ of the data.

c Annual dose is reported as 4 times the available quarterly mean data. The uncertainty is reported as the root mean square of the !!!quarterly errors reported.

d Uncertainty associated with the quarterly means is reported as two standard errors of the location data.

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Acronyms and Abbreviations

See also the Glossary for further definition of selected terms.

A	**ALARA**	As low as reasonably achievable
	ANSI	American National Standards Institute
	ATSDR	Agency for Toxic Substances and Disease Registry
	AVLIS	Advanced Vapor Laser Isotope Separation
B	**BAAQMD**	Bay Area Air Quality Management District
	Bq	Becquerel
	BSA	Blanket Service Agreement
C	**CAM**	Continuous air monitor
	CAMP	Corrective Action Monitoring Program
	CCR	California Code of Regulations
		Container Content Report
	CD	Compact disc
	CDFG	California Department of Fish and Game
	CEI	Compliance Evaluation Inspection
	CEQA	California Environmental Quality Act of 1970
	CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
	CERCLA/SARA	Superfund Amendments and Reauthorization Act (SARA)
	CFR	Code of Federal Regulations
	Chromium(VI)	Hexavalent chromium
	Ci	Curie
	CNPS	California Native Plant Society
	COC	Constituent of concern
	COD	Chemical oxygen demand
	CVRWQCB	Central Valley Regional Water Quality Control Board
	CWA	(Federal) Clean Water Act
D	**D&D**	Decommissioning and decontamination
	DCG	Derived Concentration Guide
	DHS	Department of Health Services

	DMP	Detection Monitoring Program
	DOE	U.S. Department of Energy
	DRB	Drainage Retention Basin
	DTSC	(California Environmental Protection Agency), Department of Toxic Substances Control
	DWTF	Decontamination and Waste Treatment Facility
E	**EA**	Environmental assessment
	EDE	Effective dose equivalent
	EDO	Environmental Duty Officer
	EIS	Environmental impact statement
	EML	Environmental Monitoring Laboratory
	EMRL	Environmental Monitoring Radiation Laboratory
	EMS	Environmental Management System
	EOG	Environmental Operations Group
	EPA	Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
	EPD	Environmental Protection Department (LLNL)
	EPL	Effluent pollutant limit
	ERD	Environmental Restoration Division (of the Environmental Protection Department at LLNL)
	ES&H	Environment, Safety, and Health
	ESB	East Settling Basin
	EWSF	Explosives Waste Storage Facility
	EWTF	Explosives Waste Treatment Facility
F	**FEC**	Federal Electronics Challenge
	FFA	Federal facility agreement
	FFCA	Federal Facilities Compliance Act
	FY	fiscal year
G	**GBq**	Gigabecquerel (10^9 Bq)
	GEM	Global Electric Motorcar
	GPS	Global positioning system
	GSA	General Services Area (LLNL Site 300)
	GWP	Ground Water Project

H	**HCAL**	Hazards Control Department's Analytical Laboratory
	HE	High explosives
	HEPA	High-efficiency particulate air (filter)
	HMX	Cyclotetramethyltetramine. Also referred to as octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
	HPGe	High-purity germanium
	HSU	Hydrostratigraphic unit
	HT	Tritiated hydrogen gas (See also tritium in Glossary.)
	HTO	Tritiated water and water vapor (See also tritium in Glossary.)
I	**IC**	Internal combustion
	ICRP	International Commission on Radiological Protection
	IQR	Interquartile range
	ISMS	Integrated Safety Management System
L	**LBNL**	Lawrence Berkeley National Laboratory
	LEED	Leadership in Energy and Environmental Design
	LLNL	Lawrence Livermore National Laboratory
	LLW	Low-level (radioactive) waste
	LOS	Limit of sensitivity
	LWRP	Livermore Water Reclamation Plant
M	**MAPEP**	Mixed Analyte Performance Evaluation Program
	mCi	Millicurie (10^{-3} Ci)
	MCL	Maximum contaminant level
	MDC	Minimum detectable concentration
	MEI	Maximally exposed individual
	ML	Million liters
	MIXED	Mixed low-level waste
	MRP	Monitoring and Reporting Program
	mSv	Millisievert (10^{-3} Sv)
N	**NCR**	Nonconformance report
	NCRP	National Council on Radiation Protection and Measurements
	NEPA	National Environmental Policy Act
	NESHAPs	National Emissions Standards for Hazardous Air Pollutants
	NHPA	National Historic Preservation Act

