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Environmental Report 1992

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THIS DOCUMENT CONTAINS UNCLASSIFIED INFORMATION

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

As in the 1991 report, data are presented in *Système International* (SI) units. This is consistent with the federal law stated in the Metric Conversion Action of 1975 (15 United States Code 205a et seq.); Presidential Executive Order 12770, Metric Usage in Federal Government programs (July 25, 1991); and DOE's policy on the use of the metric system (DOE Order 5900.2), which states in part that "All Departmental Elements should take steps, as directed by Executive Order 12770, to use the Metric System (SI) in procurements, grants, publications, and other business-related activities." Radiological results are presented in becquerels, and summary statistics are repeated in curies ($1 \text{ Bq} = 2.7 \times 10^{-11} \text{ Ci}$). Similarly, dose is presented in millisieverts and summary statistics are repeated in millirem ($1 \text{ mSv} = 100 \text{ mrem}$).

Results for both the Livermore site and Site 300 are presented in each chapter, and trends in monitoring data are shown graphically.

This document is the responsibility of the Environmental Monitoring and Analysis Division of the EPD. Within this division, personnel from the Environmental Monitoring Section (EMS) sampled the environment, interpreted the results, performed the impact analysis of radiological emissions from LLNL, and compiled the information presented here.

Monitoring data were obtained through the combined efforts of the EMS, the Nuclear Chemistry Division, the Radiological Analytical Sciences laboratory, and the Hazards Control Department of LLNL. Special recognition is deserved for the dedication and professionalism of these environmental monitoring technicians—Paris E. Althouse, Paul C. Dickinson, David L. Graves, Renee Needens,* Donald G. Ramsey, Rebecca J. Ward, and Rhonda L. Welsh—and to these data management personnel—Nina Hankla,* Jennifer Clark,* Colleen R. Frost, and Connie Wells.*

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Introduction

Lawrence Livermore National Laboratory (LLNL), a U.S. Department of Energy facility operated by the University of California, serves as a national resource of scientific, technical, and engineering capability with a special focus on national security. Over the years, the Laboratory's mission has been broadened to encompass such areas as strategic defense, energy, the environment, biomedicine, the economy, and education. The Laboratory carries out this mission in compliance with local, state, and federal environmental regulatory requirements and takes measures to ensure that its operations do not adversely affect the environment or public health. It does so with the support of the Environmental Protection Department, which is responsible for environmental monitoring, environmental compliance, environmental restoration, and hazardous waste management. The first activity, environmental monitoring, is the focus of this report.

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

During 1992, the Environmental Protection Department conducted sampling of air, sewage effluent, ground water, surface water, soil, vegetation and foodstuffs, and took measurements of environmental radiation. It performed more than 150,000 analyses of environmental samples. The analytical results are summarized in the chapters that follow, along with evaluations of the impact of radioactive and nonradioactive materials, a discussion of the effects of LLNL operations on the environment, and a summary of the activities undertaken to comply with local, state, and federal environmental laws.

Environmental Monitoring Results

LLNL's sampling networks undergo constant evaluation; changes to them are made, as necessary, to ensure adequate monitoring of all media potentially affected by LLNL operations. Once samples are collected, they are analyzed for radioactive and nonradioactive substances using standard methods such as EPA-

Executive Summary

approved analytical procedures, special systems such as the continuous monitoring system for Livermore site sewage, or special analytical techniques designed to measure very low levels of radionuclides. Environmental radiation is also measured directly using dosimeters.

The primary ongoing pollutant of concern continues to be tritium, the radioactive isotope of hydrogen. The emissions of tritium at the Livermore site were significantly lower in 1992 than in past years. The primary source of tritium emissions, the Tritium Facility, has ceased operations except for inventory reduction activities. The lower tritium emissions are reflected in the tritium measured in surface water, rain water, and runoff. Small decreases have also been seen in measured values for tritium in air and vegetation.

Particulate matter in air is monitored for beryllium and for radionuclides, including plutonium and uranium. Most of the radioactivity detected is from naturally occurring radionuclides and global fallout from historical nuclear weapons testing. Plutonium is found at low levels around the perimeter of the Livermore site and at even lower levels at Site 300. The highest average plutonium value was measured at a location on the Livermore site near Building 531. The average concentration there was less than 2.7×10^{-13} becquerels per milliliter (Bq/mL) of air (less than 7×10^{-18} $\mu\text{Ci/mL}$), a small fraction of the regulatory exposure guideline of 7.4×10^{-10} Bq/mL of air (2×10^{-14} $\mu\text{Ci/mL}$).

To determine whether operations at Site 300 are affecting the amounts of uranium, which occurs naturally, environmental analysts measure the relative amounts of two isotopes of uranium, uranium-238 and uranium-235. Natural uranium is primarily uranium-238, with 0.7% uranium-235. Most LLNL uranium operations use uranium-238, a slightly radioactive isotope. The observed ratio of the two isotopes, therefore, can reveal whether LLNL operations have added uranium-238 to the environment at Site 300. The ratios of airborne particulate uranium in January and October 1992 deviate from the natural ratio, indicating the presence of airborne uranium-238 from Site 300 operations. The measured concentrations of uranium-238, however, are only a small fraction (24/100,000) of the regulatory exposure guideline of $0.03 \mu\text{g/m}^3$.

Discharges of radioactive and hazardous materials to the combined sanitary and industrial sewer at the Livermore site are controlled by limiting the use of those materials, implementing engineering controls, and routing discharged material to retention tanks for later characterization and treatment. Flow proportional samples of discharged wastewater are regularly collected and analyzed to assure that LLNL's sewage effluent meets the requirements of the permit granted by the City of Livermore. In addition, effluent is monitored continuously for pH, selected metals, and radioactivity. Should concentrations be detected above warning levels, LLNL's Sewer Diversion System would be automatically activated. The diversion system will capture all but the first few

minutes of wastewater flow that causes an alarm, thereby protecting the Livermore Water Reclamation Plant (LWRP) and minimizing any required cleanup. Eight minor metal releases were detected in 1992. In every case, a more detailed analysis of the diverted sewage showed that the slight contamination did not represent a threat to LWRP operations. With the exception of elevated levels of oil and grease in the first half of 1992, no regulatory violations were noted. The results of the effluent monitoring program demonstrate the success of LLNL's discharge control programs.

As in 1991, monitoring results for sewage show concentrations of plutonium and cesium slightly higher than the lowest values seen historically. These results are related to sewer cleaning with new, more effective equipment. However, the measured plutonium activities were further elevated during the months of January through March 1992. For those three months, the data increase by a factor of ten above values measured during 1991 and the other months of 1992. Possible causes of the elevated levels were investigated, but no definite determination of the cause could be made. Nonetheless, the plutonium levels observed in LLNL effluent are 20 times below the drinking water standard for alpha radiation, and the highest activities observed in LWRP sludge are more than 16 times below the proposed EPA guideline for the unrestricted use of soil.

Water sampling and analysis are a large part of the LLNL surveillance monitoring effort. The waters monitored include lakes, streams, rainfall, tap water, storm water runoff, drinking water supply wells, and ground water monitoring wells. The samples are analyzed for gross alpha and beta radiation, tritium, and nonradioactive pollutants including solvents, metals, and pesticides. No radiological or nonradiological pollutant was observed in storm water above regulatory limits at the Livermore site. All tritium concentrations in drinking water supply wells at Site 300 were less than 2/1000 of the California drinking water standard for tritium. Trichloroethene was the major nonradiological constituent of concern in Site 300 ground water monitoring. It was detected in a backup water supply well, but its concentration in the samples from this well never exceeded one-fourth of the drinking water standard. Nevertheless, an investigation of the source of the trichloroethene is continuing.

Ground water protection activities at LLNL are performed as part of the investigation, study, monitoring and remediation of contamination caused by past practices. Ground water monitoring at the Livermore site investigates contamination at the site according to the Federal Facility Agreement for the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA). LLNL conducts ground water monitoring at Site 300 under two programs, one to meet regulatory commitments established for site-specific CERCLA investigations, and a second consisting of routine compliance monitoring around landfill and wastewater surface impoundment units.

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During 1992, the major remediation effort for the Livermore site focused on submittal of the Record of Decision in the CERCLA process and bringing one additional ground water treatment unit on-line. At Site 300, monitoring efforts continued to support ongoing remediation efforts and the preparation of a site-wide remedial investigation report. Other major efforts included closure plans of Pits 1 and 7, and conducting "pump and treat" operations in the General Services Area. Although compliance monitoring documented several areas at Site 300 where contaminants in ground water exceeded the State Maximum Contaminant Levels (MCLs) for drinking water, they were all in areas of known contamination and at levels similar to previous years, or following predicted trends. In no case did humans or animals drink or use the water.

Vegetation and foodstuffs are monitored for their tritium content; milk is further analyzed to determine the amounts of cesium-137 (a fallout radionuclide) and potassium-40 (a naturally occurring radionuclide). Generally, the milk samples taken are of goat's milk, but in 1992 one of the participants in the monitoring program acquired a cow, and this milk was analyzed as well. As in past years, the levels of radiation in milk were minimal and for the most part could not be distinguished from background radiation levels. The tritium concentrations in vegetation samples taken near the Livermore site were greater than those taken from more distant locations. The nearby vegetation tritium concentrations were about one-half those reported in 1991, while the concentrations in samples taken at greater distances were essentially unchanged from 1991. As in the past, the tritium concentrations in Livermore Valley wines are slightly above those for wines tested from Europe and other locations in California; however, even the highest detected value, 8.8 Bq/L (240 pCi/L), is just over 1% of the amount California allows in drinking water.

Soils are sampled at the Livermore site and Site 300 and are analyzed for radionuclides and beryllium; arroyo sediments from storm water drainage channels are sampled at the Livermore site and analyzed for radionuclides, metals, organic compounds, and pesticides. All measured values for 1992 were consistent with historic data and were well below regulatory limits. A special study of shallower sediment samples that were analyzed for metals and radionuclides showed beryllium-7, zinc, and copper at higher concentrations in the shallow samples. In fact, beryllium-7 was only detected in shallow samples, but because it is generated from cosmic rays and has a short half-life (53.4 days), there is little chance for it to migrate to deeper levels before decaying. The higher concentrations of zinc and copper could be attributed to the normal operation of motor vehicles. Copper is found in brake pads and diesel fuel, and zinc is present in tires; both are regarded as potential sources of storm water pollution, and motor vehicles provide a constant source of such pollutants.

LLNL also maintains an extensive network of direct radiation monitors, using thermoluminescent dosimeters (TLDs) for gamma radiation and neutron monitors developed at LLNL for neutron radiation. TLD measurements at the Livermore-site perimeter averaged 0.65 mSv (65 mrem) and at the Site 300 perimeter averaged 0.78 mSv (78 mrem). Neutron measurements at the Livermore-site perimeter averaged 0.057 mSv (57 mrem). All of these measurements are equivalent to natural background radiation levels.

Radiological Impact Assessment

The DOE environmental radiation protection standards are provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The primary DOE radiation standards for protection of the public are 1 mSv/y (100 mrem/y) effective dose equivalent for prolonged exposure, and 5 mSv/y (500 mrem/y) effective dose equivalent for occasional exposure. DOE and LLNL also comply with the EPA's standard for radiation protection, which applies to air emissions. It limits the whole-body effective dose equivalent to 0.1 mSv/y (10 mrem/y). Both limits are based on the maximum exposure that any individual member of the public could receive. Compliance with the limits is determined by computer modeling, which includes conservative assumptions and results in calculated exposures larger than exposures actually received by members of the public.

Routine LLNL operations during 1992 released a total of 6.55×10^{12} Bq (177 Ci) of tritium to the atmosphere; of that, 3.7×10^{12} Bq (100 Ci) was in the form of tritiated water. An additional 9.77×10^{12} Bq (264 Ci) was released by Sandia National Laboratories, California (SNL/CA), with approximately 4.81×10^{12} Bq (130 Ci) in the form of tritiated water. The amount of radioactivity released from LLNL during 1992 was less than that released during 1991, and was below the range of previous years. There were no accidental radionuclide releases to the atmosphere at either the Livermore site or Site 300 during 1992.

The total dose calculated for point source emissions, for a theoretical person having the greatest possible exposure at the Livermore site, is 0.69 μ Sv (0.069 mrem) and from diffuse emissions is 0.1 μ Sv (0.010 mrem), yielding a total dose of 0.79 μ Sv (0.079 mrem) for the Livermore site in 1992. This dose represents less than 1% of the EPA limit of 0.1 mSv/y (10 mrem/y) for airborne emissions. This value is much lower than those for previous years: dose values reported for 1991 and 1990 were 2.34 μ Sv (0.234 mrem) and 2.40 μ Sv (0.240 mrem). Reduced emissions of tritium from the Tritium Facility account for much of this decline.

The calculated dose to a person having the greatest possible exposure at Site 300 in 1992 was calculated to be 0.21 μ Sv (0.021 mrem) effective dose equivalent. Virtually all of this resulted from Building 801 firing table emissions that used depleted uranium during open-air high-explosives tests. The dose

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contributed by firing table operations at Site 300 has steadily declined: in 1991 it was 0.44 μSv (0.044 mrem), and in 1990 it was 0.57 μSv (0.057 mrem).

The principal radionuclides contributing to these doses are tritium in the tritiated water form—which accounts for about 49% of the dose at the Livermore site—and the isotopes of uranium with atomic numbers 238, 234, and 235, which account for about 32% of the dose at the Livermore site and all of the Site 300 dose.

The collective effective dose equivalent for LLNL 1992 operations was 0.015 person-Sv (1.5 person-rem) from the Livermore site and 0.071 person-Sv (7.1 person-rem) from Site 300, including all pathways (ingestion, air immersion, surface exposure, and inhalation pathways). These collective effective dose equivalents from the two LLNL sites are quite small compared to that from natural sources of radiation, which was estimated to be 19,000 person-Sv (1,900,000 person-rem).

Environmental Compliance Activities

Both the Livermore site and Site 300 are Superfund sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA). The proposed technique for cleaning up ground water at the Livermore site consists of managed ground water extraction at 18 locations and surface treatment. Contaminated sediments in the unsaturated zone will be treated by extracting fuel hydrocarbons or volatile organic compounds by vacuum-induced venting and treatment of the vapors. The U.S. Environmental Protection Agency and state and local agencies have approved this plan. In 1992, ground water was treated at three pilot treatment facilities: Treatment Facility A treated more than 71 million liters of ground water, removing and destroying about 10 kilograms of volatile organic compounds; Treatment Facility B treated about 9.4 million liters of ground water, removing and destroying about 1.5 kilograms of volatile organic compounds; and during four 10-hour tests, Treatment Facility F recovered about 76 liters of gasoline. The Superfund activities at Site 300 are at an earlier stage; LLNL is currently completing a site-wide remedial investigation report for the site.

In January 1992, LLNL submitted a revised Part B Permit application under the Resource Conservation and Recovery Act (RCRA). This document was again revised in April 1993. Because RCRA program authorization has been delegated to the State of California, LLNL now works with the California Department of Toxic Substances Control in seeking hazardous waste permits.

Another major document completed during 1992 was the *Final Environmental Impact Statement and Environmental Impact Report (EIS/EIR) for the Continued Operation of Lawrence Livermore National Laboratory and Sandia National*

Laboratories, Livermore. This document was prepared to comply with the National Environmental Policy Act and the California Environmental Quality Act. The EIS/EIR assessed the environmental impacts of the Laboratories' operations on air and water quality, geological and ecological systems, occupational and public health, prehistoric and historic resources, endangered species, floodplains and wetlands, socioeconomic resources, hazardous waste management, site contamination, and other environmental issues. After a public hearing, written comments were incorporated and the Final EIS/EIR was published, then certified by the Regents of the University of California and accepted by the Department of Energy.

LLNL continues to perform all activities necessary to comply with clean air and clean water requirements. In 1992, the Bay Area Air Quality Management District issued 111 permits for the Livermore site. The San Joaquin Valley Unified Air Pollution Control District issued 25 permits for Site 300 covering the operation of equipment that has emissions to the air. LLNL has permits for discharge of treated ground water, for discharges of industrial and sanitary sewage, and for discharges of storm water. Site 300 has four additional permits for inactive landfills; cooling tower discharges; operation of the sewer lagoon, septic tanks, and leach fields; and discharge of treated ground water. LLNL complies with all requirements for self-monitoring and inspections associated with these permits.

Four quarterly reports were prepared in 1992 to demonstrate compliance with National Emissions Standards for Hazardous Air Pollutants (NESHAPs). As of March 31, 1993, all 56 of the Livermore site and Site 300 facilities having the potential to release radionuclides to the atmosphere had been evaluated. Annual doses resulting from total actual emissions (after controls) were found to be well below the NESHAPs standard of 100 $\mu\text{Sv/y}$ (10 mrem/y). Estimates of effective dose equivalent for all evaluated facilities, assuming normal operations but no pollution control devices, have been calculated. Three facilities at the Livermore site have been identified as having potential unmitigated effective dose equivalent estimates greater than 1 $\mu\text{Sv/y}$ (0.1 mrem/y), and these facilities have appropriate continuous radionuclide sampling systems in place, as required by NESHAPs. Several other Livermore-site facilities also have existing sampling systems; however, potential unmitigated effective dose equivalent estimates were less than 1 $\mu\text{Sv/y}$ (0.1 mrem/y), and they do not require continuous monitoring under NESHAPs regulations. No other facilities, including all those at Site 300, were found to require continuous monitoring systems.

LLNL has one endangered species, the *Amsinckia grandiflora* (large-flowered fiddleneck), which is found at Site 300. Representatives of the California Department of Fish and Game and the U.S. Wildlife Service visited Site 300 on

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March 26, 1992, and counted a record number (546 plants) of these flowers located at Building 858 Drop Tower.

Conclusion

Like many other organizations and individuals who are concerned about the environment, LLNL is committed to protecting the environment and ensuring that operations are conducted in accordance with applicable laws and regulations that have been enacted to protect the environment. The current techniques used at LLNL for environmental monitoring are very sensitive, allowing observation of extremely low levels of constituents. The monitoring results for 1992 generally show that these low concentrations are but a very small fraction of regulatory standards. Because the analytical results and evaluations generally show a decrease in contaminant levels, they reflect the responsiveness of the Laboratory in controlling pollutants. In summary, the results of the 1992 environmental monitoring program demonstrate that the environmental impacts of LLNL are minimal and pose no threat to the public or the environment.

Introduction

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

Location

Forty years ago, when LLNL was founded to conduct weapons research and development, the Livermore site was relatively isolated, approximately 1.6 kilometers from the Livermore city limits. Over the years, Livermore evolved from a small town of less than 7000 people to its present population of nearly 55,000. The economy diversified from being primarily agricultural to including light industry and business parks. Within the last few years, low-density, single-family residential development has filled the formerly vacant fields, bringing the city limits of Livermore to LLNL's western boundary.