	NIF	National Ignition Facility
	NNSA	National Nuclear Security Administration
	NOV	Notice of violation
	NPDES	National Pollutant Discharge Elimination System
	NRC	Nuclear Regulatory Commission
	nSv	Nanosievert (10^{-9} Sv)
O	**OBT**	Organically bound tritium
	ORAD	Operations and Regulatory Affairs Division (of the Environmental Protection Department at LLNL)
	OU	Operable unit
P	**P2**	Pollution prevention
	PCB	Polychlorinated biphenyl
	PCE	Perchloroethylene (or perchloroethene). Also called tetrachloroethylene (or tetrachloroethene).
	PHA	Public health assessment
	pHMS	pH Monitoring Station
	PM-10	Particulate matter
	POC	Point of compliance
	ppb	Parts per billion
	ppm	Parts per million
	PRAG	Permits and Regulatory Affairs Group
	PV	Photovoltaic
Q	**QA**	Quality assurance
	QC	Quality control
R	**RCRA**	Resource Conservation and Recovery Act of 1976
	RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
	RHWM	Radioactive and Hazardous Waste Management Division (of the Environmental Protection Department at LLNL)
	RL	Reporting limit
	ROD	Record of Decision
	ROI	Return on investment
	RWQCB	Regional water quality control board
S	**SAA**	Streambed alteration agreement
	SAER	Site Annual Environmental Report

	Sandia/California	Sandia National Laboratories/California
	SARA	Superfund Amendment and Reauthorization Act of 1986 (see also CERCLA/SARA)
	SDF	Sewer Diversion Facility
	SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
	SI	Système International d'Unités
	Site 300	LLNL's Experimental Test Site, located approximately 24 km east of the Livermore site
	SJCEHD	San Joaquin County Environmental Health Department
	SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District
	SLAC	Stanford Linear Accelerator Center
	SMS	Sewer Monitoring Station
	SOP	Standard operating procedure
	SOV	Summary of violations
	STP	Site Treatment Plan
	Sv	Sievert
	SW-MEI	Site-wide maximally exposed individual member (of the public)
	SWPPP	Storm Water Pollution Prevention Plan
T	**TAG**	Technical Assistance Grant
	TBq	Terabecquerel (10^{12} Bq)
	TCE	Trichloroethene (or trichloroethylene)
	TDS	Total dissolved solids
	TF	Treatment facility
	TLD	Thermoluminescent dosimeter
	TNT	Trinitrotoluene
	TOC	Total organic carbon
	TOX	Total organic halides
	TRI	Toxics Release Inventory
	Tri-Valley CAREs	Tri-Valley Communities Against a Radioactive Environment
	TRU	Transuranic (waste)
	TSCA	Toxic Substances Control Act
	TSS	Total suspended solids
	TTO	Total toxic organics

	TWMS	Total Waste Management System
U	**UC**	University of California
	USFWS	U.S. Fish and Wildlife Service
V	**VOC**	Volatile organic compound
	VTF	Vapor treatment facility
W	**WAA**	Waste accumulation area
	WDR	Waste Discharge Requirement
	WMA	Waste Management Area
	WSS	Work Smart Standards
Z	**Zone 7**	Alameda County Flood Control and Conservation District, Zone 7

GLOSSARY

A **Absorbed dose:** the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material, in which the absorbed dose is expressed in units of rad or gray (1 rad = 0.01 gray)

Accuracy: the closeness of the result of a measurement to the true value of the quantity measured

Action level: defined by regulatory agencies, the level of pollutants which, if exceeded, requires regulatory action

Aerosol: a gaseous suspension of very small particles of liquid or solid

Alameda County Flood Control and Water Conservation District: also known as Zone 7, the water management agency for the Livermore-Amador Valley with responsibility for water treatment and distribution, and responsible for management of agricultural and surface water and the ground water basin

Alluvium: sediment deposited by flowing water

Alpha particle: a positively charged particle emitted from the nucleus of an atom, having mass and charge equal to those of a helium nucleus (two protons and two neutrons)

Ambient air: the surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures; not considered in monitoring purposes when immediately adjacent to emission sources

Analysis of variance (ANOVA): a test of whether two or more sample means are statistically different

Analyte: the specific component measured in a chemical analysis

Anion: a negatively charged ion, such as Cl^-

Aquifer: a saturated layer of rock or soil below the ground surface that can supply usable quantities of ground water to wells and springs, and be a source of water for domestic, agricultural, and industrial uses

Aquitard: low-permeability geologic formation that bounds an aquifer

Atom: the smallest particle of an element capable of entering into a chemical reaction

Atomic absorption (AA) spectroscopy: a method used to determine the elemental composition of a sample, where the sample is vaporized and its light absorbance measured

B **Barcad:** device that samples water in a well in which water, collected in a discrete water-bearing zone, is forced to the surface by pressurized nitrogen

Bay Area Air Quality Management District (BAAQMD): the local agency responsible for regulating stationary air emission sources (including the LLNL Livermore site) in the San Francisco Bay Area

Becquerel (Bq): the SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second

Beta particle: a negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron

Biochemical (biological) oxygen demand (BOD): a measure of the amount of dissolved oxygen that microorganisms need to break down organic matter in water, used as an indicator of water quality

Blowdown: water discharged from cooling towers in order to control total dissolved solids concentrations by allowing make-up water to replenish cooling apparatuses

C **California Code of Regulations (CCR):** codification of regulations promulgated by the State of California

California Environmental Quality Act of 1970 (CEQA): statute that requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions

CAP88-PC: computer code required by the EPA for modeling air emissions of radionuclides

Categorical discharge: discharge from a process regulated by EPA rules for specific industrial categories

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

Chemistry and Materials Science Environmental Services (CES): an LLNL laboratory that analyzes environmental samples

Chlorofluorocarbon (CFC): a compound that has fluorine and chlorine atoms on a carbon backbone, such as Freons

Chlorocarbon: a compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethene

Code of Federal Regulations (CFR): a codification of all regulations promulgated by federal government agencies

Collective dose equivalent and collective effective dose equivalent: the sums of the dose equivalents or effective dose equivalents to all individuals in an exposed population within 80 km (50 miles) of the radiation source. These are evaluated by multiplying the dose received by an individual at each location by the number of individuals receiving that dose, and summing over all such products for locations within 80 km of the source. They are expressed in units of person-rem or person-sievert. The collective EDE is also referred to as the "population dose."

Committed dose equivalent: the predicted total dose equivalent to a tissue or organ over a 50-year period after an intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert; 100 rem equals one sievert).

Committed effective dose equivalent: the sum of the committed dose equivalents to various tissues in the body, each multiplied by an appropriate weighting factor representing the relative vulnerability of different parts of the body to radiation. Committed effective dose equivalent is expressed in units of rem or sievert.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA): administered by EPA, this program, also known as Superfund, requires private parties to notify the EPA after the release of hazardous substances or conditions that threaten to release hazardous substances, and undertake short-term removal and long-term remediation.