LLNL's Livermore site occupies an area of 3.28 square kilometers, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories, California (SNL/CA), operated by AT&T Technologies, Inc., under DOE contract. SNL/CA provides research and development associated with nuclear weapons systems engineering, as well as related national security tasks. Although their primary missions are similar, LLNL and SNL/CA are separate facilities, each with its own management and each reporting to a different DOE operations office.

Other property to the south includes agricultural areas devoted to grazing, orchards, and vineyards; some low-density residential areas; and a business park. Farther south, property is primarily open space or rural ranchettes, with some agricultural use. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends

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to the foothills of the intercoastal range that defines the eastern margin of the Livermore Valley.

A business park is located north of the Livermore site, and a 199.6-hectare parcel of open space to the northeast has been rezoned to allow development of a center for heavy industry.

Site 300, LLNL's experimental testing site, is located 24 kilometers east of the Livermore site in the Altamont Hills of the Diablo Range and occupies an area of 30.3 square kilometers. It is in close proximity to two other testing facilities; Physics International operates a testing facility that is adjacent and to the east of Site 300, and SRI International operates the other facility, which is located approximately 1 kilometer south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills northwest of the site. The remainder of the surrounding area is in agricultural use, primarily grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 25,000), located 10 kilometers to the northeast.

Operations

LLNL is a research laboratory with the infrastructure—including security, fire, and medical departments—necessary to support its operations and personnel. Cafeteria, banking, and limited shopping services are available on site, and electrical, sewerage, engineering, maintenance, and waste management activities support LLNL's operations.

LLNL's mission is to serve as a national resource of scientific, technical, and engineering capability with a special focus on national security. Over the years, this mission has evolved to include a wide variety of activities including inertial confinement fusion, laser isotope separation, magnetic fusion energy, biomedical and environmental research, energy and resources, environmental restoration and waste management, and scientific and institutional support.

Climate

Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. The mean annual temperature is 12.5°C; the normal seasonal temperature range is defined by nighttime winter lows in the vicinity of 0°C and summer daytime highs around 38°C. Annual wind data for the Livermore site are given in **Figure 1-1** and in **Table 1-1**. For approximately 45% of the year, prevailing winds are from the west and southwest. During the remainder of the year, it is calm (approximately 33% of the year) or wind directions are variable.

Both rainfall and wind exhibit a strong seasonal pattern. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months. The highest and lowest annual rainfalls on record are 782 millimeters and 138 millimeters. In 1992, the Livermore site received 299 millimeters of rain.

The climate at Site 300, while generally similar to the Livermore site, is modified by higher elevation and more pronounced relief. The temperature range is somewhat more extreme than the Livermore site, and topography significantly influences surface wind patterns. Annual wind data are presented in Figure 1-2 and Table 1-1. Rainfall for 1992 was 305 millimeters.

Geology

Topography

Livermore Site. 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 forms an irregularly shaped lowland area approximately 26 kilometers long and an average of 11 kilometers wide. The floor of the valley slopes from an elevation of approximately 200 meters at the eastern end to approximately 90 meters at its drainage outlet, which is located near the southwestern corner.

Site 300. The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges are oriented along a generally northwest/southeast trend and are separated by intervening ravines. The elevation ranges from approximately 150 meters

1. Site Overview

at the southeast corner of the site to approximately 538 meters in the northwestern portion.

Hydrogeology

Livermore Site. The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several recent and continuing investigations. Detailed discussions of these investigations can be found in Stone and Ruggieri (1983); Carpenter et al. (1984); Webster-Scholten and Hall (1988); Dresen et al. (1989a-f, 1990); and Thorpe et al. (1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District,

Zone 7, the agency responsible for ground water management in the Livermore Valley basin.

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

Beneath the Livermore site, the depth to the water table varies from about 8 to 43 meters. **Figure 1-3** shows a contour map of water-table elevations (feet above mean sea level) for the Livermore-site area. Although water-table elevations vary slightly with seasonal and year-to-year variations 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, ground water gradients (change in elevation per unit of horizontal distance) are relatively steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Ground water flow under the northern and western portions of the site is generally westward. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 meters per day (Isherwood et al. 1991).

1. Site Overview

This, in combination with the observed water-table gradients, yields an average ground water velocity estimate of 20 meters per year (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

Site 300. At Site 300, local perched aquifers containing small amounts of water occur in some of the channel deposits in the nonmarine Tertiary sequence. Perched aquifers contain unconfined water that is separated from an underlying main body of water by impermeable layers; normally they are small and highly localized. Because water quality 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.

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

Figure 1-4 shows the elevation contours for water in the regional aquifer at Site 300. The map of the piezometric surface (the level to which water rises in a well that penetrates a confined or unconfined aquifer) is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Conclusion

LLNL appreciates the importance of our environment and recognizes that our setting provides a habitat for a number of species of native flora and fauna. Like many other organizations concerned about the environment, LLNL is committed to protecting it and ensuring that operations at the Laboratory are conducted in accordance with applicable laws and regulations that have been enacted to protect the environment.

1. Site Overview

Table 1-1. Average annual percent frequency of wind direction at 10 m above ground level, versus wind speed (m/s) for the Livermore site and Site 300, 1992 (one-hour averages).

Direction	Livermore site					Total
	Calm 0.0–0.9	1.0–2.9	3.0–4.9	5.0–6.9	>7.0	
N	1.7	0.4	0.3	0.3	0.1	2.8
NNE	1.7	1.8	2.0	0.5	0.1	6.1
NE	1.7	2.5	1.7	0.1	0.0	6.0
ENE	1.7	1.3	0.2	0.0	0.0	3.2
E	1.7	0.9	0.1	0.0	0.0	2.7
ESE	1.7	1.1	0.0	0.0	0.0	2.8
SE	1.7	0.7	0.1	0.0	0.0	2.5
SSE	1.7	0.8	0.3	0.0	0.0	2.8
S	1.7	4.1	0.7	0.3	0.2	7.0
SSW	1.7	7.0	2.0	1.2	0.3	12.2
SW	1.7	6.8	5.6	1.8	0.2	16.1
WSW	1.7	7.4	5.3	0.9	0.0	15.3
W	1.7	3.6	5.1	2.2	0.1	12.7
WNW	1.7	0.9	0.3	0.0	0.0	2.9
NW	1.7	0.6	0.1	0.0	0.0	2.4
NNW	1.7	0.6	0.1	0.1	0.0	2.5
Total	27.2	40.4	23.9	7.4	1.0	100.0

Direction	Site 300					Total
	Calm 0.0–0.9	1.0–4.9	5.0–6.9	7.0–10.9	>11.0	
N	0.4	2.0	0.8	0.2	0.1	3.5
NNE	0.4	1.4	0.0	0.0	0.0	1.8
NE	0.4	2.0	0.0	0.0	0.0	2.4
ENE	0.4	1.9	0.0	0.0	0.0	2.3
E	0.4	1.9	0.1	0.0	0.0	2.4
ESE	0.4	1.4	0.2	0.1	0.0	2.1
SE	0.4	2.1	0.3	0.2	0.0	3.0
SSE	0.4	2.9	0.2	0.2	0.0	3.7
S	0.4	3.3	0.5	0.2	0.0	4.4
SSW	0.4	2.0	0.2	0.1	0.0	2.7
SW	0.4	1.8	0.5	0.9	0.3	4.0
WSW	0.4	3.6	6.6	19.5	3.3	33.4
W	0.4	4.3	3.4	1.4	0.0	9.5
WNW	0.4	3.0	1.1	0.1	0.0	4.6
NW	0.4	4.3	1.6	1.1	0.0	7.4
NNW	0.4	5.8	3.0	2.2	1.1	12.5
Total	6.4	43.7	18.5	26.2	4.8	100.0

Introduction

In 1992, LLNL conducted numerous environmental activities to comply with legal and internal requirements. These activities, performed at both the Livermore site and Site 300, encompassed environmental safety and health, hazardous waste management, wastewater, air quality, and general environmental issues. Documents that provide detailed information on these activities can be found at the LLNL Visitors Center and the City of Livermore Public Library. A summary of the environmental permits issued to or held by LLNL during the year is presented at the end of this chapter (**Table 2-1**). In addition, a list of 1992 Environmental Protection Department (EPD) publications is presented in Appendix A. This chapter includes background information to place the 1992 activities in context, as well as information about activities in the first quarter of 1993.

Department of Energy Tiger Team

The Department of Energy (DOE) Tiger Team Assessment of LLNL Environmental, Safety, and Health (ES&H) Programs in 1990 concluded that curtailment or cessation of any LLNL operations was not warranted and that compliance issues identified by the team are known to local, state, and federal regulatory agencies. Specific findings are presented in more detail in the Tiger Team Assessment (U.S. Department of Energy 1990).

In response to the Tiger Team Assessment, LLNL developed an Action Plan, which was approved by the DOE in early October of 1990, in which LLNL committed to correct identified deficiencies. The Action Plan describes changes in organizational structure to strengthen line management responsibility and accountability for ES&H/quality assurance issues; self-assessment activities to identify, resolve, and prevent future noncompliance with regulations; and commitment of significant funding for corrective actions.

The Action Plan also includes descriptions of the actions to be taken at the site to respond to the findings, along with schedules and estimated costs for each action. A progress report issued on a semiannual basis contains a brief status of the activity, the individual responsible for the action, and any revisions in the scheduled completion date. The Tiger Team Action Plan has been extended from a five-year to a seven-year plan (FY91–FY97).

2. Compliance Summary

LLNL continues to undertake those activities identified in its Action Plan, and significant progress has been made towards the 581 subtasks identified in it. As of December 31, 1992, approximately 66% of these subtasks have been completed, 3% are on schedule, 1% are behind schedule, and 27% are considered late, with 20 low priority subtasks (the remaining 3%) not funded. The majority of those subtasks behind schedule or late are a result of funding limitations in fiscal year 1993 or the inability in fiscal year 1991 to acquire qualified staff as fast as originally anticipated.

CERCLA/SARA—Title I

Also known as the "Superfund" Act, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is a federal statute that gives the federal government the authority to identify and clean up sites when hazardous chemicals and substances have been released to the environment. The U.S. Environmental Protection Agency (EPA) is responsible for managing CERCLA.

The Superfund Amendments and Reauthorization Act (SARA) amended various provisions of CERCLA, including the establishment of a process for federal facility participation in CERCLA regulation.

Livermore-Site Ground Water Project

The Ground Water Project continues to address CERCLA compliance issues at the Livermore site. Because some of the ground water at LLNL contains volatile organic compounds (VOCs), primarily trichloroethene (TCE) and tetrachloroethene (PCE), the site is on the EPA's National Priorities List (NPL). The Ground Water Project complies with provisions specified in a Federal Facility Agreement (FFA) made by the EPA, DOE, the California EPA Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB), San Francisco Bay Region. As required by the FFA, the project addresses compliance issues through investigations of potential source areas (such as old release sites, solvent handling areas, and leaking underground tank systems), continued monitoring of ground water, and remediation.

Source investigations are used to evaluate all possible contamination areas. A computerized source investigation tracking system has been implemented to aid the investigation of all potential sources at LLNL. If any contamination above regulatory standards is detected, the area is evaluated further to determine the extent of the contamination and to assess its potential for migration.

Based on compliance monitoring and sampling of ground water, surface water, soil, sediments, and air for toxic materials, the primary medium of concern appears to be ground water and the principal compounds of potential concern appear to be VOCs and fuel hydrocarbons. This was fully confirmed

by the *CERCLA Remedial Investigation Report for the LLNL Livermore-Site* (Thorpe et al. 1990).

The Record of Decision (ROD) and Responsiveness Summary were signed by the U.S. EPA on August 5, 1992. On January 6, 1993, LLNL completed the Remedial Action Implementation Plan (RAIP) for cleaning up ground water and soil at the Livermore site. The RAIP is the first step in the Remedial Design/Remedial Action (RD/RA) process under CERCLA. Its proposed technique for cleaning up ground water consists of managed ground water extraction at 18 locations and surface treatment. Contaminated sediments in the unsaturated zone will be treated by extracting fuel hydrocarbons or VOCs through vacuum-induced venting and oxidizing the vapors at the surface. The EPA, DTSC, and RWQCB have approved the RAIP.

The scope of these assessment and restoration efforts encompasses a set of diverse activities designed to investigate, evaluate, and eventually remediate potentially hazardous compounds that may have affected soil and ground water. These activities include the following: investigation of the hydrology, geology, soil properties, and hydrogeology of the site; investigation (including searches of historical records) of known and suspected sources of contamination; installation of piezometers and monitoring and extraction wells; sampling and analysis of soil and ground water; aquifer testing; development of computer models and a conceptual site model to aid ground water study; assessment of potential risks to public health from contaminants in soil and ground water; provision of project information to the public and coordination of community involvement; evaluation of numerous studies designed to aid site remediation; preparation of reports documenting the investigation, evaluation, and remediation; and testing and implementation of appropriate technologies to accomplish environmentally responsive cleanup.

On March 12, 1993, the first of five Remedial Design (RD) Reports for LLNL was completed. As described in the RAIP, the five RD Reports will be prepared over a three-year period to be consistent with projected funding levels and to optimize the cleanup. The first RD Report is for Treatment Facilities A and B and their respective extraction wells and piezometer networks. Both of these facilities were constructed and tested under an EPA-approved pilot study for the Southwest Corner/Offsite Area. Treatment Facility A (TFA) has been operating since September 1989, and Treatment Facility B (TFB) has operated intermittently since October 1990. In addition, work continues on various computer models and algorithms to support and optimize remediation design and planning activities. Effective remediation will require the use of our predictive capabilities during both the phased-in construction of extraction and treatment facilities and in full-scale operations.

2. Compliance Summary

TFA treated more than 71 million liters of ground water during 1992, removing and destroying approximately 10 kilograms (6.3 L) of VOCs. About 200 million liters have been treated since TFA began operating. TFB treated about 9.4 million liters of water in 1992, removing and destroying approximately 1.5 kilograms (0.9 L) of VOCs from ground water. More than 15 million liters have been treated since TFB began operating.

Construction activities for Treatment Facility F (TFF), a steam injection/ground water and vapor extraction and treatment system, continued at the Gasoline Spill Area throughout 1992. TFF supports the DOE-sponsored Dynamic Stripping research project as well as unsaturated zone and ground water remediation. Remediation operations at TFF during 1992 were limited to four 10-hour soil vapor extraction tests conducted between August and December. Vapor extraction occurred for a total of about 40 hours at a combined vapor extraction rate of about 50 standard cubic feet per minute (scfm). Total fuel hydrocarbon concentrations measured in extracted air ranged from about 4000 to 6000 parts per million by volume (ppmv), resulting in a fuel hydrocarbon removal in 1992 of about 76 liters of gasoline. Full operation of TFF began in February 1993.

Previous remedial activities from 1988 through 1991 at TFF resulted in a total removal of about 7500 liters of gasoline. Therefore, through 1992 a total of about 7600 liters of gasoline have been removed. Results for 1993 TFF performance are currently being evaluated and will be recorded in future reports.

The LLNL Ground Water Project continued its community relations program by holding four Community Work Group meetings in 1992, and by publishing quarterly Ground Water Update information to keep interested parties informed. The draft revised Community Relations Plan (CRP) was completed on January 29, 1993, and submitted to regulatory agencies as well as the Community Work Group. Copies of all LLNL ground water restoration documents, including monthly progress reports and annual project reports, which provide detailed information about the LLNL Ground Water Project's activities, are available at the LLNL Visitors Center and the Livermore Public Library.

Site 300 Environmental Restoration Project

At Site 300, ongoing remedial investigations, feasibility studies, and remedial actions are being performed as a part of the Environmental Restoration Project. Site 300 investigations and remedial actions are conducted under the joint oversight of the EPA, Central Valley RWQCB, and DTSC under the authority of a separate FFA. The Site 300 FFA was negotiated to encompass the environmental restoration requirements of RCRA as well as CERCLA. The FFA negotiations began in the fall of 1990 and the FFA was executed in June 1992.

The issues and areas of investigation at Site 300 include (1) TCE in soil, sediment, rock, and/or ground water at the Building 834 Complex, High Explosives (HE) Process Area, General Services Area (GSA), Pits 5, 6, and 8, and Building 833 Area; (2) HE compounds in the HE Process Area; and (3) tritium in the East and West Firing Areas. Highlights of these activities are presented below; the area-specific individual draft Remedial Investigation (RI) and Feasibility Study (FS) reports should be consulted for additional details.

As discussed in the Environmental Report for 1991, a number of draft RI and FS reports were completed for Site 300 during 1991. These reports present the results of investigations in a given study area; they were submitted to regulatory agencies for consideration of appropriate choices for remediation. The draft RI reports include detailed discussions of the environment, geology and hydrogeology, environmental risk of any toxic chemicals encountered, and assessment of the risk to public health and safety. The FS reports include proposals for remedial action alternatives with cost estimates under several conditions, from no action to full remediation.

In mid-1991, the regulatory agencies requested that LLNL prepare a site-wide remedial investigation report to replace the previously submitted individual draft RI reports. Compilation of the draft site-wide remedial investigation (SWRI) report began in 1991 and is scheduled to be completed in August of 1993. The SWRI is organized by study areas that roughly correspond to the areas covered by the individual RI reports. It contains a detailed risk assessment for the entire site. Final FS reports for the individual study areas will be prepared after submittal of the SWRI.

General Services Area (GSA) Study Area. According to the draft RI (McIlvride et al. 1990) and draft FS (Ferry et al. 1990) reports, VOCs have been identified in the shallow ground water beneath the GSA in three localities. One plume is in the western GSA, three small plumes are in the central GSA, and one plume is in the eastern GSA. Additional investigation revealed that the plume located in the western part of the study area originates from the HE Process Area. Therefore, this plume is included in the HE Process Area study area in the SWRI. The eastern GSA plume extends about 1.2 kilometers off site in the gravels of Corral Hollow Creek. A ground water treatment unit to remove VOCs from the eastern GSA was designed, put into operation in June 1991 as a CERCLA Removal Action, and operated throughout 1992. Total treated water at the GSA through February 1993 was about 42 million liters. The average TCE concentration (TCE is the primary VOC in the ground water) in the water treated at the eastern GSA treatment facility between June 1991 and February 1993 was 38 µg/L; thus, approximately 160 grams of TCE have been removed. Design work began on a ground water treatment and vapor extraction unit to remove VOCs from the central GSA.

2. Compliance Summary

Building 834 Complex Study Area. An isolated, perched aquifer that contains TCE has been defined and reported in the draft RI/FS report (Bryn et al. 1990). Techniques for removal of TCE vapor from the vadose zone above the water table and from the shallow perched water have been evaluated and pilot-tested. From January to March 1992, under funding from the EPA Emerging Technologies Program, LLNL in conjunction with Purus, Inc., evaluated a treatment technology for TCE. An ultraviolet flashlamp system was used to destroy TCE in air from the vacuum extraction system. Although 99% of the ingoing TCE was destroyed, by-product analyses showed that oxidation was not complete.