Cosmic radiation: radiation with very high energies originating outside the earth's atmosphere; it is one source contributing to natural background radiation

Curie (Ci): a unit of measurement of radioactivity, defined as the amount of radioactive material in which the decay rate is 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute; one Ci is approximately equal to the decay rate of one gram of pure radium

D **Daughter nuclide:** a nuclide formed by the radioactive decay of another nuclide, which is called the parent

De minimis: shortened form of "de minimis non curat lex," which means, "The law does not care for, or take notice of, very small or trifling matters," meaning a level that is so inconsequential that it cannot be cause for concern

Depleted uranium: uranium having a lower proportion of the isotope ^{235}U than is found in naturally occurring uranium. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 occur in depleted uranium in the weight-percentages 99.8, 0.2, and 5×10^{-4}, respectively. Depleted uranium is sometimes referred to as D-38.

Derived Concentration Guide (DCG): concentrations of radionuclides in water and air that could be continuously consumed or inhaled for one year and not exceed the DOE primary radiation standard to the public (100 mrem/y EDE)

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 that an organ or tissue would receive during a specified period of time (e.g., 50 or 70 years) as a result of one year's intake of one or more radionuclides

Dose equivalent: the product of absorbed dose in rad (or gray) in tissue and a quality factor representing the relative damage caused to living tissue by different kinds of radiation, and perhaps other modifying factors representing the distribution of radiation, etc. expressed in units of rem or sievert (1 rem = 0.01 sievert)

Dosimeter: a portable detection device for measuring the total accumulated exposure to ionizing radiation

Dosimetry: the theory and application of the principles and techniques of measuring and recording radiation doses

Downgradient: in the direction of groundwater flow from a designated area; analogous to downstream

Drainage Retention Basin (DRB): man-made, lined pond used to capture storm water runoff and treated water at the LLNL Livermore site

E **Effective dose equivalent (EDE):** an estimate of the total risk of potential effects from radiation exposure, it is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the decimal fraction of the risk arising from irradiation of a selected tissue to the total risk when the whole body is irradiated uniformly to the same dose equivalent. These factors permit dose equivalents from nonuniform exposure of the body to be expressed in terms of an effective dose equivalent that is numerically equal to the dose from a uniform exposure of the whole body that entails the same risk as the internal exposure (ICRP 1980). The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent caused by penetrating radiation from sources external to the body, and is expressed in units of rem (or sievert).

Effluent: a liquid or gaseous waste discharged to the environment

Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA): act that requires facilities that produce, use, or store hazardous substances to report releases of reportable quantities or hazardous substances to the environment

Environmental impact report (EIR): a detailed report prepared pursuant to CEQA on the environmental impacts from any action carried out, approved, or funded by a California state, regional, or local agency

Environmental impact statement (EIS): 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.

Evapotranspiration: a process by which water is transferred from the soil to the air by plants that take the water up through their roots and release it through their leaves and other aboveground tissue

F **Federal facility:** a facility that is owned or operated by the federal government, subject to the same requirements as other responsible parties when placed on the Superfund National Priorities List

Federal facility agreement (FFA): a negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, RWQCB, and DOE).

Federal Register: a document published daily by the federal government containing notification of government agency actions, including notification of EPA and DOE decisions concerning permit applications and rule-making

Fiscal year: LLNL's fiscal year is from October 1 through September 30.

Freon 11: trichlorofluoromethane

Freon 113: 1,1,2-trichloro-1,2,2-trifluoroethane; also known as CFC 113

G **Gamma ray:** high-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom, frequently accompanying the emission of alpha or beta particles

Gram (g): the standard metric measure of weight approximately equal to 0.035 ounce

Gray (Gy): the SI unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray equals 100 rads, or 1 joule per kilogram.

Groundwater: all subsurface water

H **Half-life (radiological):** the time required for one-half the radioactive atoms in a given amount of material to decay; for example, after one half-life, half of the atoms will have decayed; after two half-lives, three-fourths; after three half-lives, seven-eighths; and so on, exponentially

Hazardous waste: hazardous wastes exhibit any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test), but other wastes that do not necessarily exhibit these characteristics have been determined to be hazardous by EPA. Although the legal definition of hazardous waste is complex, according to EPA the term generally refers to any waste that, if managed improperly, could pose a threat to human health and the environment.

(California) Hazardous Waste Control Act (HWCA): legislation specifying requirements for hazardous waste management in California

High-efficiency particulate air filter (HEPA): a throwaway, extended-media, dry type filter used to capture particulates in an air stream; HEPA collection efficiencies are at least 99.97% for 0.3 micrometer diameter particles

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX): a high-explosive compound

High explosives (HE): materials that release large amounts of chemical energy when detonated

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

I **Inorganic compounds:** compounds that either do not contain carbon or do not contain hydrogen along with carbon, including metals, salts, and various carbon oxides (e.g., carbon monoxide and carbon dioxide).

In situ: refers to the treatment of contaminated areas in place without excavation or removal, as in the in situ treatment of on-site soils through biodegradation of contaminants

Interim status: a legal classification allowing hazardous waste incinerators or other hazardous waste management facilities to operate while EPA considers their permit applications, provided that they were under construction or in operation by November 19, 1980 and can meet other interim status requirements

International Commission on Radiological Protection (ICRP): an international organization that studies radiation, including its measurement and effects

Interquartile range (IQR): the distance between the top of the lower quartile and the bottom of the upper quartile, which provides a measure of the spread of data

Isotopes: forms of an element having the same number of protons in their nuclei, but differing numbers of neutrons

L **Less than detection limits:** a phrase indicating that a chemical constituent was either not present in a sample, or is present in such a small concentration that it cannot be measured by a laboratory's analytical procedure, and therefore is not identified or not quantified at the lowest level of sensitivity.

Liter (L): the SI measure of capacity approximately equal to 1.057 quart

Livermore Water Reclamation Plant (LWRP): the City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site

Low-level waste: waste defined by DOE Order 5820.2A, which contains transuranic nuclide concentrations less than 100 nCi/g

Lower limit of detection: the smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level

Lysimeter: an instrument for measuring the water percolating through soils and determining the dissolved materials

M **Maximally exposed individual (MEI):** a hypothetical member of the public at a fixed location who, over an entire year, receives the maximum effective dose equivalent (summed over all pathways) from a given source of radionuclide releases to air. Generally, the MEI is different for each source at a site.

Maximum Contaminant Level (MCL): the highest level of a contaminant in drinking water that is allowed by the U.S. Environmental Protection Agency regulation

Multiple completion: a borehole with water surveillance monitoring devices (Barcads) placed at various levels and separated by impermeable layers of material such as grout. Usually referred to as a well, the uppermost "completion" is accessible from the surface, making physical sample-taking possible (as opposed to Barcads).

Metric units: Metric system and U.S. customary units and their respective equivalents are shown in Table GL-1. Except for temperature for which specific equations apply, U.S. customary units can be determined from metric units by multiplying the metric units by the U.S. customary equivalent. Similarly, metric units can be determined from U.S. customary equivalent units by multiplying the U.S. customary units by the metric equivalent.

Mixed waste: waste that has the properties of both hazardous and radioactive waste

N **National Emission Standards for Hazardous Air Pollutants (NESHAPs):** standards found in the Clean Air Act that set limits for hazardous air pollutants

National Environmental Policy Act (NEPA): federal legislation enacted in 1969 that requires all federal agencies to document and consider environmental impacts for federally funded or approved projects and the legislation under which DOE is responsible for NEPA compliance at LLNL

National Institute for Standards and Technology (NIST): the federal agency, formerly known as the National Bureau of Standards, responsible for reference materials against which laboratory materials are calibrated

National Pollutant Discharge Elimination System (NPDES): federal regulation under the Clean Water Act that requires permits for discharges into surface waterways