HE Process Area Study Area. The ground water beneath a small part of the HE Process Area near Buildings 815 and 817 contains low concentrations of the HE compound RDX (Crow and Lamarre 1990). Trace concentrations of the HE compound HMX, in water from one well, were found very near the detection limit. The area where HE compounds are present in the ground water has been successfully defined.

TCE has been detected at levels above maximum contaminant levels (MCLs) in the first two aquifers beneath an area near and southeast of Building 815. The data collected from several monitoring wells in the central and southern parts of the HE Process Area identified the TCE plume to extend into the western GSA.

East Firing Area and West Firing Area Study Area. The draft RI of the Building 850/East Firing Area (Taffet et al. 1992) and the draft FS (Taffet and Oberdorfer 1991) discuss the distribution of tritium in the ground water near the firing table at Building 850, in the alluvium in Doall Ravine to the southeast, and in the adjacent part of the East Firing Area to the southeast along Elk Ravine. The draft FS report includes various remediation alternatives. The RI/FS of the Pit 7 Complex (Taffet et al. 1989b) discusses the distribution of tritium and TCE in the ground water in the vicinity of the Pit 7 Complex, which is located in the West Firing Area, as well as various remediation alternatives.

Pit 6 Area Study Area. The draft RI of the Pit 6 Landfill Area (Taffet 1990) discusses the small plume of TCE in ground water, which discharges to the surface at small springs at the southeastern edge of the Pit 6 Area. The draft FS (Taffet et al. 1991) discusses options for its remediation.

As discussed in the *Environmental Report for 1991* (Gallegos et al. 1992a), during geologic mapping in the vicinity of Pit 6, a fault showing evidence of Holocene displacement was observed in a cut slope on State of California property (the State Vehicle Recreation Area Manager's residence), about 300 meters southeast of the landfill. As a result of subsequent detailed geologic investigations, project staff have determined that the fault represents a potentially active strand of the Corral Hollow-Carnegie Fault Zone, which is located generally south and west of the Site 300 property. Details of the

investigation are described in *Investigation of Holocene Faulting Near Closed Landfill Pit 6, Lawrence Livermore National Laboratory Site 300* (Carpenter et al. 1991).

Building 833 Area Study Area. Low concentrations of TCE and associated VOCs have been detected in shallow soils and sediments (to a depth of 15 meters) beneath the Building 833 Area. During the remedial investigation of the Building 833 Area, concentrations of up to 1,800 µg/L (ppb) were detected in ground water in two boreholes. Results of the investigation were published in Webster-Scholten et al. (1991).

Closure of Landfill Pits 1 and 7. During December of 1992, LLNL completed the capping of landfill Pits 1 and 7, located at the northern part of Site 300. This work was done under an LLNL RCRA closure plan previously approved by the EPA, DTSC, and the Central Valley RWQCB. The primary components of the closure design consist of a closure cover system, surface water control system, and subsurface water control system. The *Construction Quality Assurance Closure Report, Lawrence Livermore National Laboratory Site 300, Pits 1 and 7* (Golder Associates, Inc. 1993) documents the construction quality assurance (CQA) activities for the final closure of Pits 1 and 7. This documentation includes construction and testing of the test fill pad and the sealed double-ring infiltrometer, construction and CQA verification of the closure cover cap system, construction of the subsurface interceptor drainage trench (Pit 7), and construction and CQA testing of the concrete surface water control channels.

SARA—Title III

The Superfund Amendments and Reauthorization Act (SARA) Title III also is known as the Emergency Planning and Community Right-to-Know Act. It requires owners/operators of facilities that have certain hazardous chemicals on site to provide information on the manufacture, use, and storage of those chemicals to organizations responsible for emergency-response planning. In California, this information must be provided to the California Office of Emergency Services, the county, and the local fire department.

A physical inventory of all chemicals subject to reporting under SARA Title III was conducted during the months of November and December 1988. The inventory included the chemical name, location, weight, type of container, and physical state of the substance. The inventory included the Livermore site, Site 300, and leased space off site. In early 1989, the data were entered into a computerized database system and reports were generated for local emergency planning agencies. As in previous years, in 1992 EPD continued updates of the inventory to reflect changes in chemicals handled on site.

2. Compliance Summary

RCRA

Hazardous Waste Management Activities

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 (HWCA) sets requirements for the management of hazardous wastes in California. RCRA and HWCA regulate treatment, storage, and disposal facilities, including permit requirements. In July 1992, California was authorized to administer the federal RCRA program and DTSC became the primary agency administering these activities. The permit process requires DTSC to review and approve Part A and Part B permit applications, which provide information on the facility and the wastes managed therein.

As discussed in last year's report, LLNL is continuing discussions with DTSC regarding LLNL's 52 waste accumulation areas (WAAs). In December 1992, DTSC added the WAAs to the LLNL Interim Status Document (ISD CA 2890012584). LLNL is awaiting the final decision from DTSC as to whether the WAAs will need to be included in the Part B permit application and subsequently permitted (see further discussion in "Current Issues and Actions" at the end of this chapter).

DOE Hazardous Waste Disposal Moratorium

In May 1991, DOE Headquarters imposed a moratorium on the shipment of hazardous waste from all DOE facilities to off-site treatment and disposal facilities. The moratorium was in response to concerns that a DOE contractor on the East Coast (not associated with LLNL) had inadvertently shipped radioactive hazardous waste to a hazardous waste treatment facility.

The lifting of this moratorium was contingent upon developing criteria and procedures to satisfy DOE Headquarters that shipments of hazardous waste would have no added radioactivity from DOE activities. After a series of meetings to resolve comments on LLNL's draft criteria and procedures, DOE Headquarters lifted the moratorium for LLNL on December 20, 1991. DOE's San Francisco Operations Office lifted the final restrictions on January 20, 1992.

Hazardous Waste Report for 1992

The Hazardous Waste Management Division completed the 1992 Hazardous Waste Report, which is required by DTSC under 22 CCR 66264.75, by the April 1, 1993, deadline.

The report, which is maintained on file at the request of DTSC, comprises four forms. The identification and certification (IC) form provides general facility information, including addresses, contacts, and general waste minimization information. The waste generation and management (GM) form represents

"cradle-to-grave" tracking of each waste stream category. The waste received from off site (WR) form includes descriptions and quantities of wastes that were received from the off-site facilities (Site 300 and the Livermore Airport), and the process system (PS) form includes waste quantities treated by each waste management unit on site.

Hazardous Waste Permits

The Livermore-site hazardous waste storage and treatment management units continue to operate under interim status provisions (ISD CA2890012584). Waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction).

With RCRA program authorization being given to the State of California, LLNL is now working solely with DTSC in maintaining hazardous waste permits. Since the submittal of a revised Part B permit application on January 17, 1992, LLNL has deemed it necessary to make further additions and revisions. Accordingly, a new Part B revision was submitted to DTSC on April 30, 1993.

An update to the waste management units mentioned in last year's report follows:

- Building 419 will be closed under interim status. Present plans call for closure to commence in 1994.
- The Building 624 incinerator has been closed, and the incinerator itself has been dismantled. LLNL has received acknowledgment of closure from DTSC.
- Closure of the Area 612-3 Container Storage Unit began in November 1992. Operation of the Building 693 Container Storage Unit began that same month.
- The Building 233 Container Storage Unit will be upgraded to meet current seismic standards and has been added to the new Part B permit application.
- Five mixed waste treatment units have been added to the Building 514-1 Complex.

Extremely Hazardous Waste Permit

Permit Number 2-13640 is required, pursuant to 22 CCR 67430.1, to transport extremely hazardous waste to an off-site hazardous waste disposal facility. As a condition of the permit, LLNL must prepare a list of the extremely hazardous wastes (including concentration, quantity, packaging, proposed hauler, disposal facility, and proposed method of disposal) and submit it to DTSC two weeks prior to the shipment of any such waste. This permit must be renewed annually; the application for renewal was submitted in August 1992.

2. Compliance Summary

Hazardous Waste Transport Registration

This registration is required, pursuant to 22 CCR 66263.10, to transport hazardous wastes over public roads (e.g., from one LLNL site to another). Conditions for registration include annual inspections of transport vehicles and trailers by the California Highway Patrol, special training and annual physical examinations for drivers, and annual submission of lists of transport vehicles and trailers to DTSC. The registration renewal application was sent to DTSC in October 1992.

Medical Waste Permit

LLNL generates several types of medical wastes (previously identified as infectious wastes). In July 1991, LLNL submitted an application for a medical waste permit to the Alameda County Environmental Health Services (ACEHS). The application contained detailed information concerning the management and treatment of medical wastes generated by LLNL's biomedical research and health services facilities (including Site 300 medical waste generated by the Center for Chemical Forensics). The permit, which is valid for five years with annual renewal of registration, was issued in August 1991.

Site 300 Permits

Landfill Pits 1 and 7 were operated at Site 300 under provisions of ISD CA2890090002 until November 1988, when their use ceased. The landfills had been used for disposing of firing-table gravel and debris. The closures of these landfills were completed in 1992 in accordance with the closure plan approved by EPA, DTSC, and the Central Valley RWQCB.

The Site 300 Building 883 Hazardous Waste Container Storage Facility continued to operate through 1992 under provisions of the Part B permits (Part B CA2890090002) issued by EPA and DTSC in November 1989. These permits allow the facility to store specific wastes in containers, provided that certain administrative and operational conditions are met.

A High Explosives (HE) burn facility operated at Site 300 under interim status standards until November 1992. Work has begun on the design and permitting of a new HE open burn/open detonation facility to replace this unit. The RCRA Part B permit application for a Site 300 Explosive Waste Storage Facility was submitted to DTSC on July 20, 1992. This facility will allow for longer-than-90-day storage of explosive wastes prior to treatment. The application is still in the initial review process.

Inspections

The DTSC performed its annual inspection of the Livermore site on June 30; on July 1, 2, 7, and 8; and on August 3, 1992. The inspection included the review of the retention tank system on the east side of Building 141, which includes two

aboveground tanks (141-R2O3 and 141-R5O1) used to collect hazardous rinse waters. These tanks had been operated as less-than-90-day hazardous waste collection tanks but were removed from service in 1991. The DTSC inspector informed LLNL that closure plans would be required for closure of these tanks but that the regulatory agencies would not have to review or approve them because their purpose is simply to document how the tank is closed. Closure plans for the two tanks were completed in February 1993, and the tanks will be closed in 1993.

Following its inspection of the Livermore site, DTSC issued a Report of Violation (ROV) that LLNL received on August 18, 1992. Eleven violations were noted, and LLNL took the following actions in response to the ROV:

- Revised the tank certification procedures.
- Segregated waste in the Building 614 East Cells Container Storage Unit.
- Expanded the EP0006 training course to cover chemical compatibility, to reinforce 90-day regulatory storage limitations at the WAA, to include Contingency Plan implementation, and to reinforce one-year storage limitation at the point of generation.
- Developed an improved system of labeling to address the storage of incompatible waste.
- Repaired paint cracks in the secondary containment of the Area 514 Storage Tank 514-R5O1 Unit.
- Trained hazardous waste management employees in proper inspection techniques of secondary containment.
- Developed and installed a computerized WAA inventory tracking system.
- Established a Continuous Quality Improvement group to identify and resolve 90-day storage issues at the WAA.
- Implemented a continuous operating record at the WAA.
- Corrected all labels that were incomplete or inaccurate.
- Updated the Battery Shop practices for the management of lead/tin solder dross.
- Relocated the eyewash/safety shower unit at the Building 361 WAA.

On November 20, 1992, DTSC and Department of Health Services (DHS) visited the Livermore site to review the proposed Mixed Waste Management Facility technologies. The visit was for information only; no Notices of Violation (NOVs) or Notices of Deficiencies (NODs) resulted from this visit.

2. Compliance Summary

DTSC conducted an inspection of the Site 300 hazardous waste facilities in January 1992. Following its inspection of Site 300, DTSC issued an ROV received at LLNL on April 8, 1992. Thirteen violations were noted in the ROV; LLNL took the following actions in response:

- Expedited the analysis, handling, and tracking of hazardous waste in the WAAs.
- Corrected labels that were incomplete or inaccurate.
- Revised RCRA landfill cover inspection procedures.
- Replaced eyewash units at Building 827.
- Corrected the 1989 Annual Report on quantity of explosive wastes treated at Site 300, and revised record-keeping procedures.
- Implemented new DTSC requirements to keep hazardous waste containers of oily rags shut tight.
- Closed the Building 836 WAA.
- Modified WAA inspection frequency to every 7 days or less.
- Modified the Building 829 Waste Acceptance Plan to include peroxides.
- Removed all waste not included in the Building 883 permit.
- Negotiated with the State to resolve waste code issues in Building 883 hazardous waste storage.
- Used the U.S. EPA number of Livermore site as the transporter identification number on Hazardous Waste Manifests.

Pits 1 and 7 at Site 300 were inspected by DTSC, Central Valley RWQCB, and EPA on December 15, 1992. No NOVs or NODs resulted from this inspection.

On January 14, 1993, DTSC visited Site 300 to review current and future Explosive Waste Treatment and Storage Facilities. The visit was for information only and no NOVs or NODs were issued.

Waste Accumulation Areas

During 1992, there were 52 WAAs in operation at LLNL: 51 WAAs at the Livermore site and 1 WAA at the Livermore Airport. Environmental Protection Department (EPD) personnel performed 1040 biweekly WAA walk-throughs at the Livermore site WAAs and 21 biweekly WAA walk-throughs at the Airport WAA during 1992. During the first quarter of 1993, EPD personnel performed 306 biweekly WAA walk-throughs at the Livermore site and 6 biweekly WAA walk-throughs at the Airport WAA. The walk-throughs are informal checks of

items such as capacity, labeling, and secondary containment; formal inspections of these items are conducted by program personnel.

There were 14 WAAs being operated at Site 300 during 1992. The Building 836 WAA was taken out of service in October 1992, leaving a total of 13 active WAAs at Site 300. EPD personnel performed 330 biweekly WAA walk-throughs at Site 300 during 1992. As of the first quarter of 1993, 13 WAAs remain in operation at Site 300 and during this quarter, 65 biweekly WAA walk-throughs were performed.

Underground Storage Tank Management

Federal and state laws provide comprehensive regulation of the design, operation, monitoring, and closing of tank systems that contain hazardous products or hazardous waste. The California Underground Tank Regulations, found in 23 CCR Chapter 16, regulate underground storage tank (UST) systems used for containment of hazardous products or hazardous waste. The state underground tank regulations are administered at the Livermore site by the Alameda County Environmental Health Services (ACEHS) and at Site 300 by the San Joaquin County Public Health Services (SJCPHS). Federal standards for design, construction, operation, maintenance, and closure of these USTs are found in 40 CFR 280. Additional federal standards for petroleum tanks are given in 40 CFR 112. Standards for design, construction, operation, maintenance, and closure of USTs that contain hazardous wastes (both aboveground and underground) are the subject of RCRA regulations in 40 CFR 265.

The Livermore site has 46 aboveground and 49 underground tanks in service, which may contain either hazardous products or hazardous waste. Of these, 36 tanks contain wastewater, and the other 59 tanks contain hazardous products.

Underground tanks at Site 300 contain diesel fuel, gasoline, and contaminated wastewater; aboveground tanks contain diesel fuel, insulating oil, trichloroethene, and contaminated wastewater. Some of the wastewater systems are a combination of underground and aboveground tanks. Site 300 currently has 12 aboveground and 16 underground tanks in service, of which 21 contain hazardous products and 7 contain hazardous wastewater.

Underground Tank Permits

In 1992, LLNL paid annual fees to the ACEHS for 49 hazardous waste, mixed waste, and hazardous product underground storage tank permits for the Livermore site. The number of underground tanks that require permits remained the same as in 1991. Three underground storage tanks were closed, one underground storage tank was reclassified as nonhazardous because of changes in use, and four mixed waste underground storage tanks were added to the list.

2. Compliance Summary

In 1992, LLNL paid fees to SJCPHS for 16 petroleum underground storage tanks at Site 300; all of these tanks remain in service.

Tank Integrity Testing

Under the tank leak-tightness testing program, underground tank systems are tested to determine structural integrity, in accordance with requirements established in state and federal regulations. Single-walled, underground wastewater systems are tested, including those not presently regulated. The underground portions of tank systems are tested (as a whole or by component parts) using methods that may include precision tests, dye tests, helium-injection detection, and hydrostatic tests. All leak-tightness test results for regulated systems are provided to ACEHS or SJCPHS. Twenty-three underground diesel fuel and gasoline systems at the Livermore site and 10 systems at Site 300 were tested in 1992. Testing of petroleum tanks in 1992 revealed two system failures at the Livermore site. One system was repaired, retested, and returned to service; the second system was removed from service. For the repaired system, the contaminated soil was removed at the time of repair. For the other system, most of the contaminated soil was excavated when the tank system was removed from service; the corrective action plan will specify any additional soil removed and any further sampling, if appropriate.

In addition, 15 (11 at the Livermore site and 4 at Site 300) underground wastewater retention systems were tested in 1992. These systems receive and retain wastewater from processes of potential concern (i.e., metal plating, printed-circuit boards, semiconductors, and oily water from floor cleanup and steam-cleaning operations). Water is retained by these systems until the appropriate mode of disposal has been determined, based on the results of tank content analyses. Testing in 1992 identified one wastewater system at Site 300 that had a leak in its secondary system. This system was removed from service and is awaiting repair. The leak was minor and did not result in an adverse impact on the environment.

Closure and Leak Documentation

Closure plans, closure reports, and leak reports were completed in 1992 for tank systems (or portions of systems) that were taken out of service, previously removed (but not officially closed), or expected to be removed from service. Closure requirements for hazardous USTs include a closure plan prior to commencing work to close the system, quarterly reports if a leak has been identified, and a closure report upon completion of closure activities. The closure plans require a detailed review of the uses of the tank, a sampling plan, a site plan, and other information to verify that no environmental contamination has occurred—or, if it has occurred, to ensure its cleanup. Thirty-five closure plans and reports for hazardous waste tank systems and six leak reports for hazardous and

nonhazardous waste tank systems were submitted for regulatory review in 1992. Although not required for submittal to regulatory agencies, three closure plans and reports were prepared for nonhazardous waste tank systems as a part of LLNL's best management practices.

Tank Upgrade Project

In fiscal year 1992, LLNL received line item funding for four years to upgrade or close approximately 126 tanks in accordance with existing local, state, and federal tank regulations or to decrease the potential for contamination of the environment as the result of a release from a tank or its appurtenances. These tanks include wastewater retention tanks (nonhazardous, hazardous, mixed, and radioactive) and product retention tanks (including petroleum products). In fiscal year 1993, additional funding was granted to provide overflow and spill protection to aboveground oil-filled electrical equipment (e.g., transformers) and additional aboveground petroleum tanks, giving a revised total of 214 tanks or transformers being closed or upgraded.

As of the first quarter of 1993, construction was completed for one tank and that tank is in use; construction is in progress for 15 tanks; design is in progress for 52 tanks; and another 58 tanks are in the preliminary stage of the upgrade process. Overflow and spill protection design and construction have not yet begun for the remaining tanks and transformers. Engineering assessments to certify the integrity of all single-walled hazardous waste systems and all newly installed systems are in progress.