NEWTRIT: model used to calculate doses from environmental measurements

Table GL-1. Metric and U.S. customary unit equivalents

Metric unit	U.S. customary equivalent unit	U.S. customary unit	Metric equivalent unit
Length			
1 centimeter (cm)	0.39 inches (in)	1 inch (in)	2.54 centimeters (cm)
1 millimeter (mm)	0.039 inches (in)		25.4 millimeters (mm)
1 meter (m)	3.28 feet (ft)	1 foot (ft)	0.3048 meters (m)
	1.09 yards (yd)	1 yard (yd)	0.9144 meters (m)
1 kilometer (km)	0.62 miles (mi)	1 mile (mi)	1.6093 kilometers (km)
Volume			
1 liter (L)	0.26 gallons (gal)	1 gallon (gal)	3.7853 liters (L)
1 cubic meter (m^3)	35.32 cubic feet (ft^3)	1 cubic foot (ft^3)	0.028 cubic meters (m^3)
	1.35 cubic yards (yd^3)	1 cubic yard (yd^3)	0.765 cubic meters (m^3)
Weight			
1 gram (g)	0.035 ounces (oz)	1 ounce (oz)	28.6 gram (g)
1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.373 kilograms (kg)
1 metric ton (MT)	1.10 short ton (2000 pounds)	1 short ton (2000 pounds)	0.90718 metric ton (MT)
Geographic area			
1 hectare	2.47 acres	1 acre	0.40 hectares
Radioactivity			
1 becquerel (Bq)	2.7×10^{-11} curie (Ci)	1 curie (Ci)	3.7×10^{-10} becquerel (Bq)
Radiation dose			
1 rem	0.01 sievert (Sv)	1 sievert (Sv)	100 rem
Temperature			
°C = (°F–32)/1.8		°F = (°C x1.8) + 32	

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), or into air (e.g., a pile of uranium tailings)

Nuclear Regulatory Commission (NRC): the federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense

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.

O **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

P **Part B permit:** the second, narrative section submitted by generators in the RCRA permitting process that covers in detail the procedures followed at a facility to protect human health and the environment

Parts per billion (ppb): 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

Parts per million (ppm): 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

Perched aquifer: aquifer that is separated from another water-bearing stratum by an impermeable layer

Performance standards (incinerators): specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in incinerator emissions

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.

Piezometer: instrument for measuring fluid pressure used to measure the elevation of the water table in a small, nonpumping well

Pliocene: geological epoch of the Tertiary period, starting about 12 million years ago

PM-10: fine particulate matter with an aerodynamic diameter equal to or less than 10 microns

Point source: any confined and discrete conveyance (e.g., pipe, ditch, well, or stack)

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

Q **Quality assurance (QA):** a system of activities whose purpose is to provide the assurance that standards of quality are attained with a stated level of confidence

Quality control (QC): 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, usually used because some types of radiation, such as alpha particles, are biologically more damaging than others. Quality factors for alpha, beta, and gamma radiation are in the ratio 20:1:1.

Quaternary: the geologic era encompassing the last 2–3 million years

R **Rad:** the unit of absorbed dose and the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue, and equal to 0.01 joule per kilogram, or 0.01 gray.

Radioactive decay: the spontaneous transformation of one radionuclide into a different nuclide (which may or may not be radioactive), or de-excitation to a lower energy state of the nucleus by emission of nuclear radiation, primarily alpha or beta particles, or gamma rays (photons)

Radioactivity: the spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope

Radionuclide: an unstable nuclide. See nuclide and radioactivity.

Regional Water Quality Control Board (RWQCB): 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.

Rem: a unit of radiation dose equivalent and effective dose equivalent describing the effectiveness of a type of radiation to produce biological effects; coined from the phrase "roentgen equivalent man," and the product of the absorbed dose (rad), a quality factor (Q), a distribution factor, and other necessary modifying factors. One rem equals 0.01-sievert.

Resource Conservation and Recovery Act of 1976 (RCRA): a program of federal laws and regulations that govern the management of hazardous wastes, and applicable to all entities that manage hazardous wastes

Risk assessment: the use of established methods to measure the risks posed by an activity or exposure by evaluating the relationship between exposure to radioactive substances and the subsequent occurrence of health effects and the likelihood for that exposure to occur

Roentgen (R): a unit of measurement used to express radiation exposure in terms of the amount of ionization produced in a volume of air

S **Sampling and Analysis Plan:** a detailed document that describes the procedures used to collect, handle, and analyze groundwater samples, and details quality control measures that are implemented to ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements

San Francisco Bay Regional Water Quality Control Board (SFBRWCB): the local agency responsible for regulating stationary air emission sources (including the Livermore site) in the San Francisco Bay Area

San Joaquin County Health District (SJCHD): the local agency that enforces underground-tank regulations in San Joaquin County, including Site 300

San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD): the local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County

Sanitary waste: most simply, waste generated by routine operations that is not regulated as hazardous or radioactive by state or federal agencies

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

Sievert (Sv): the SI unit of radiation dose equivalent and effective dose equivalent, that is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. 1 Sv equals 100 rem.

Sitewide Maximally Exposed Individual (SW-MEI): a hypothetical person who receives, at the location of a given publicly accessible facility (such as a church, school, business, or residence), the greatest LLNL-induced effective dose equivalent (summed over all pathways) from all sources of radionuclide releases to air at a site. Doses at this receptor location caused by each emission source are summed, and yield a larger value than for the location of any other similar public facility. This individual is assumed to continuously reside at this location 24 hours per day, 365 days per year.

Specific conductance: measure of the ability of a material to conduct electricity; also called conductivity

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.

Superfund Amendments and Reauthorization Act (SARA): act enacted in 1986, which amended and reauthorized CERCLA for five years at a total funding level of $8.5 billion

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.

Système International d'Unités (SI): an international system of physical units which include meter (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent)

T

Thermoluminescent dosimeter (TLD): a device used to measure external beta or gamma radiation levels, and which contains a material that, after exposure to beta or gamma radiation, emits light when processed and heated

Total dissolved solids (TDS): the portion of solid material in a waste stream that is dissolved and passed through a filter

Total organic carbon (TOC): the sum of the organic material present in a sample

Total organic halides (TOX): the sum of the organic halides present in a sample

Total suspended solids (TSS): the total mass of particulate matter per unit volume suspended in water and wastewater discharges that is large enough to be collected by a 0.45 micron filter

Tritium: the radioactive isotope of hydrogen, containing one proton and two neutrons in its nucleus, which decays at a half-life of 12.3 years by emitting a low-energy beta particle

Transuranic waste (TRU): material contaminated with alpha-emitting transuranium nuclides, which have an atomic number greater than 92 (e.g. ^{239}Pu), half-lives longer than 20 years, and are present in concentrations greater than 100 nCi/g of waste

U **Unsaturated zone:** that portion of the subsurface in which the pores are only partially filled with water and the direction of water flow is vertical; is also referred to as the vadose zone.

U.S. Department of Energy (DOE): the federal agency responsible for conducting energy research and regulating nuclear materials used for weapons production

U.S. Environmental Protection Agency (EPA): 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.

V **Vadose zone:** the partially saturated or unsaturated region above the water table that does not yield water to wells

Volatile organic compound (VOC): liquid or solid organic compounds that have a high vapor pressure at normal pressures and temperatures and thus tend to spontaneously pass into the vapor state

W **Waste accumulation area (WAA):** 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

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, and the level to which a well that is screened in the unconfined aquifer would fill with water

Weighting factor: a tissue-specific value used to calculate dose equivalents which 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 International Commission on Radiological Protection (ICRP 1980).

Wind rose: a diagram that shows the frequency and intensity of wind from different directions at a specific location

Z **Zone 7:** the common name for the Alameda County Flood Control and Water Conservation District

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