Remedial Activities

At the Building 292 area, a leak of tritiated rinse water from an underground storage tank was discovered in July 1989. The tank was immediately taken out of service, but not disconnected from the influent piping. On December 23, 1990, freezing weather caused a water pipe in Building 292 to break, allowing clean water to flow into floor drains and discharge into the tank. Subsequently, the floor drains leading from the building to the tank were sealed.

The tritium distribution and ground water flow conditions around the Building 292 area have been characterized using chemical and hydraulic data from 18 boreholes and wells, tritium ground surface flux measurements, and tritium transpiration measurements from selected vegetation in the area. Since the fall of 1990, the maximum detected ground water tritium activity was 280 Bq/L (7,700 pCi/L) from piezometer UP-292-001 measured on November 30, 1990. In 1992, an additional piezometer, UP-292-020, was installed approximately 6 meters west of Building 292. Preliminary data for this piezometer indicate that no tritium is present in saturated and unsaturated sediment samples from this borehole. Also, no tritium activity was detected in the ground water collected from this piezometer. There are currently eight piezometers in wells in the

2. Compliance Summary

Building 292 area that are being monitored quarterly. In 1993, tritium in the area will continue to be monitored.

In December 1992, the underground diesel fuel tank at Building 298 showed a leak in the fuel supply line, which was reported to ACEHS. The tank has been removed from service and is scheduled for removal and closure in 1993. Soil samples from beneath the tank and its piping will be collected at that time. Contaminated soil, if found during closure activities, will be removed in accordance with applicable regulations.

Soil samples collected from the base of an excavation during closure of a diesel fuel tank at Site 300's Building 877 showed diesel fuel contamination. The presence of diesel fuel in the soil is believed to have resulted from occasional overfilling. A Corrective Action Plan, which specifies excavation to remove the contaminated materials and additional sampling to confirm that the contamination has been removed, has been prepared for review and approval by SJCPHS.

In the Site 300 Building 879 automotive fleet facility, mineral oil was released through an underground casing for the ram of the hydraulic hoist system. Contaminated soil is planned to be removed in 1994 according to the procedure established with the Central Valley RWQCB.

Inspections

On February 19 and March 27, 1992, an inspector from ACEHS inspected the progress of the installation of new underground portions of the Building 161 wastewater retention tank system.

On March 10, 1992, an inspector from ACEHS witnessed the removal of a 1100-liter underground diesel fuel tank at Building 424. The tank (424-D1U1) formerly supplied fuel to the Building 424 emergency generator.

On April 2 and 3, 1992, an inspector from ACEHS witnessed closure activities (tank removal and soil sampling) for the closure of the 231-R3U1 and 231-R3U2 tank systems. The two 57,000-liter tanks and their associated piping were located at the southwest corner of Building 231 and had been used to supply fuel oil for two boilers located inside Building 231.

On May 20, 1992, an inspector from ACEHS witnessed closure activities (in-place closure and soil sampling) for the closure of the 325-I1U1 tank system. The closed 12,800-liter tank is located on the east side of Building 325 and had been used to retain wastewater from the mixed-bed ion exchangers located inside Building 325.

On October 14, 1992, an inspector from ACEHS inspected the sources of wastewater discharge into the Building 298 wastewater retention tank system. This inspection was for information only.

On May 4 and 5, 1992, an inspector from SJCPHS inspected the closure and closure sampling of the underground diesel fuel tank systems at Buildings 875 and 877.

On June 1, 5, 10, 11, July 23, and August 17, 1992, an inspector from SJCPHS inspected the construction and testing of the newly installed underground diesel fuel system at Building 875.

No NOV's or NOD's were received as a result of any of these inspections.

National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA)

NEPA

NEPA (42 U.S.C. 4371 et seq.) establishes federal policy for protection of environmental quality. The major method of achieving established NEPA goals is the requirement for federal agencies to assess the potential environmental impacts of their proposed actions through preparation of an Environmental Impact Statement (EIS) for any major federal or federally funded project that may have significant impact on the quality of the human environment. If the need for an EIS is not clear, an Environmental Assessment (EA) must be prepared, which leads to a definitive conclusion concerning whether to prepare an EIS or whether a Finding of No Significant Impact (FONSI) can be issued. In the latter case, an EIS is not required.

Certain groups of actions that do not have a significant effect on the environment, either individually or cumulatively, can be categorically excluded from further NEPA review. Subpart D of the April 1992 DOE NEPA Implementing Procedures identifies those actions that do not require the preparation of either an EA or an EIS.

Within DOE, an Action Description Memorandum (ADM) often is prepared when the proposed action does not clearly fit one of the categories of actions outlined in DOE NEPA Implementing Procedures as specifically requiring preparation of an EA or an EIS. This document provides DOE with sufficient information to determine which type of assessment document may be needed.

In accordance with the DOE Secretary of Energy Notice 15-90 and supplemental procedural guidance for its implementation, proposed actions that could be categorically excluded under the proposed revision to the DOE NEPA Guidelines (55 Federal Register 213) would require the preparation of a Brief EA until such time as these guidelines were approved. Because of the extremely limited potential for significant environmental impacts, Brief EAs were to be relatively short (3 to 10 pages). A number of these Brief EAs were prepared; then, after the revised DOE NEPA Implementing Procedures were finalized (April 24, 1992), draft Brief EAs still being reviewed by DOE were either processed as EAs

2. Compliance Summary

or, if appropriate, were converted to Categorical Exclusions (CXs) in accordance with the April 1992 DOE NEPA Implementing Procedures.

In 1992 and first quarter 1993, LLNL prepared 117 documents in accordance with policies and procedures for DOE review and determination as to compliance with the NEPA. These included 2 ADMs, 111 CXs, 3 EAs, and 1 EIS (described below). DOE issued the following 11 FONSIIs during that period for previously submitted EAs or Brief EAs:

- Microwave Tokamak Experiment/Experimental Test Accelerator II (MTX/ETA II)
- Super High Altitude Research Project (SHARP), formerly Cheap Access to Orbit (CATO) Experimental Tests
- Brilliant Pebbles Tether Test at the Nevada Test Site
- Pilot Tritium Evaporator at the LLNL Site 300 Well 8 Spring
- Vacuum Process Laboratory Relocation
- Electric Utility System Distribution, Replacements, and Upgrades
- Advanced Materials Configuration Laboratory
- Security Administration Building
- Diamond-Anvil High Pressure Cell
- Laser Guide Star Experiment
- Multipass Beamlet Testbed in Building 381

Environmental Assessments Submitted to DOE

Brief descriptions of the three proposed actions for which NEPA EAs were prepared during 1992 and first quarter 1993 are presented below.

Environmental Assessment for the Verification, International Security, and Technology Analysis (VISTA) Center addressed the potential environmental impacts associated with the proposed construction and use of a two-story building, which would be adjacent to and become part of Building 261, to be used for offices and bench-scale laboratories at the Livermore site. This proposed project is discussed in the *Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (EIS/EIR) for the entire site (U.S. DOE and UC 1992b). At this time, DOE is still reviewing the draft EA as well as the information contained within the EIS.

Environmental Assessment for the Site 300 Explosive Waste Storage Facility addressed the potential environmental impacts associated with the construction and operation of the storage facility for explosive wastes at Site 300. This

proposed project is also discussed in the EIS/EIR for the entire site (U.S. DOE and UC 1992b). At this time, DOE is still reviewing the draft EA as well as the information contained within the EIS.

Environmental Assessment for the Building 197 Physics Laboratory addressed the potential environmental impacts associated with current and planned operations in Building 197 at the Livermore site. The proposed action includes development of advanced techniques and technology for production of extremely high-speed integrated semiconductor circuits for high-performance supercomputers, optics for the wide-field-of-view telescope and the x-ray microscope, and feasibility of laser-initiated propulsion for launching moderate masses into orbit. At this time, DOE is still reviewing this draft EA.

Environmental Impact Statement/Environmental Impact Report

The *Draft Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (EIS/EIR; U.S. DOE and UC 1992a) was issued for public comment in March 1992. The EIS/EIR analyzed the potential environmental impact of continued operation, including near-term (within 5 to 10 years) proposed projects, of LLNL and SNL/CA. The EIS/EIR also analyzed alternatives that involved continuing operation at fiscal year 1992 funding levels without further growth, modifying the continued operations alternative that reduced adverse environmental impacts of operation or facilities, and shutting down and decommissioning. To meet CEQA requirements, the EIS/EIR also examined the alternative of discontinuing the University of California's management of LLNL after September 1992. (In the fall of 1992, UC was awarded a 5-year contract to continue management of LLNL.) The EIS/EIR assessed the environmental impacts of the laboratories' operations on air and water quality, geological and ecological systems, occupational and public health, prehistoric and historic resources, endangered species, floodplains and wetlands, socioeconomic resources, hazardous waste management, site contamination, and other environmental issues. A public hearing on the Draft EIS/EIR was held on April 30, 1992. Written comments were accepted for 90 days, from March 11 until June 11, 1992. The Final EIS/EIR, with comments incorporated, was published in August 1992 (U.S. DOE and UC 1992b). The EIS/EIR was certified on November 25, 1992, by the Board of Regents, concluding the CEQA evaluation process. The NEPA Record of Decision (ROD) was signed by the Secretary of Energy on January 1, 1993. When DOE publishes the appropriate Mitigation Action Plan (MAP), the DOE NEPA process will be complete.

CEQA

CEQA (California Public Resources Code Sections 21000 et seq.) establishes state policy for protection of environmental quality. The goals of CEQA are

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achieved by requiring local and state agencies to assess the potential environmental impacts of proposed actions for which they may have a decision-making role. This is done through the preparation of an Initial Study (IS), which leads to issuance of a Negative Declaration or a requirement to prepare an Environmental Impact Report (EIR). An EIR may also be prepared directly for projects that may have significant environmental impacts.

One EIR was prepared under the UC CEQA procedures and submitted to the UC Regents in August 1992. This document, the *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 1992b), also served as a DOE EIS and has been previously discussed under the information on NEPA implementation.

One IS for LLNL's proposed Explosive Waste Storage Facility (EWSF) at Site 300 was submitted to DTSC to assist that agency in meeting its CEQA responsibilities. At this time, DTSC is still reviewing the IS.

Endangered Species Act

Under Section 7 of the U.S. Endangered Species Act, a list is prepared of endangered or threatened species and other species of concern that may exist or are known to exist at the LLNL and SNL/CA sites. LLNL conducted numerous field surveys during 1991, and these were reported in the 1992 EIS/EIR.

In November 1992, LLNL surveyed the northern Livermore-site boundary when conditions in Arroyo Las Positas provided an opportunity to inventory animal tracks. Six mammal species, two bird species, and miscellaneous insect species were observed during the survey. No signs of sensitive species were observed along the arroyo, and species signs observed were a subset of the species identified in the 1992 EIS/EIR for the Livermore site.

In 1992, LLNL also conducted (for a Site 300 proposed project) a survey of potential dens of the San Joaquin kit fox (*Vulpes microtis mutica*) and known burrows of two other sensitive species [American Badger (*Taxidea taxus*) and burrowing owl (*Athene cunicularia*)]. No potential kit fox dens or known burrows for the other two of these species were noted during this survey. Representatives of the California Department of Fish and Game and the U.S. Fish and Wildlife Service visited Site 300 on March 26, 1992, and counted a record number (546 plants) of mature large-flowered fiddleneck (*Amsinckia grandiflora*), an endangered species, located at the Building 858 Drop Tower.

National Historic Preservation Act

Under Section 106 of the National Historic Preservation Act, a cultural resource assessment of the Livermore site and of a single historic archeological

property within Site 300 was conducted in 1992 by William Self Associates (William Self Associates 1992). The purpose of the assessment was to determine National Register of Historic Places (NRHP) eligibility potential of all or part of the Livermore site and Site 300 historic property. Twenty-three buildings at the Livermore site were examined (some cursorily) pursuant to NRHP criteria. LLNL is studying the preliminary conclusions in the report.

Clean Water Act—NPDES/Waste Discharge Requirements

Clean water is the subject of local, state, and federal regulations. The National Pollutant Discharge Elimination System (NPDES), under the Federal Clean Water Act, establishes permit requirements for discharges into surface waterways. In addition, the State of California requires permits, known as Waste Discharge Requirement (WDR) Orders, for any discharges that could adversely affect the beneficial uses of waters of the state. The Regional Water Quality Control Boards (RWQCBs) are responsible for issuance and enforcement of both permit types. Finally, the Livermore Water Reclamation Plant (LWRP) requires permits for discharges to the city sanitary sewer system.

Ground Water and Surface Water Discharge Permits

WDR Order No. 88-075, issued by the San Francisco Bay RWQCB, pertains to activities undertaken to investigate and remediate contaminants in ground water at the Livermore site. The order allows treated ground water that meets specified standards to be discharged to specified areas on DOE property. The NPDES permit (CA0029289, also designated as WDR Order No. 91-091) applies to treated ground water discharged to the ground from monitoring wells used in the ground water investigation and to other treated ground water discharged to ground and surface waters. The self-monitoring programs required by these permits are described in Chapter 3, Environmental Program Information.

Two Notices of Intent (NOI) were submitted to the State Water Resources Control Board to cover the Livermore site and Site 300 under the California Industrial Activity Storm Water NPDES permit during the first quarter of 1992. This permit allows LLNL storm water discharges under the State General Permit, which became effective October 1, 1992. In addition, three NOIs were submitted to the State Water Resources Control Board to cover construction projects greater than 5 acres under the General Construction Activity Storm Water NPDES permit. The NOIs were submitted for the Livermore-site Building 132 and for the Site 300 Roadway Improvement Project and closure of landfill Pits 1 and 7. Both the Livermore site and Site 300 are implementing draft Storm Water Pollution Prevention Plans. The storm water monitoring programs were implemented by January 1, 1993, as required by the State General Discharge Permit.

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Site 300 has four additional permits issued by the Central Valley RWQCB: WDR Order No. 80-184 pertains to inactive landfills; WDR Order No. 82-105 applies to the cooling-tower discharges (an NPDES permit—CA0081396—is also required for the cooling-tower discharges because discharges may enter storm water drains); WDR Order No. 85-188 is a permit for operation of the sewer lagoon, septic tanks, leachfields, and the Class II surface impoundment for HE rinse water; and WDR Order No. 91-052 (NPDES Permit No. CA0082651) is a permit for discharge of treated ground water from the eastern General Services Area ground water treatment facility to Corral Hollow Creek. The self-monitoring programs for these permits are also discussed in Chapter 3, Environmental Program Information.

LLNL obtained permission from the San Francisco Bay RWQCB to temporarily discharge treated ground water from Treatment Facility A (TFA) into the on-site Central Drainage Basin to maintain the basin's water level and to prevent deterioration of its water quality due to evaporative losses. LLNL began discharging TFA water in October 1992 and discontinued discharging in December 1992 because of increased rainfall. The self-monitoring agreement submitted to the San Francisco Bay RWQCB for discharges from the Central Drainage Basin is detailed in Chapter 3, Environmental Program Information.

Wastewater Permits

A Wastewater Discharge Permit from the Livermore Water Reclamation Plant (LWRP) provides for the continued discharge of LLNL sanitary and industrial effluent to the city sewer system. Permit No. 1250(91-92) was in effect from September 1991 through September 1992, and renewal Permit No. 1250(92-93) is effective from September 1992 to September 1993. Under the provisions of this permit, LLNL is required to conduct a monitoring program at its outfall into the LWRP sewer system. Daily and monthly effluent sampling are performed to satisfy permit compliance requirements. The daily samples are composited to represent (and are reported as) weekly values. The monitoring results of the total LLNL effluent are reported monthly to the LWRP. In accordance with federal pretreatment regulations, additional quarterly and semiannual sampling is required of all identified categorical processes. These additional monitoring results are reported semiannually to LWRP.

Processes that are regulated under 40 CFR 403 (categorical processes) include metal-finishing and certain electrical and electronic processes. As stated in Permit No. 1250(92-93), there are 22 individual processes. Some processes discharge to the sanitary sewer and are monitored; some processes do not discharge to the sanitary sewer and are not monitored; and some processes discharge to one of five tank systems, which are monitored. All of these

discharges are reported to the LWRP in the Semiannual Wastewater Reports (see e.g., Grayson and Brigdon 1992, Grayson 1992).

LWRP personnel spent five days on site during 1992 (in February, April, July, October, and November), inspecting and sampling discharges. LLNL was granted three Discharge Permits by the LWRP for discharge to the sanitary sewer during 1992: additional ground water discharge Permit No. 1508G for discharge of sewerable waste from Treatment Facility F, ground water discharge Permit No. 1510G for an Environmental Restoration Division treatability study, and wastewater discharge Permit No. 1250(92-93) for site-wide discharge of wastewater.

The LWRP issued two NOV's to LLNL in 1992: one for violation of the permitted effluent limitation of oil and grease, and one for violation of the permitted effluent limitation of copper. Neither of these violations resulted in any fines. LLNL also received a letter of concern regarding elevated levels of oil and grease in the LLNL effluent. None of these actions resulted in any adverse impact on the operation of the LWRP.

Inspections

The San Francisco Bay RWQCB spent one-half day on September 1, 1992, meeting with LLNL and inspecting areas of recent minor spills. Areas visited were Building 341, where a recent release of low conductivity water had occurred, and the Area 612 Facility yard, where rinse water from a tanker that had contained sewerable water had been released. These incidents are discussed in more detail in Chapter 12 under the Environmental Occurrences subsection.

California Department of Fish and Game personnel inspected the Livermore site on February 5, 1993, to determine the need for a streambed alteration agreement for proposed work to reinforce the Arroyo Seco bank where it crosses the southwestern corner of the Livermore site. Fish and Game personnel inspected Site 300 twice during 1992 to determine conditions for the Main Roadway Improvement Project Streambed Alteration Agreement. The first inspection occurred on June 1, 1992, and the second inspection was on August 3, 1992.

Streambed Alteration Agreements

Two streambed alteration agreements were issued by the California Department of Fish and Game for construction projects impacting the natural drainage at Site 300. The projects were the Super High Altitude Research Project (SHARP), which was formerly CATO (Cheap Access to Orbit), and the Main Roadway Improvement Project.

2. Compliance Summary

Clean Air Act/Air Quality Management Activities

The Clean Air Act is the federal law that authorizes the EPA to set air quality standards and to assist state and local governments in developing and executing air pollution prevention and control programs. The Bay Area Air Quality Management District (BAAQMD) is the agency responsible for enforcing these standards (as well as the state and local standards) for air emissions from stationary sources in the San Francisco Bay Area (including the Livermore site), and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) is the agency responsible for enforcing these standards in San Joaquin County (including Site 300).

After reviewing LLNL's air toxics emission inventory that was submitted in November 1989, as required by the Air Toxics "Hot Spots" Information and Assessment Act of 1987 (AB 2588, California Health and Safety Code Section 44360 et seq.), the BAAQMD requested that LLNL assess the impact of toxic air emissions on the surrounding area. A screening assessment was completed and risk was found to be below the threshold values that are used to determine need for further evaluation. Results of this work were submitted to the BAAQMD in fall of 1990.

After reviewing LLNL's AB 2588 inventory for Site 300, which was submitted in June 1990, the SJVUAPCD requested that LLNL provide additional emissions data for a small burner used for disposal of explosives waste. Test results were sent to SJVUAPCD in March 1993.

These air toxics emission inventories are required every two years, and both updated inventories (Livermore site and Site 300) were submitted during the summer of 1992.

Air Permits

Air permits are obtained from the BAAQMD for the Livermore site and from the SJVUAPCD for Site 300. In 1992, the BAAQMD issued 111 permits for the Livermore site. These permits authorize 19 operations that involve the use of solvent cleaners, 16 degreasers, 9 ovens, 8 furnaces, 6 printing presses, 5 paint spray booths, 4 explosive operations, 3 machine tool lathes, 3 plating operations, 3 silk-screen operations, 3 semiconductor fabrication operations, 3 etchers, 2 storage tanks, 2 polishing operations, 1 rock crusher, 1 roof mixer, 1 drum crusher, 1 transfer tank, 1 extraction/treatment system, 1 oil-shale combuster, 1 metal-finishing operation, 1 kiln, 1 shale hopper and preheater, 1 fire test cell, 1 optic coating operation, 1 paper pulverizer system, 1 vacuum chamber, 1 milling machine, 1 dry-film developer, 1 welding operation, 1 filter test, 1 service station, and 7 miscellaneous uses.

In 1992, the SJVUAPCD issued 25 permits covering the operation of 9 internal combustion engines/emergency power generators, 7 drying ovens (one permit), 5 boilers, 2 gasoline tanks with vapor recovery (one permit), 2 dispensing systems with vapor recovery, 1 machining equipment with dust filter, 1 evaporative tower, 1 carbon absorption system, 1 portable air compressor, 1 sawdust collector, 1 paint spray booth, and 1 crane.

Inspections

BAAQMD personnel conducted 14 days of inspections at the Livermore site during 1992. On January 8, 1992, BAAQMD issued an NOV citing excessive pressure in the spray wand of a degreaser. The equipment was immediately brought into compliance.

The SJVUAPCD conducted one inspection at Site 300 during 1992, and no NOVs were issued.

During the first quarter of 1993, BAAQMD conducted five days of inspections at the Livermore site. As a result of these inspections, LLNL received one NOV, issued for Building 511 for use of adhesive without a permit. LLNL has applied to the BAAQMD for permits authorizing the use of adhesives.

National Emission Standards for Hazardous Air Pollutants (NESHAPs)

In October 1989, the EPA issued new NESHAPs standards concerning radionuclide emissions from DOE facilities. DOE initiated discussions with the EPA to develop a Memorandum of Understanding on how the DOE facilities would achieve compliance with these standards. Pending resolution of the DOE/EPA discussions, LLNL drafted a work plan to satisfy the new requirements and began to assemble information needed to meet the new standards. This effort included reviewing all operations that employ radionuclides and gathering data to model each source.

After reviewing the initial data, the EPA found that LLNL could not demonstrate compliance with the new standards. On April 19, 1991, a Finding of Violation and an order to come into compliance was issued by the EPA to UC and DOE. The law requires that every release-point from an operation using radionuclides must be evaluated using an EPA-approved computer model or be continuously monitored. Under NESHAPs requirements, the decision to install stack monitoring or to perform periodic monitoring depends on the calculated, potential, unabated off-site dose from stack emissions, and whether the resultant dose exceeds or is less than one percent of the NESHAPs standard (100 μ Sv/y or 10 mrem/y). EPA acknowledged in the Finding of Violation document that it appeared that LLNL had monitored and modeled the major contributors to its emissions.

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LLNL completed its evaluations of emissions in the first quarter of 1993, as in a proposed schedule agreed upon by EPA, DOE, and LLNL as part of negotiations for establishing a Federal Facilities Compliance Agreement (FFCA).

In the NESHAPs Action Plan dated May 23, 1991, which was submitted by LLNL and DOE to the EPA, LLNL made a commitment to provide quarterly progress reports until all buildings in which radionuclides are used, or activation products occur, are assessed for compliance with NESHAPs regulations (40 CFR 61). Thereafter, annual summary reports will be submitted.

Four quarterly reports were prepared in 1992 (Lamson 1992; Biermann and Lamson 1992a, b; Biermann et al. 1992) and one in 1993 (Biermann et al. 1993). As of March 31, 1993, all 56 of the Livermore site and Site 300 facilities having the potential to release radionuclides to the atmosphere have been evaluated for compliance with the NESHAPs regulations. These include facilities designated as high-priority, medium-priority, and low-priority. Operations involving non-nuclear explosive testing at Site 300 were also evaluated. Additionally, eight continuously monitored facilities have been evaluated.

Annual doses resulting from total actual emissions (after controls) were not found to exceed the NESHAPs standard of $100 \mu\text{Sv}/\text{y}$ ($10 \text{ mrem}/\text{y}$). Estimates of effective dose equivalent (EDE) for all evaluated facilities, assuming normal operations and no control devices, have been calculated. Three facilities at the Livermore site (Buildings 331 and 332 and the hardened portion of Building 251) have been identified as having potential unmitigated EDE estimates greater than $1 \mu\text{Sv}/\text{y}$ ($0.1 \text{ mrem}/\text{y}$), and these facilities have appropriate radionuclide monitoring systems in place, as required by NESHAPs. Several other Livermore-site facilities (Buildings 175, 231, 419, 490, and 491, and the unhardened portion of Building 251) also have monitoring systems; however, their potential unmitigated EDE estimates were less than $1 \mu\text{Sv}/\text{y}$ ($0.1 \text{ mrem}/\text{y}$) and do not require continuous monitoring under NESHAPs regulations. No other facilities, including all those at Site 300, were found to require continuous monitoring systems. Descriptions of, and testing conducted on, the existing sampling systems indicate that representative sampling is being performed. Therefore, LLNL has demonstrated compliance with the 40 CFR 61.93 NESHAPs regulations.

Inspections

On December 14 and 15, 1992, EPA personnel performed an inspection to evaluate LLNL progress toward compliance with NESHAPs regulations. The inspector stated that all deficiencies had been identified by LLNL in the quarterly reports and should continue to be addressed as actions are taken under the existing compliance schedule.

Toxic Substances Control Act (TSCA)

TSCA regulations affecting the Livermore site are those that regulate the storage and disposal of polychlorinated biphenyls (PCBs) and asbestos wastes. The PCB annual report, required under 40 CFR 761.180, is a record of PCB-containing equipment in service, taken out of service, or disposed of during the year. At LLNL, equipment containing PCBs is used in a totally enclosed manner until the equipment is taken out of service, at which time it is removed to Hazardous Waste Management for disposal at an approved site. Statistics for PCBs were compiled in 1992 and are kept on file, available for EPA inspection. Asbestos wastes are reported in the Hazardous Waste Report, which is required by DTSC under 22 CCR 66264.75.

Current Issues and Actions

Uncertainty remains over the applicability of Assembly Bill 107 (Section 25123 of the California Health and Safety Code) to LLNL's Waste Accumulation Areas (WAAs). DTSC headquarters and Region 2 have not agreed on the interpretation of the new definition of a storage facility and whether or not LLNL must submit permit applications for all its WAAs.

In response to an NOD from EPA on the LLNL 1989 RCRA Part B permit application, LLNL substantially revised the permit application. A 38-volume Part B permit application was submitted on January 17, 1992, fully describing each of the 24 waste management units to be permitted. The revised permit application fully addressed EPA's comments and concerns and better reflected operations and management of the LLNL Hazardous Waste Management Facilities. In addition to the revised Part B, the Part A permit application was also revised to reflect current operations. The revised Part A was submitted on December 13, 1991.

Both parts have since been submitted again—Part A on December 18, 1992, and Part B on April 30, 1993. These newest revisions include addition of the Building 233 Facility (container storage unit for hazardous and mixed wastes), several mixed waste treatment facilities in the Building 514-1 Complex, and a revised Waste Analysis Plan.

Closure plans for the Building 419 Size Reduction Unit and the Building 419 Solidification Unit were submitted to DTSC on February 7, 1992. Size reduction operations were transferred to the Building 612 Size Reduction Unit, and solidification was transferred to the existing solidification operations at the Building 513 Solidification Unit. This change is described in the revised Part B permit application. Additionally, closure has begun on the Area 612-3 Container Storage Unit and is in progress on the Building 169 Temporary WAA.

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In 1991, LLNL was concerned about the need to offset newly identified air emissions. On February 14, 1992, LLNL appealed BAAQMD's requirement to offset eight precursor organic compound (POC) emission sources. BAAQMD granted LLNL's appeal, with the result that LLNL has more POC emission credits available for future projects.

Table 2-1. Summary of Permits as of March 15, 1993.

Type of Permit	Livermore Site	Site 300
Air	111 (Various equipment)	25 (Various equipment)
Water	WDR Order No. 88-075	WDR Order No. 80-184
	WDR Order No. 91-091, NPDES Permit No. CA0029289	WDR Order No. 82-105, NPDES Permit No. CA0081396
		WDR Order No. 85-188
		WDR Order No. 91-052, NPDES Permit No. CA0082651
	WDR Order No. 91-13-DWQ (as amended by Order No. 92-12-DWQ) NPDES General Permit No. CAS000001	WDR Order No. 91-13-DWQ (As amended by Order No. 92-12-DWQ) NPDES General Permit No. CAS000001
Hazardous waste	WDR Order No. 92-08-DWQ NPDES General Permit No. CAS000002 Site Id. No. Bldg. 132 2015300881	WDR Order No. 92-08-DWQ NPDES General Permit No. CAS000002 Site Id. Nos. 5B395300882 Main Gate Road Improvement Pits 1 and 7 Closure 5B395300882
	ISD CA2890012584	Part B CA2890090002
	DTSC Permit No. 2-13640 for disposal of extremely hazardous waste Hazardous waste transport registration 1351	ISD CA2890090002
Sewer	Discharge Permit Nos. 1250(92-93), 1508G, and 1510G	
Tanks	Fees paid for 49 tanks	Fees paid for 16 tanks
Other	FFA, ground water investigation/ remediation; ACEHS medical waste permits for treatment and storage	

3. Environmental Program Information

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Introduction

LLNL has a substantial commitment to environmental compliance and accountability. Each year, the Environmental Protection Department (EPD) monitors the environment surrounding the Livermore site and Site 300. In 1992, over 150,000 analyses of environmental samples were performed. This effort, which is conducted in accordance with DOE Orders 5400.1, 5400.5, and 5484.1, has three purposes: (1) to assess the effectiveness of pollution control programs, (2) to assess compliance with applicable environmental laws and regulations, and (3) to evaluate the impact of operations on the environment. Data are produced from sampling of air, sewage effluent, ground water, surface water, soil, vegetation, foodstuff, and environmental radiation; the type of samples collected at a specific location depends on the site and the potential pollutants to be monitored. Details regarding individual monitoring activities can be found in specific chapters herein for each environmental medium. These chapters also document a special study of tritium in rain and storm water runoff, discussed in Chapter 6 on Surveillance Water Monitoring. Summary information on monitoring activities can be found in Chapter 11 on Radiological Dose Assessment and Chapter 12 on Nonradiological Impact.

Although its monitoring activities are quite comprehensive, EPD's main mission is to interact with LLNL programs to ensure that operations are conducted in a manner that limits environmental impacts to levels consistent with regulatory guidelines. The activities that are required by environmental statutes are described in the preceding chapter. In addition to giving a brief description of each division of EPD, this chapter describes the activities, carried out by EPD, that were mandated by DOE or implemented independently by LLNL.

Environmental Protection Department

LLNL management has designated EPD as the lead environmental support organization, with responsibility for providing the guidance and expertise to ensure that LLNL meets the environmental requirements of all relevant local, state, and federal regulations and DOE Orders. [The primary responsibility for formal, active implementation of the Laboratory's Environmental, Safety, and Health (ES&H) issues rests with the Associate Directors of the Laboratory, who

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form the ES&H Council. The ES&H Working Group, which includes each Associate Director's Assurance Officer, heads of ES&H departments, and environmental legal counsel, assists the ES&H Council in implementing ES&H policies and actions (LLNL 1991).]

Principal functions of EPD operations include preparing and maintaining LLNL environmental plans and guidelines, informing management about pending changes in environmental regulations impacting LLNL, representing LLNL in day-to-day interactions with regulatory agencies, assessing the effectiveness of pollution control programs, and monitoring the environment to determine the impact of LLNL operations. EPD also helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; and responds to emergencies so as to minimize any impact on the environment.

Training is also a principal function of EPD. Major efforts are ongoing to provide LLNL employees with training on environmentally related topics and improve their ability to comply with environmental regulations. Training tasks address both specialized training for environmental professionals in EPD and training in a variety of environmental topics for employees at all levels throughout LLNL.

EPD is divided into four operating divisions: Operations and Regulatory Affairs Division (ORAD), Hazardous Waste Management Division (HWMD), Environmental Restoration Division (ERD), and Environmental Monitoring and Analysis Division (EMAD).

Operations and Regulatory Affairs Division

ORAD helps LLNL programs operate in a manner that meets all environmental compliance requirements. The ORAD staff consults with program personnel on regulatory compliance, permitting issues, waste minimization, pollution abatement, inspections, and monitoring to help identify and mitigate potential environmental contamination and compliance concerns in existing and planned projects.

The ORAD staff works with LLNL programs in all facets of environmental permitting activities. They interpret pertinent environmental regulations and requirements; they analyze existing operations and evaluate new facilities and operations during planning stages to identify environmental concerns and permitting needs; and they obtain the necessary permits. After a permit has been obtained, ORAD staff assists programs in evaluating environmental protection controls and procedures so that these controls and procedures are properly implemented.

Other permitting activities include guiding LLNL programs through the regulatory process to help ensure that they meet regulatory requirements; meeting and conferring with regulators regarding permitting and compliance issues; and coordinating regulatory requirements for tank systems. ORAD staff also responds to emergencies and other urgent concerns to advise on environmental cleanup, sampling, and regulatory reporting.

ORAD prepares and maintains many types of documents for LLNL programs. ORAD staff issues guidance documents that describe how environmental laws, regulations, and DOE Orders are implemented at LLNL; issues templates for operational plans for tank systems and provides guidance and assistance to the programs in preparation of these plans; develops and maintains chemical-tracking databases; and prepares permits and regulatory documents, including documentation for compliance with the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA). In addition, ORAD staff works with a Training and Development Group to prepare and present in-house training programs for LLNL employees on environmental issues, sampling methodologies, and waste-handling protocols.

Hazardous Waste Management Division

HWMD manages all hazardous, radioactive, and mixed wastes generated at all LLNL facilities. Operationally, HWMD staff processes these wastes for temporary storage, treatment, and transportation for either recycling or off-site disposal. Principally, the HWMD staff processes, stores, packages, solidifies, treats, or prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer.

HWMD tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas to final disposition; decontaminates LLNL equipment; ensures that containers for shipment of waste meet specifications of the U.S. Department of Transportation and other regulatory agencies; responds to emergencies; and participates in the cleanup of hazardous and radioactive spills at LLNL facilities. HWMD staff prepares annual and biennial hazardous waste reports, which are required by the state and federal environmental protection agencies.

Additionally, HWMD is actively involved in locating and evaluating facilities that may accept mixed waste for storage or disposal, and subsequently ensuring that shipments from LLNL meet the acceptance criteria of any selected site.

Environmental Restoration Division

ERD was established to evaluate and remediate problems resulting from past hazardous materials handling and disposal practices for hazardous materials and from leaks and spills that have occurred at the Livermore site and Site 300, both prior to and during LLNL operations. These past practices and spills have

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resulted in concentrations of environmental contaminants that are unacceptable by current standards. In addressing Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) compliance issues, ERD staff plans, directs, and conducts assessments to determine both the impact of such releases on the environment and the restoration activities needed to reduce contamination concentrations to protect human health and the environment.

The ERD staff investigates field sites to determine the existence and extent of contamination and its impact on human health and the environment. ERD evaluates various remediation technologies, including state-of-the-art technologies, and recommends and implements actions for site restoration. Finally, ERD is responsible for managing remediation activities, such as soil removal and ground water and surface water treatment, and for assisting in closing inactive facilities in a manner designed to prevent environmental contamination.

Environmental Monitoring and Analysis Division

EMAD functions include effluent and surveillance monitoring, wastewater regulatory guidance, sample analysis, risk assessment, and reporting. EMAD provides guidance on how to implement laws and regulations and DOE Orders relating to wastewater. EMAD is responsible for monitoring the environmental effects, both radiological and nonradiological, of effluent streams (air, sewage, and storm water runoff) and for sampling federally regulated point-source discharges for compliance with federal regulations. The division also conducts surveillance monitoring of direct radiation as well as radiological and nonradiological surveillance monitoring of air, soil, water, ground water, vegetation, and foodstuff. Wastewater effluent monitoring and regulatory guidance is the responsibility of EMAD, and its staff is working with the programs to prepare storm water pollution prevention plans and eliminate illicit wastewater discharges. EMAD staff supports LLNL site waste generators, as well as the HWMD, in performing chemical and radiological analysis to identify, characterize, and certify waste for proper disposal. EMAD staff also conducts risk assessment and impact modeling and analysis.

EMAD is responsible for producing this annual LLNL Environmental Report, as well as for radionuclide effluent reporting under the National Emission Standards for Hazardous Air Pollutants (NESHAPs) of the Clean Air Act; the Quarterly Ground Water Report for the California Regional Water Quality Control Board, Central Valley Region; the Semiannual Wastewater Report; and a number of other documents including those dealing with wastewater management for regulatory compliance, including permit applications, monitoring reports, and compliance plans.

Self-Monitoring Programs

Self-monitoring programs are required by the following permits issued by the San Francisco Bay Regional Water Quality Control Board: Waste Discharge Requirements (WDR) Order No. 88-075 for discharge of treated ground water to a percolation pond or for on-site use; and National Pollutant Discharge Elimination System (NPDES), Permit No. CA0029289, WDR Order No. 91-091 for discharge of treated ground water to the surface drainage system (this WDR Order replaced WDR Order No. 90-106 on June 19, 1991).

Monitoring conducted to fulfill the requirements of WDR Orders 80-114 (1980) and 85-188 for Pit 1 Area, Pit 7 Complex, Building 817 HE Process Area, and Pit 6 Area at Site 300 is discussed in detail in Chapter 7, Ground Water Protection.

Treatment Facility A

During the past year, LLNL continued a self-monitoring program, as required by the WDR Order No. 88-075, to verify the performance and effectiveness of Treatment Facility A (TFA) and the LLNL recharge basin, located south of East Avenue. In 1992, TFA successfully treated over 71 million liters of ground water containing volatile organic compounds (VOCs). Analytic results of TFA effluent samples indicate that WDR Order No. 88-075 discharge limits were not exceeded during 1992. The TFA total VOC discharge limit is 5 ppb. As an example, the self-monitoring sample collection schedule for TFA is presented in Table 3-1.

Treatment Facility B

LLNL also continued the self-monitoring program, as required by WDR Order No. 91-091, to verify the performance and effectiveness of Treatment Facility B (TFB). In 1992, TFB successfully treated more than 9.4 million liters of ground water.

Analytic results of TFB effluent samples indicate that the WDR Order No. 91-091 VOC discharge limit, which is 5 ppb, was not exceeded during 1992. The discharge limit for hexavalent chromium, 11 ppb, is very close to the detection limit of 10 ppb. Although this limit was exceeded in 1992, LLNL has taken measures to reduce the levels of hexavalent chromium, and the levels are being controlled.

Treatment Facility F

Treatment Facility F (TFF) is used in support of the DOE-sponsored Dynamic Stripping research project as well as soil and ground water remediation. During 1992, its operations were limited to four 10-hour soil vapor extraction tests conducted between August and December at the Gasoline Spill Area. The extracted air had fuel hydrocarbon concentrations ranging from 4000 to 6000 parts per

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million by volume, resulting in removal of about 76 liters of gasoline. When added to the 7500 liters of gasoline removed in remedial activities from 1988 to 1991, TFF has removed close to 7600 liters of gasoline through 1992.

General Construction Activity

Visual observance monitoring required by the California General Construction Activity Permit for three construction projects began in December 1992. Monitoring for the General Construction Activity Storm Water NPDES Permit includes visual observations of construction sites before anticipated storms and after each actual storm causing runoff from the construction site. This monitoring is used to determine that best management practices are in place and are adequate, and to identify areas contributing to a storm water discharge.

General Industrial Activity

Self-monitoring required by the General Industrial Activity Storm Water NPDES Permit consists of sampling two storms per year, one which must be during the rainy season. (This sampling occurred in January 1993.) In addition, during the rainy season, monthly observations were performed of the discharge outfalls from our one storm water runoff event. During the dry season, monitoring is required twice to identify any dry weather flows. Finally, the permit requires an annual facility inspection to ensure that best management practices to prevent storm water pollution are adequate and in place.

The self-monitoring sample collection procedure and schedule for both Livermore site and Site 300 are presented in the storm water monitoring procedures. An annual certification of compliance with the provisions of the General Industrial Activity Storm Water Permit and the Storm Water Pollution Prevention Plans will be submitted on July 1 of each year in the annual monitoring report to the Regional Water Quality Control Boards (RWQCBs).

Central Drainage Basin

Monitoring of discharges from the Central Drainage Basin under NPDES Permit No. CA0029289 began in December 1992 and continued through the first quarter of 1993. Monitoring data for the drainage basin are presented in Chapter 6, Surveillance Water Monitoring.

LLNL submitted to the RWQCB a proposed monitoring plan, which includes monitoring releases occurring after the first storm of the season and monthly thereafter, through the end of the 1992/1993 rainy season. Future discharge monitoring includes the first release storm and two additional storm water releases performed in conjunction with NPDES storm water monitoring.

Quarterly Minor Spill Report

The Minor Spill Report is based on an agreement with the San Francisco Bay RWQCB and provisions in NPDES Permit No. CA0029289 and WDR Order

No. 88-075 that require a report of all releases to the ground or surface waters that are not specifically allowed in the permit. The permit does not specify a *de minimis* level. The only discharge allowed by these permits is treated ground water. This report is used for minor spills that are below reportable quantities and are well contained and characterized. Should a spill of a reportable quantity of material or one that is not contained occur, the appropriate agencies are contacted immediately.

Cooling Tower

The Cooling Tower Report is submitted to the Central Valley RWQCB according to the provisions in NPDES Permit No. CA0081396 (WDR Order No. 82-105). LLNL submits quarterly data on temperature, pH, flow, and total dissolved solids (TDS). Because cooling tower pH values exceed the permit limitations approximately 95% of the time, LLNL has submitted a time schedule to the Central Valley RWQCB identifying actions to eliminate surface water discharges from 13 of the 16 cooling towers that could discharge to surface drainage ways. LLNL proposes to continue discharging the three remaining cooling towers as before but has requested the Central Valley RWQCB to expand the allowable pH discharge range.

Waste Minimization and Pollution Abatement

Waste Minimization and Pollution Prevention Awareness Plan

The combined Waste Minimization and Pollution Prevention Awareness Plan was prepared in accordance with DOE Order 5400.1 and is dated May 31, 1992. This plan was originally issued on May 31, 1991, but since then there have been significant changes in regulatory requirements that have affected Laboratory operations.

Some changes involved new laws: California passed a law requiring reporting of recycled non-RCRA wastes; the California Hazardous Waste Management and Source Reduction Review Act led LLNL to identify its largest hazardous waste streams and select waste minimization options for them, along with a commitment for their implementation; the Pollution Prevention Act of 1990 required significant modifications to the existing LLNL hazardous waste data reporting procedures; and the Land Ban placed new restrictions on the generation of mixed wastes.

Other changes resulted from new definitions, requirements, and restrictions. These include the reduction by DOE of the level of radioactivity that defines waste as radioactive or mixed; new offset requirements for local air emissions that have increased the difficulty of obtaining air permits; an Executive Order issued in September 1991 that requires new emphasis on the use of recycled materials by all federal facilities; California's increased restrictions on the

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quantities of nonhazardous wastes that may be disposed of in landfills; and the directives by the DOE Secretary to participate in the EPA 33/50 program to reduce emissions of 17 priority chemicals and to submit progress reports on the program, as well as to phase out Class I ozone-depleting chemicals (ODCs) by the end of 1995 and to submit progress reports on this phase-out.

With these changes in mind, the strategies proposed in the Waste Minimization and Pollution Prevention Awareness Plan include the following actions. The first is to develop specific ways for the programs to conserve resources, minimize waste generation, and prevent pollution. This includes creating incentives for pollution prevention; developing specific goals and schedules for waste minimization activities; promoting the use of nonhazardous materials; substituting, reformulating, modifying, managing, and/or recycling waste materials to achieve minimal adverse effects; targeting policies, procedures, or practices that may be barriers to waste minimization; and integrating and coordinating waste generators and waste managers on waste minimization issues.

The second action is to enhance communication of waste minimization goals and ideas. This involves developing and implementing employee pollution prevention awareness and occupational training programs; collecting and exchanging waste minimization information through technology transfer, outreach, and educational networks; and developing mechanisms for fully disseminating current technical information.

The third action involves identifying and implementing methods and technologies for waste minimization, for example, characterizing waste streams and developing a baseline of waste generation data.

In 1992 LLNL conducted a number of activities in support of this plan. LLNL continued to communicate management's commitment to curtail pollution, and publicized the goals of pollution prevention through posters and articles in *Newsline* (the LLNL biweekly newspaper). LLNL conducted formal training on pollution prevention and on the responsibilities of waste generators. Pollution prevention displays and handouts were presented during Earth Week, at two Earth Day Fairs (April 1992 and April 1993), and at an on-site Energy Fair (October 1992). Environmental Alerts (one-page flyers) were published and distributed to all LLNL employees, conveying information on environmental problems and possible solutions, on recommended practices, and on pertinent environmental regulatory issues. Changes and additions to regulatory requirements, new technologies, and management changes related to environmental issues continued to be conveyed in 1992 by the environmental analysts assigned to specific site areas. Finally, the LLNL-wide safety and health awards program was expanded in 1992 to include environmental ideas.

Waste Minimization

The Waste Minimization Project (WMP), assisted by program representatives, prepared the Annual Waste Reduction Report for the Department of Energy on both the Livermore site and Site 300. WMP also updated the 1991 Livermore site SB14 report and submitted a report to Alameda County concerning recycling of non-RCRA hazardous wastes.

The reduction of waste has been a major effort at LLNL. A significant part of this effort has concentrated on both liquid solvents, which are disposed of as liquid hazardous waste, and volatile solvents, which evaporate into the air. Several LLNL programs are collaborating in a project to evaluate the substitution of less hazardous solvents or cleaners for chemicals currently in use. Preliminary results are very encouraging and have led to the elimination of some cleaning operations that used halogenated solvents.

For example, Chemistry and Materials Science has reduced by about 70% the amount of hazardous solvents used in radioactive materials management areas, representing a significant reduction in mixed wastes. This reduction is a direct result of employee education and of switching to nonhazardous solvents. Chemistry and Materials Science has also implemented a procedure to remove the chlorofluorocarbon (CFC) solvent from a degreaser whenever the machine is not in use, thereby reducing CFCs lost through evaporation by approximately 250 kilograms per year.

The Lasers Directorate reduced evaporative losses of CFCs by switching to a formulation that has a lower vapor pressure and by installing a CFC recovery system. The Lasers program also implemented a system to reuse optical cleaning solutions in Building 490, thereby reducing generation of metal-contaminated wastewater by 2636 kilograms per year, and installed oil-free vacuum pumps to reduce both lubricating oil wastes and system maintenance costs.

The volume of hazardous wastewater produced at LLNL has also been reduced through use of Transportable Treatment Units (TTU) to process hazardous wastewater from retention tanks. Since mid-1992, TTUs have treated more than 84,000 kilograms of metal-contaminated wastewater from Building 141. Treated wastewater was discharged to the sewer system instead of being hauled off site for disposal, resulting in a cost savings of more than \$66,000. LLNL has initiated procurement actions to extend this service to all other qualified waste streams.

The Engineering Directorate converted the rinsing operation for the manufacture of printed wiring boards to series flow, which reduced (by about 90%) the quantity of its largest hazardous waste stream—contaminated rinse water. The Machine Shop installed a recycling system in Building 321 that has reduced the generation of waste machine-tool coolant by about 90% and eliminated more than 9100 kilograms of waste per year. During its first full year

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of operation, the Plating Shop rinse water recycling system processed 265 million liters of water and generated only 1100 liters of metal-bearing aqueous waste, a reduction of 99.7%. The Lasers Directorate reduced alcohol solvent use by about 800 liters per year by switching to a nonhazardous alternative cleaner.

Other changes in operations, as well as reuse and recycling of materials, have led to substantial reductions in wastes. Personnel from Nuclear Design and from Materials Fabrication at Site 300 continue to recycle and reuse high explosives pieces for shot tank evaluations, microbarograph testing, and employee training exercises. Employees at Site 300 continue to segregate packaging to ensure that only those wrappers that contact high explosives are disposed of as hazardous waste.

Energy Research used to store processed oil shale in 55-gallon drums that were used only once, then disposed of as hazardous waste. The program now uses recyclable transportainers to store processed shale that is awaiting disposal. This eliminated more than 550 kilograms per year of hazardous waste. Magnetic Fusion Energy now returns spent insulating oil to the manufacturer, where it is purified for reuse; this reduced oily waste by about 2000 kilograms per year. Plant Operations also ceased regenerating its ion exchanger resin beds on site in 1991. The resin vendor now regenerates these beds off site, eliminating a large wastewater stream contaminated with metals.

Automotive Fleet Division of Business Services has substituted reusable stainless steel containers that use pressurized air as propellant in place of aerosol cans at Site 300. This provides an 80% reduction in the amount of waste generated and a savings of \$500 per year. Plant Operations now changes compressor and generator lubricating oils only when analyses show high metal content; previously, oil changes followed a time schedule. The Motor Pool started using recapped tires instead of buying new ones for certain vehicles. The Hazardous Waste Management Division sent between 135 and 180 kilograms of metallic lead bricks, hammers, and shot to LLNL salvage operations for off-site recycling.

LLNL initiated an alternative solvent and coolants research project to minimize the use of ozone-depleting chemicals, halogenated hydrocarbons, and material with volatile organic compounds. The WMP solicits LLNL programs for parts that are currently cleaned with toxic solvents. After cleaning these parts with alternative solvents, the WMP returns them to the programs with suggestions for alternative solvent use. Substituting less toxic cleaning materials minimizes environmental management and waste management costs, minimizes employee health risk exposures, reduces potential impact to the environment, and correlates well with guidance and objectives from the U.S. EPA.

LLNL evaluated the effectiveness of more than 40 alternative solvents for cleaning grease, oil, and dirt from commonly used substrates such as optical

glass, aluminum, other machined metals, printed wiring boards, and plastic. Advanced spectrometry methods are used to quantify cleanliness achieved with the various solvent cleaners. In addition, aquatic toxicity tests are conducted on materials that provide promising cleaning results. Several alternative solvents have proved to be not only less hazardous but also better cleaners than the more toxic material currently used.

Some of the solvent substitutions to date include: the main bay machine shop substituted a nonhazardous alternative cleaner (815GD) for 1,1,2-trichloroethane (TCA); the Plating Shop replaced its potassium ferrocyanide chromate conversion coating process with a less hazardous noncyanide process and substituted oxalic acid for sulfuric acid in its aluminum anodizing process; the Engineering Records Center replaced alcohol with vinegar and water for daily cleaning of the camera bed and is using diluted sodium hypochlorite instead of standard sulfonic acid and dichromate tray cleaner for cleaning processor racks; the Building 141 machine shop substituted nonhazardous cleaner SD1291 for TCA; Plant Engineering switched to 1990GD for spray washing in Building 511; and the Technical Information Department replaced a high-speed printing press with a dry-toner copier (eliminating 102 liters per year of hazardous chemicals).

TSCA hazardous waste decreased about 6400 kilograms; RCRA hazardous waste increased about 152,800 kilograms; and non-RCRA hazardous waste decreased about 173,400 kilograms. Overall, hazardous waste generation declined nearly 28,110 kilograms or 2.8% during 1992, and low-level radioactive waste generation decreased about 10,000 kilograms or 4.5%. Mixed waste generation increased about 43,000 kilograms or 42%; most of this increase has been traced to one building's retention tank, which has since been replaced, and the increase can thus be considered as nonrecurring. Transuranic waste increased because of intentional inventory reduction in the plutonium facility and because some of the processing equipment was shut down during part of 1991, resulting in lower generation for that year.

Nonhazardous Materials Recycling

In April 1991, LLNL implemented a site-wide white paper recycling program that has collected more than 200 tons of paper in its first year.

The WMP completed the first of a series of nonhazardous waste assessments. Paper waste constituted approximately 50% (by weight) of the total material sampled. The paper waste was sorted into subcategories, including newsprint, colored paper, coated paper, computer (green bar) paper, and paper towels. Only minor quantities of white paper were observed during the assessment, indicating success with the white paper recycling program. Cardboard comprised the second largest waste stream category. Plastics, primarily polystyrene from food service wastes, comprised the third. Glass and aluminum cans represented a very

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small portion of the waste stream, indicating that individual employee efforts to collect and recycle these materials are successful.

Because cardboard comprises the second largest waste stream, LLNL has implemented a pilot program for cardboard recycling with Biology and Biotechnology, Business Operations, Engineering, Shipping, and Salvage. Also, LLNL has implemented a pilot program within the Environmental Protection Department to substitute rechargeable batteries for alkaline batteries in pagers and other small electronic equipment. The WMP is studying the feasibility of recycling polystyrene at LLNL's three cafeterias.

LLNL has established a Buy Recycle Committee in response to Executive Order 12780, which mandates federal facilities to increase use of recycled materials. LLNL Stores now carries a white ledger paper with 50% recycled fiber content, refillable bottles that replace aerosol cans, aqueous-base correction fluid, low-alkalinity dishwashing compound, and refurbished laser printer toner cartridges. The Technical Information Department demonstrated that recycled paper could be used in most copiers and laser printers, stimulating acceptance by many other departments.

Compliance Activities

The Environmental Operations Group within ORAD is responsible for working closely with LLNL programs and departments to implement environmental requirements so that planned and current operations and experiments comply with local, state, and federal environmental regulations. The group consists of environmental analysts assigned to specific LLNL programs and departments to assist in day-to-day environmental activities. In addition to advising LLNL staff, analysts review and verify that proper procedures are followed for the management of hazardous wastes and for the implementation of appropriate pollution abatement controls. Compliance status is maintained and verified by the analysts who keep abreast of existing and planned activities, review construction documents, inspect facilities, and assess waste management procedures.

Building Inspections

Formal, detailed building inspections for each LLNL facility are conducted based on a schedule established by the facility manager with the Hazards Control Health and Safety Team. These inspections scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of waste accumulation areas (WAAs), potential release pathways to the environment (e.g., storm and sanitary sewer drains), hazardous product storage areas, wastewater retention systems, operating equipment (e.g., vacuum pumps, transformers, capacitors, and baghouses), and

laboratory and machine shop areas. An inspection report is prepared for the program or department, and follow-up checks are conducted to ensure implementation of recommendations or corrections. Walk-through inspections are conducted on an as-needed basis. During 1992, 190 formal building inspections were conducted and 9 audits of Building 883 at Site 300 were completed. In addition, nine Hazardous Waste Management Facility audits were conducted.

For the first quarter of 1993, 49 formal building inspections were conducted and 3 audits of Building 883 at Site 300 were completed. In addition, three Hazardous Waste Management Facility audits were conducted.

Waste Accumulation Area Inspections

Inspections are conducted at least weekly at all WAAs by program representatives to help ensure that WAAs are operated in compliance with regulatory requirements. An inspection checklist is completed and corrective actions are implemented. In addition, EPD staff conducts biweekly routine checks at all WAAs to help ensure that programs manage their WAAs and wastes in compliance with federal and state requirements. During 1992, 1040 biweekly WAA routine checks were conducted on the Livermore site, 21 biweekly checks at the Livermore Airport, and 330 biweekly checks at Site 300. Additional information is provided in Chapter 2, under the subsection titled Waste Accumulation Areas.

Spill Response

Investigation, sampling, and evaluation of all spills and leaks that are potentially hazardous to the environment are conducted when necessary. The spill response process includes identifying the spill or leak, shutting off the source (if safe to do so), eliminating ignition sources, contacting appropriate emergency personnel, cordoning off the area, containing the spill or leak, absorbing and neutralizing the spill or leak, assisting in clean up of the spill or leak, determining if a spill or leak must be reported to regulatory agencies, and verifying that cleanup (including decontaminating and replenishing spill equipment) is complete. Environmental analysts also provide guidance to the programs on preventing spill recurrence.

Site Evaluations Prior to Construction

Sampling and analysis for potential contaminants are conducted at all proposed construction sites to ensure that any soil and debris generated is disposed of appropriately. During 1992, environmental analysts conducted preconstruction site evaluations for 79 construction projects. During the first quarter of 1993, 22 additional preconstruction site evaluations were conducted.

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Environmental Training

In 1992, the Environmental Protection Department (EPD) sponsored training, including RCRA and SARA/OSHA programs, for 4490 people for a total of 19,084 contact hours. For the first quarter 1993, EPD trained 614 people for a total of 3269 contact hours. These Training Program statistics do not include the number of hours devoted to on-the-job training, which is handled separately by each division. Additionally, EPD routinely participates in biweekly briefings to orient all new employees concerning approved environmental practices and procedures, including persons to contact during emergencies.

Table 3-1. TFA WDR self-monitoring sampling and analysis schedule.

Frequency	TFA-I001	TFA-PP3	TFA-C1E/C1W, TFA-C2E/C2W	Land observation
Daily	Flow rate	Flow rate	—	—
Weekly	—	EPA 601	—	Perform observation
Monthly	EPA 301 pH	Temperature pH		Complete report
Quarterly (Mar., June, Sept., Dec.)	Chlorides	Chlorides Fish toxicity ^a Turbidity ^b	Chlorides EPA601	—
Semiannually (Apr., Oct.)	Metals ^c	Metals ^c	Metals ^c Gross alpha and beta particles, tritium Fish toxicity ^a	
Annually (Apr.)	EPA 624 ^d EPA 625	EPA 624 ^d EPA 625 Gross alpha and beta particles, tritium	EPA 602 EPA 625	

Specific requirements:

- Sampling of TFA-C1E/C1W and TFA-C2E/C2W should be coincident with TFA-I001 and TFA-PP3 sampling.
- If any instantaneous maximum limit is exceeded, then sampling frequency shall be increased to daily, until two samples collected on consecutive days show compliance with instantaneous maximum.

^a Fish toxicity, 96 hours survival in undiluted waste.

^b Jackson turbidity units.

^c Priority pollutant metals: antimony, chromium (total), mercury, silver, arsenic, copper, nickel, thallium, beryllium, lead, selenium, zinc, cadmium. Samples also are analyzed for boron, chromium (+6), iron, manganese, and cyanide.

^d When schedule calls for coincident EPA 601 and 624 analyses, perform only EPA 624.

Introduction

Air surveillance monitoring is performed to evaluate compliance with local, state, and federal regulations, which ensure that human health and the environment are protected from hazardous emissions into the air. LLNL complies with all appropriate local, state, and federal environmental air quality laws and U.S. Department of Energy (DOE) regulations including: 22 CCR 67264.700 and 66265.710, *Environmental and Compliance Monitoring*; 40 CFR 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act; *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991); and DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*. In general, LLNL analyzes for most constituents at levels that are far below regulatory standards to determine any environmental impact.

LLNL monitors ambient air to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations, what the concentrations are, and what the trends are in the LLNL environs. Air monitoring involves measurement of particles collected on filters, or of vapor chemically trapped on a collection medium. Concentrations of various airborne radionuclides (including particulates and tritium water vapor), beryllium, and lead are measured at the Livermore site, Site 300, at off-site locations throughout the Livermore Valley, and at an off-site location in Tracy.

Methods

LLNL maintains eight (including two used for a special study) continuously operating, high-volume, air particulate samplers on the Livermore site (**Figure 4-1**), eleven in the Livermore Valley (**Figure 4-2**), eight at Site 300, and one in Tracy (**Figure 4-3**). The samplers are positioned to ensure reasonable probability that any significant concentration of particulate effluents from LLNL operations will be detected. Geographical details of particulate sampling locations are outlined in a written procedure, which is included in Appendix B of the *Environmental Monitoring Plan* (Gallegos et al. 1992b).

Each air particulate sampler pulls air continuously at a constant rate of 400 liters per minute through a 20.3 cm × 25.4 cm Whatman-41 cellulose filter. The flow is maintained at better than the DOE requirement of ±20% of the nominal flow by using a mass flow controller that adjusts motor speed. These flow rates are verified at regular intervals with a portable field-calibration unit. If a sampler fails, it is repaired and then calibrated with a

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Figure 4-1. Air particulate and tritium sampling locations, Livermore site, 1992.

spirometer that itself was calibrated using a unit traceable to National Institute for Standards and Technology (NIST).

An easily dissolvable filter and a low trace-metal background are required for airborne-beryllium analyses. Whatman-41 filters provide a balance between such requirements and particulate-collection efficiency (Lindeken et al. 1963).

Particulate filters are changed each week at all locations. After each particulate filter is removed from a sampler, it is identified by location, date on, date off, elapsed time, and flow rate, and is given a sample identifier (a four-field code) that accompanies it throughout the analysis. Filters are then placed in glassine envelopes and transported to the Livermore site, where all recorded information is transferred to log sheets. After a four-day delay for decay of the radon-thoron daughters, gross alpha and beta activities on the filters are determined with a gas-flow proportional counter.

Separate ^{239}Pu and ^{90}Sr calibration sources determine alpha and beta counting efficiencies, respectively. These standards are traceable to NIST or equivalent certification. Counting-efficiency measurements are made with each set of counted filters. A background count is taken at the beginning of each run and between each set of ten samples. Records are kept of background and counting-efficiency variations that occur in the counting equipment.

Monthly composites of filters from each of the Livermore-site perimeter locations (SALV, MESQ, CAFE, MET, VIS, and COW) are placed into individual plastic bags. The six bags are then combined and sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. The Site 300 filters are sealed and counted in a similar manner. Following gamma counting, the composited filters from each Livermore-site perimeter location are analyzed for the presence of ^{239}Pu , ^{235}U , and ^{238}U . The off-site samples from the Livermore Valley are analyzed for ^{239}Pu , and all of the Site 300 samples are composited and analyzed for ^{239}Pu , ^{235}U , and ^{238}U . The filters are ashed and then dissolved in a mixture of nitric acid

(HNO_3) and hydrochloric acid (HCl) and/or hydrofluoric acid (HF). Plutonium and uranium are separated by an ion-exchange process. Each separated element is purified further by ion exchange. Then any plutonium is electroplated onto a stainless steel disk and submitted for alpha spectrometry, while uranium is submitted for analysis by mass spectrometry.

Replicate samples are processed to confirm the results obtained from the samplers. In addition, a duplicate QA/QC sampler is operated for two months in parallel with the permanent one at a given site. The QA/QC filters also are exchanged weekly, and both filter sets are submitted for analysis in the usual manner. After two months, the QA/QC sampler is rotated to another location.

A total volume of approximately 4 million liters of air is sampled at each location per week. LLNL's Radiation Analytical Sciences laboratory analyzes the filters for radionuclides, including mixed fission products, plutonium, and uranium. The details of air particulate sampling and sample change-out are described in Appendix B of the *Environmental Monitoring Plan* (Gallegos et al. 1992b). Details of high-volume sampler flow calibration are also discussed in an Environmental Monitoring Section procedure, and details of air sample analysis procedures are outlined in Garrison et al. (1985).

As outlined in U.S. Department of Energy (1991), gross alpha and gross beta air filter results are used only as trend indicators; specific radionuclide analysis is done for plutonium, uranium, and all gamma emitters. All analytical results are reported as a measured concentration, or at the minimum detection limit (MDL) when no activity is detected. In all cases, the MDL is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that are present or may be present in the air sample.

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Particle size distributions are not determined, because the estimated effective dose equivalent to the maximally exposed individual is well below the 0.01 mSv (1 mrem) allowable limit.

In addition to radionuclide analyses, beryllium measurements are performed on Livermore-site perimeter filters. Beryllium and lead measurements are performed on Site 300 samples. Each month, half of each of the weekly air filters are composited by sample location. The filters are wet-ashed with nitric acid and quantification is done by atomic absorption spectroscopy. These analyses are performed by an outside contract laboratory.

Beryllium measurements from half of each of the weekly air filters from the Livermore-site perimeter and Site 300 samplers are composited by sampling location every month. Two paper filters at a time are wet-ashed with a mixture of 80% HNO₃ and 20% perchloric acid (HClO₄). The solutions then are evaporated to a few milliliters (care is taken to prevent the samples from baking dry). The samples are diluted

with water and filtered. Any residues are discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is accomplished by atomic absorption spectrophotometry with electrothermal atomization.

LLNL also maintains 11 continuously operating airborne tritium samplers on the Livermore site (**Figure 4-1**) and 6 samplers in the Livermore Valley (**Figure 4-2**). Four of the Livermore site locations (B331, B292, B514, and B624) are part of a special study. The tritium sample locations are detailed in Appendix B of the *Environmental Monitoring Plan* (Gallegos et al. 1992b). The tritium samplers, operating at a flow rate of 700 mL/min, use silica-gel in flasks to trap water vapor. These flasks are changed every two weeks, and the samples are identified by location, date on, date off, elapsed sampling time, and flow rate. The flow rate is the average of the initial and final flow rates, which are measured biweekly with a rotometer that is calibrated once a year. Each sample is given a sample identifier that accompanies it through analysis. Two additional samplers are rotated among the locations at two-month intervals to provide a duplicate QA/QC sample. Details of the actual tritium sampling and a description of tritium sampler calibration can be found in Appendix B of the *Environmental Monitoring Plan* (Gallegos et al. 1992b).

The tritium concentration in the collected water vapor is determined by liquid-scintillation counting. Airborne tritium sample analysis is done by LLNL's Radiation Analytical Sciences laboratory. Details of the analytical procedure are described in Garrison et al. (1985).

Results

Livermore Site

Airborne Radioactivity. The values reported for gross alpha and gross beta activities are similar to those observed in previous years and show no significant differences between samples taken at the Livermore-site perimeter and Livermore Valley. Most of the gross alpha determinations were at or near the detection limit of the method. Typical gross alpha activity is less than 1.3×10^{-10} Bq/mL ($<3.4 \times 10^{-15}$ μ Ci/mL), and typical beta activity is 5.4×10^{-10} Bq/mL (1.5×10^{-14} μ Ci/mL). The primary sources of observed alpha and beta activity are the naturally occurring radioisotopes of uranium and thorium and their decay products.

Table 4-1 lists the activities of gamma-emitting radionuclides that contribute to the activity in the Livermore-site perimeter samples. Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th occur naturally. The primary source of ^{137}Cs is long-term global fallout and fallout resuspension. An investigation to determine the source of ^{22}Na has begun.

In addition to providing baseline data on global fallout, analysis of these fission products enables LLNL to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL. The Derived Concentration Guides (DCGs) for these radionuclides are also shown in **Table 4-1**. For air, DCGs specify the concentrations of radionuclides that could be inhaled continuously 365 days a year without exceeding the DOE primary

4. Air Monitoring

radiation protection standard to the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent (DOE Order 5400.5). (Chapter 11 on Radiological Dose Assessment provides an explanation of this and other units of dose.) Finally, the percentage of the DCGs is presented. These values demonstrate the low levels of gamma activity present at the Livermore-site perimeter.

Table 4-2 shows the concentration of plutonium on air filter samples collected in the Livermore Valley. The highest off-site concentration occurred in June at Location LWRP (at the Livermore Water Reclamation Plant). The LWRP contains some contamination principally resulting from sludge-spreading operations following an estimated 32 mCi of plutonium released to the sewer in 1967 (see Chapter 8 on Soil and Sediment Monitoring). In June of 1992, the LWRP began construction of a new clarifier tank located approximately 25 meters upwind of the air sampling station. These construction activities caused large amounts of resuspension that could be responsible for the elevated ^{239}Pu results in June. **Table 4-3** shows the concentrations of airborne ^{239}Pu , ^{235}U , and ^{238}U (depleted uranium) on air filter samples from the Livermore-site perimeter. For these data, the DCG is based on the typical environmental oxide chemical form. Because of problems with the analysis of the April samples for Locations SALV, MESQ, CAFE, MET, VIS, and COW, some 5.1-cm-diameter sections of these samples were retrieved from another analytical lab and used for reanalysis. Although the results are higher than normal for these locations, they represent the limit of detection for filter samples of this size. The April sample for Location SALV, which is on the site perimeter of the Livermore site, registered the highest concentrations of plutonium in air of all perimeter sampling locations. The concentration reported for this sample, 2.11×10^{-13} Bq/mL (5.70×10^{-18} $\mu\text{Ci/mL}$), represents 0.00029 of the DCG. No other statistically significant differences between locations or samples were noted, and the overall ^{239}Pu levels essentially were the same as those reported in 1991. The maximum measured concentrations of ^{238}U are less than 0.0006 of the DCG (DOE Order 5400.5). Except for the April results, when analytical problems occurred, all $^{235}\text{U}/^{238}\text{U}$ ratios are as expected for naturally occurring uranium.

Figure 4-4 shows the annual mean concentrations of ^{239}Pu for Locations SALV (on site) and FCC (off site) from 1982 to 1992. Location FCC represents a typical background location and SALV represents the perimeter location having the highest annual average over this 11-year period. The higher values at SALV may be attributed to historical activities at LLNL.

In June 1991, two air-particulate sampling locations (B531 and CRED) were added as part of a special study to investigate elevated levels of plutonium in air and surface soil in the southeast quadrant of the Livermore site [see the 1991 Soil and Sediment Monitoring chapter for general background on this study (Gallegos et al. 1992a)]. **Table 4-4** shows the monthly concentrations of airborne ^{239}Pu at these locations. The average concentration of less than

2.74×10^{-13} Bq/mL ($<7.4 \times 10^{-18}$ μ Ci/mL) at Location B531 is higher than the average concentration for any of the other air particulate sampling locations but are still far below the DCG. These sampling locations will become part of our routine monitoring network and will provide data for diffuse source dose assessments.

Table 4-5 shows the average biweekly concentrations of tritiated water-vapor that were observed at the Livermore-site perimeter sampling locations. The highest annual mean concentration was observed at Location POOL. The mean concentration at POOL was 3.3×10^{-7} Bq/mL (8.9×10^{-12} μ Ci/mL), or 0.00009 of the DCG.

Four additional air tritium sampling locations (B331, B292, B514, and B624) were installed in July 1991 to evaluate diffuse sources of tritium on the Livermore site. Table 4-6 shows the average biweekly concentrations of tritiated water-vapor for the new sampling locations. The highest average concentrations were observed at Locations B292 and B624. These concentrations were 5.0×10^{-6} Bq/mL (1.4×10^{-10} μ Ci/mL) and 1.7×10^{-6} Bq/mL (4.5×10^{-11} μ Ci/mL), respectively, and represent 0.0014 and 0.0005 of the DCG. The 1992 average concentrations at B292 and B624 are lower than the average concentrations in 1991. The highest biweekly tritium concentrations of 2.5×10^{-5} Bq/mL (6.8×10^{-10} μ Ci/mL) in May and 1.2×10^{-5} Bq/mL (3.3×10^{-10} μ Ci/mL) in August

4. Air Monitoring

were observed at Location B292. These concentrations represent 0.0068 and 0.0032 of the DCG, respectively. The B292 area is adjacent to an underground retention tank that had previously leaked (see the Underground Storage Tank Management section of Chapter 2, Compliance Summary, for information regarding the B292 area). Another noteworthy biweekly tritium concentration of 1.0×10^{-5} Bq/mL (2.7×10^{-10} μ Ci/mL) was observed at Location B331 in July. Although this concentration is much higher than any biweekly concentrations in 1991, the 1992 average concentration at B331 is the same as 1991. As with the two new air particulate sampling locations, the new tritium sampling locations will be continued to provide diffuse emission source data.

Table 4-7 shows the average biweekly concentrations of tritiated water-vapor for the Livermore Valley sampling locations. The highest annual average concentrations were observed at Locations ZON7 and VET. This concentration of approximately 9.5×10^{-8} Bq/mL (2.6×10^{-12} μ Ci/mL) represents 0.00002 of the DCG. The highest biweekly concentration was observed in February at Location VET. This concentration, 2.6×10^{-7} Bq/mL (7.0×10^{-12} μ Ci/mL), is 0.00007 of the DCG. These 1992 tritium values generally are lower than those reported last year.

Beryllium in Air. The average monthly concentrations of airborne beryllium for the Livermore-site perimeter sampling locations are shown in

Table 4-8. The concentrations are less than 0.007 of the monthly ambient concentration limit of 10,000 pg/m³ established by the Bay Area Air Quality Management District (BAAQMD).

Figure 4-5 is a plot of the average beryllium concentration at the LLNL-site perimeter from 1974 through 1992 (the medians of 1981, 1989, and 1990 values are shown because some of the varying analytical techniques have high detection limits). The average concentration was calculated to be 0.004 of the ambient concentration guide. Unless there is a change in LLNL's operations, it is expected that the beryllium levels will remain unchanged.

Site 300

Airborne Radioactivity. Most gross alpha determinations were at, or near, the analytical limit of detection for the method. Typical gross alpha activity is $<1.2 \times 10^{-10}$ Bq/mL ($<3.2 \times 10^{-15}$ μ Ci/mL). Typical beta activity is 5.0×10^{-10} Bq/mL (1.4×10^{-14} μ Ci/mL). The primary sources of observed gross alpha and beta activity are naturally occurring radioisotopes of uranium and thorium and their decay products.

Table 4-9 lists the activities, as well as the DCGs, of gamma-emitting radionuclides in samples from Site 300 and Tracy. All these radionuclides were measured at concentrations significantly below the DCGs. Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th are naturally occurring. The primary source of ^{137}Cs normally is long-term global fallout and fallout resuspension. An investigation to determine the source of ^{22}Na has begun.

Table 4-10 shows the concentration of ^{239}Pu , ^{238}U , and ^{235}U on air filter samples collected from Site 300. The highest concentrations of ^{239}Pu were observed in the April and May composites at a level of approximately 3.1×10^{-14} Bq/mL (8.2×10^{-19} μ Ci/mL, or 0.00004 of the DCG). The highest concentration of ^{238}U was observed in the April composite at a level of 2.5×10^{-4} $\mu\text{g}/\text{m}^3$ (0.0008 of the DCG). The highest concentration of ^{235}U was also observed in the April composite at a level of 1.7×10^{-6} $\mu\text{g}/\text{m}^3$ (0.00004 of the DCG). No other significant differences between locations or samples were noted. The overall levels were essentially the same as those reported in previous years.

The ratio of ^{235}U to ^{238}U can be used as an indicator of the source of the uranium. Both ^{235}U and ^{238}U occur naturally in the area, but only 0.7% of the naturally occurring uranium is ^{235}U , and the remainder is ^{238}U . Because LLNL uses ^{238}U at Site 300, but does not use ^{235}U , it follows that if the ratio remains constant and near 0.7% (within the limit of sampling and analytical error), then the ^{238}U measured is from natural sources. The $^{235}\text{U}/^{238}\text{U}$ ratio for January and October show statistically significant deviations from the natural ratio, indicating the presence of airborne depleted uranium from Site 300 operations. The measured concentrations of ^{238}U , however, are only 0.00024 of the DCG (DOE Order 5400.5).

Beryllium in Air. The average monthly concentrations of airborne beryllium for the Site 300 sampling locations are shown in **Table 4-11**. The highest beryllium concentration of 304.9 pg/m^3 occurred at Location WOBS in July. We will continue to investigate beryllium concentrations at this location. The concentrations average 0.003 or less (with the highest value being 0.03) of the federal standard, which is 10,000 pg/m^3 . These data are well below the standards and do not indicate the presence of a threat to the environment or public health.

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Environmental Impact

Radioactive Effluents

In 1992, a total of 6.55×10^{12} Bq (177 Ci) of tritium was released to the atmosphere from operations at LLNL. Of this, approximately 3.70×10^{12} Bq (100 Ci) were released as tritiated water (HTO). The remaining tritium was elemental tritium gas (HT). Once released to the environment, the potential dose from elemental tritium gas is approximately 25,000 times lower than a dose from a comparable release of tritiated water. Therefore, the tritiated hydrogen gas did not contribute significantly in calculations of the overall dose. Most of the tritium discharged to the atmosphere by LLNL in 1992 came from the Tritium Facility (Building 331). The highest single weekly emission from the facility was 4.81×10^{11} Bq (13 Ci), of which 3.70×10^{11} Bq (10 Ci) was elemental tritium gas. This emission was measured between August 6 and August 25, 1992. The diffuse tritium sources at B292, B331, B514, and B624 have a localized effect; however, no high tritium concentrations were detected at the site perimeter or off site.

The electron-positron linear accelerator at B194 was not activated in 1992. Therefore, no releases of ^{13}N and ^{15}O occurred. Comparative releases of radioactive effluents at LLNL during the 12-year period from 1981 through 1992 are shown in **Table 4-12**. The radioactive atmospheric emissions from LLNL operations during 1992 were much lower than previous years.

The concentrations of beryllium and radionuclides measured around Site 300 and in the City of Tracy were well below all standards and, except for uranium isotopes, reflect background or naturally occurring levels of these chemicals. Two of the $^{235}\text{U}/^{238}\text{U}$ ratios shown in **Table 4-11** are less than the ratio of naturally occurring concentrations of these isotopes, and this suggests the presence of LLNL-induced depleted uranium in air samples from Site 300, although the actual concentrations are not statistically elevated over background.

Nonradioactive Effluents

The concentrations of beryllium at both sites can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and the Livermore area and Central Valley air typically contains 10 to 100 μg of particulates per cubic meter. Using a value of $50 \mu\text{g}/\text{m}^3$ for an average dust load and 1 ppm for beryllium content of dust, an airborne beryllium concentration of $50 \text{ pg}/\text{m}^3$ can be calculated. In view of the range of natural variation expected in these background values, this value is in excellent agreement with the data in **Tables 4-8** and **4-9**.

The estimated releases from exempt and permitted sources of air pollutants at the Livermore site can be compared to the most recent estimated 1992 daily release of air pollutants for the entire Bay Area. For example, the total emissions of oxides of nitrogen (NO_x) released in the Bay Area is 500 metric tons per day compared to LLNL's 0.079 metric tons per day (0.0002 of total Bay Area

emissions). The Bay Area Air Quality Management District estimate for reactive organic emissions (ROG) is at 743 metric tons/day, versus Livermore site's 0.013 metric tons/day (0.00002 of total Bay Area emissions) in 1992.

Table 4-13 lists the estimated LLNL 1992 total releases for organic precursor and nonprecursor compounds, chlorofluorocarbons (an organic nonprecursor), and other LLNL airborne emissions.

Certain equipment operations at Site 300 require permits from San Joaquin County. Total estimated emissions are reported to the San Joaquin Valley Unified Air Pollution Control District. The total estimated air emissions during 1992 from equipment operations at Site 300 are given in **Table 4-13**.

4. Air Monitoring

Table 4-1. Gamma activity on air filters, Livermore-site perimeter, 1992.^a

Month	[10 ⁻⁹ Bq/mL]	[10 ⁻¹² Bq/mL]		
	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na
Jan.	2.69 ± 0.04	<4.18	<0.17	<0.19
Feb.	3.91 ± 0.06	<5.81	<0.20	<0.23
Mar.	3.87 ± 0.08	<6.92	<0.26	<0.28
Apr.	5.34 ± 0.09	<4.54	<0.17	0.76 ± 0.41
May	5.82 ± 0.09	<5.89	<0.21	0.70 ± 0.49
June	3.17 ± 0.05	<6.80	<0.23	<0.26
July	4.10 ± 0.10	23.41 ± 13.91	<0.16	<0.19
Aug.	5.91 ± 0.09	23.69 ± 11.18	0.62 ± 0.44	0.73 ± 0.48
Sept.	5.45 ± 0.09	35.83 ± 14.69	1.05 ± 0.48	<0.22
Oct.	6.10 ± 0.10	15.82 ± 10.79	0.53 ± 0.31	<0.19
Nov.	5.75 ± 0.15	<6.50	<0.21	0.81 ± 0.54
Dec.	4.00 ± 0.09	<4.21	<0.23	<0.24
Median	4.68 ^b	<6.65	<0.22	<0.25
MAD	1.18 ^c	— ^d	— ^d	— ^d
DCG	1.5 × 10 ⁻³	3.3 × 10 ⁻⁵	1.5 × 10 ⁻⁵	3.7 × 10 ⁻⁵
Fraction of DCG	3.1 × 10 ⁻⁶	<2.0 × 10 ⁻⁷	<1.5 × 10 ⁻⁸	<6.8 × 10 ⁻⁹
[μCi/mL]				
Median	1.3 × 10 ^{-13b}	<1.8 × 10 ⁻¹⁶	<6.0 × 10 ⁻¹⁸	<6.8 × 10 ⁻¹⁸
MAD	3.2 × 10 ^{-14c}	— ^d	— ^d	— ^d
DCG	4 × 10 ⁻⁸	9 × 10 ⁻¹⁰	4 × 10 ⁻¹⁰	1 × 10 ⁻⁹

...continued

Table 4-1. Gamma activity on air filters, Livermore-site perimeter, 1992^a
(concluded).

Month	[10 ⁻¹² Bq/mL]		
	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Jan.	<0.37	<0.70	<0.38
Feb.	<0.43	<1.60	<0.42
Mar.	<0.53	<1.17	<0.61
Apr.	0.90 ± 0.51	1.97 ± 1.51	1.12 ± 0.64
May	<0.98	<1.22	<0.53
June	<1.03	<1.09	<0.53
July	<0.70	2.16 ± 1.48	0.92 ± 0.65
Aug.	1.70 ± 1.10	3.14 ± 1.36	2.06 ± 1.23
Sept.	2.38 ± 0.82	3.10 ± 1.53	2.11 ± 0.98
Oct.	1.51 ± 0.64	2.39 ± 1.29	1.57 ± 0.85
Nov.	<0.48	<0.97	<0.54
Dec.	<0.50	<0.88	<0.60
Median	<0.80	<1.41	<0.61
MAD	— ^d	— ^d	— ^d
DCG	3.7 × 10 ⁻⁸	1.1 × 10 ⁻⁷	1.5 × 10 ⁻⁹
Fraction of DCG	<2.2 × 10 ⁻⁵	<1.3 × 10 ⁻⁵	<4.0 × 10 ⁻⁴
	[μCi/mL]		
Median	<2.2 × 10 ⁻¹⁷	<3.8 × 10 ⁻¹⁷	<1.6 × 10 ⁻¹⁷
MAD	— ^d	— ^d	— ^d
DCG	1 × 10 ⁻¹²	3 × 10 ⁻¹²	4 × 10 ⁻¹⁴

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a All Livermore-site perimeter samples composited.

^b Mean value reported because of QA requirements; see Quality Assurance chapter.

^c Standard deviation reported because of QA requirements; see Quality Assurance chapter.

^d No measure of dispersion calculated; see Quality Assurance chapter.

4. Air Monitoring

Table 4-2. Plutonium-239 activity on air filters (in 10^{-13} Bq/mL), Livermore Valley, 1992.

Month	Sampling location ^a					
	TANK	ZON7	FCC	HOSP	LWRP	FIRE
Jan.	0.56 ± 0.18	<0.08	0.24 ± 0.13	0.50 ± 0.20	0.51 ± 0.20	0.23 ± 0.15
Feb.	<0.07	0.34 ± 0.16	0.13 ± 0.10	— ^b	0.48 ± 0.23	0.20 ± 0.16
Mar.	0.09 ± 0.09	0.31 ± 0.16	0.16 ± 0.10	<0.09	0.35 ± 0.15	0.10 ± 0.09
Apr.	0.19 ± 0.10	<0.03	<0.06	0.10 ± 0.07	0.75 ± 0.20	0.19 ± 0.11
May	<0.05	<0.02	<0.05	0.08 ± 0.08	0.28 ± 0.20	<0.06
June	<0.03	<0.07	<0.08	<0.21	2.23 ± 0.45	<0.12
July	<0.02	0.10 ± 0.07	<0.03	<0.03	0.36 ± 0.25	<0.22
Aug.	<0.07	0.09 ± 0.09	<0.38	<0.08	0.57 ± 0.29	0.10 ± 0.08
Sept.	0.63 ± 0.56	0.31 ± 0.20	0.13 ± 0.11	0.15 ± 0.13	0.42 ± 0.23	<1.25
Oct.	<0.02	0.13 ± 0.11	<0.46	<0.23	0.71 ± 0.20	<0.01
Nov.	<0.23	<0.05	<0.29	<0.06	0.31 ± 0.14	<0.04
Dec.	<0.06	<0.04	<0.02	<0.02	<0.34	<0.01
Median	<0.07	<0.09	<0.13	<0.09	$<0.61^c$	<0.11
MAD	— ^e	— ^e	— ^e	— ^e	$>0.53^d$	— ^e
Fraction of DCG	$<9.3 \times 10^{-6}$	$<1.2 \times 10^{-5}$	$<1.8 \times 10^{-5}$	$<1.2 \times 10^{-5}$	$<8.2 \times 10^{-5}$	$<1.5 \times 10^{-5}$
[$\mu\text{Ci/mL}$]						
Median	$<1.9 \times 10^{-19}$	$<2.3 \times 10^{-19}$	$<3.5 \times 10^{-19}$	$<2.5 \times 10^{-19}$	$<1.6 \times 10^{-18c}$	$<3.0 \times 10^{-19}$
MAD	— ^e	— ^e	— ^e	— ^e	$>1.4 \times 10^{-18d}$	— ^e

...continued

Table 4-2. Plutonium-239 activity on air filters (in 10^{-13} Bq/mL), Livermore Valley, 1992
(concluded).

Month	Sampling location ^a					
	TFIR	ALTA	ERCH	LCCY	RRCH	PATT
Jan.	<0.10	0.16 ± 0.10	0.08 ± 0.07	0.25 ± 0.15	0.74 ± 0.23	0.09 ± 0.07
Feb.	0.19 ± 0.14	0.19 ± 0.13	0.56 ± 0.29	0.32 ± 0.18	0.16 ± 0.12	0.61 ± 0.25
Mar.	0.20 ± 0.12	0.22 ± 0.12	0.19 ± 0.11	0.16 ± 0.11	0.20 ± 0.11	0.24 ± 0.13
Apr.	0.13 ± 0.09	0.16 ± 0.10	0.13 ± 0.09	0.20 ± 0.11	0.12 ± 0.08	0.10 ± 0.05
May	<0.04	<0.04	0.28 ± 0.14	<0.02	<0.05	<0.04
June	0.12 ± 0.09	<0.13	0.42 ± 0.26	0.23 ± 0.21	<0.04	<0.22
July	<0.05	<0.06	0.14 ± 0.13	<0.05	<0.37	<0.05
Aug.	0.68 ± 0.36	0.20 ± 0.14	0.27 ± 0.15	<0.42	<0.001	<0.002
Sept.	0.21 ± 0.17	<1.22	<0.04	0.19 ± 0.14	0.15 ± 0.11	<0.92
Oct.	<0.33	<0.21	<0.08	<0.09	0.14 ± 0.11	0.15 ± 0.11
Nov.	<0.004	<0.20	<0.17	0.10 ± 0.08	0.07 ± 0.07	<0.18
Dec.	<0.15	<0.33	<0.33	0.21 ± 0.17	<0.09	<0.24
Median	<0.14	<0.20	<0.22 ^c	<0.19 ^c	<0.13	<0.17
MAD	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e
Fraction of DCG ^f	$<1.9 \times 10^{-5}$	$<2.7 \times 10^{-5}$	$<3.0 \times 10^{-5}$	$<2.5 \times 10^{-5}$	$<1.8 \times 10^{-5}$	$<2.2 \times 10^{-5}$
[$\mu\text{Ci/mL}$]						
Median	$<3.8 \times 10^{-19}$	$<5.3 \times 10^{-19}$	$<6.1 \times 10^{-19}$ ^c	$<5.1 \times 10^{-19}$ ^c	$<3.5 \times 10^{-19}$	$<4.5 \times 10^{-19}$
MAD	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 4-2 for sample locations. Location TFIR is in the city of Tracy.

^b No data; see Quality Assurance chapter.

^c Mean value reported because of QA requirements; see Quality Assurance chapter.

^d Standard deviation reported because of QA requirements; see Quality Assurance chapter.

^e No measure of dispersion calculated; see Quality Assurance chapter.

^f DCG = 7.4×10^{-10} Bq/mL for ^{239}Pu activity in air (2×10^{-14} $\mu\text{Ci/mL}$).

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Table 4-3. Plutonium and uranium activity on air filters, Livermore-site perimeter, 1992.

Location ^a	Month	[10 ⁻¹³ Bq/mL]	[10 ⁻⁵ µg/m ³]	[10 ⁻⁷ µg/m ³]	[10 ⁻³]
		²³⁹ Pu	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U
SALV	Jan.	0.23 ± 0.14	2.06	1.50	7.28
	Feb.	0.50 ± 0.26	2.37	1.68	7.09
	Mar.	0.23 ± 0.12	2.74	1.92	7.00
	Apr. ^b	2.11 ± 1.01	2.41	1.38	5.72
	May	0.91 ± 0.24	11.40	8.10	7.11
	June	0.47 ± 0.19	10.50	7.54	7.21
	July	1.72 ± 0.74	8.35	6.13	7.35
	Aug.	0.47 ± 0.20	11.90	8.59	7.23
	Sept.	0.69 ± 0.25	18.30	13.30	7.29
	Oct.	0.25 ± 0.24	7.89	5.66	7.18
	Nov.	0.17 ± 0.14	7.13	5.11	7.17
	Dec.	0.35 ± 0.22	2.24	1.60	7.16
MESQ	Jan.	0.15 ± 0.10	2.79	1.98	7.10
	Feb.	0.12 ± 0.11	3.32	2.40	7.21
	Mar.	0.19 ± 0.13	3.54	2.52	7.11
	Apr. ^b	0.98 ± 0.70	2.90	1.65	5.68
	May	0.30 ± 0.14	5.79	4.16	7.18
	June	0.14 ± 0.10	8.68	5.70	6.56
	July	<0.28	6.04	4.40	7.29
	Aug.	0.40 ± 0.17	7.60	5.56	7.32
	Sept.	0.44 ± 0.24	15.10	11.00	7.26
	Oct.	0.14 ± 0.12	8.16	5.79	7.10
	Nov.	0.27 ± 0.13	6.83	4.85	7.09
	Dec.	0.27 ± 0.18	2.54	1.87	7.37
CAFE	Jan.	<0.10	5.08	3.58	7.04
	Feb.	0.30 ± 0.15	5.46	3.94	7.21
	Mar.	0.41 ± 0.20	6.66	4.68	7.02
	Apr. ^b	0.94 ± 0.85	3.90	3.62	9.28
	May	0.41 ± 0.20	9.89	7.11	7.18
	June	0.24 ± 0.18	8.56	6.10	7.13
	July	0.34 ± 0.13	9.11	6.82	7.49
	Aug.	0.40 ± 0.21	14.20	10.20	7.20
	Sept.	0.51 ± 0.23	16.00	11.80	7.33
	Oct.	0.21 ± 0.13	10.90	7.89	7.24
	Nov.	0.26 ± 0.19	7.07	5.15	7.28
	Dec.	0.34 ± 0.20	4.23	3.10	7.31

...continued

Table 4-3. Plutonium and uranium activity on air filters, Livermore-site perimeter, 1992
(continued).

Location ^a	Month	[10 ⁻¹³ Bq/mL]	[10 ⁻⁵ µg/m ³]	[10 ⁻⁷ µg/m ³]	[10 ⁻³]
		²³⁹ Pu	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U
MET	Jan.	0.22 ± 0.13	2.06	1.48	7.20
	Feb.	0.16 ± 0.12	2.75	1.99	7.23
	Mar.	0.14 ± 0.10	2.76	1.98	7.17
	Apr. ^b	0.67 ± 0.53	2.84	1.87	6.61
	May	0.28 ± 0.13	5.10	3.68	7.22
	June	0.98 ± 0.41	5.33	3.56	6.69
	July	<0.09	4.34	3.16	7.27
	Aug.	0.34 ± 0.19	8.27	6.21	7.51
	Sept.	0.35 ± 0.15	9.63	6.98	7.25
	Oct.	0.23 ± 0.17	7.57	5.49	7.25
	Nov.	0.24 ± 0.14	6.11	4.54	7.43
	Dec.	<0.07	2.27	1.67	7.35
VIS	Jan.	0.28 ± 0.15	2.46	1.74	7.05
	Feb.	0.23 ± 0.14	2.92	2.08	7.13
	Mar.	0.31 ± 0.16	2.77	1.97	7.11
	Apr. ^b	0.86 ± 0.65	2.30	1.66	6.12
	May	0.37 ± 0.17	3.97	2.86	7.20
	June	0.28 ± 0.13	5.01	3.29	6.57
	July	0.34 ± 0.13	4.41	3.30	7.49
	Aug.	0.51 ± 0.24	6.72	4.97	7.40
	Sept.	0.62 ± 0.24	9.67	6.96	7.20
	Oct.	0.33 ± 0.25	6.36	4.64	7.29
	Nov.	0.30 ± 0.18	5.57	4.08	7.32
	Dec.	0.16 ± 0.15	2.06	1.47	7.13
COW	Jan.	0.30 ± 0.16	3.40	2.42	7.11
	Feb.	0.30 ± 0.16	3.92	2.78	7.11
	Mar.	0.45 ± 0.23	5.38	3.79	7.05
	Apr. ^b	1.03 ± 0.71	4.97	3.33	6.70
	May	0.17 ± 0.12	10.70	7.73	7.21
	June	0.51 ± 0.26	8.76	6.23	7.11
	July	0.30 ± 0.22	7.42	5.45	7.35
	Aug.	0.31 ± 0.17	10.10	7.23	7.13
	Sept.	0.26 ± 0.15	12.90	8.89	6.89
	Oct.	<0.20	9.03	6.64	7.14
	Nov.	0.17 ± 0.13	6.97	4.83	6.93
	Dec.	0.25 ± 0.16	2.45	1.81	7.36

...continued

4. Air Monitoring

Table 4-3. Plutonium and uranium activity on air filters, Livermore-site perimeter, 1992 (*concluded*).

Sampling location ^a	SALV	MESQ	CAFE	MET	VIS	COW
²³⁹Pu						
Mean (10^{-13} Bq/mL)	0.68	<0.31	<0.37	<0.31	0.38	<0.35
Std dev (10^{-13} Bq/mL)	0.62	>0.23	>0.21	>0.26	0.19	>0.24
Fraction of DCG ^c	9.13×10^{-5}	$<4.13 \times 10^{-5}$	$<5.03 \times 10^{-5}$	$<4.23 \times 10^{-5}$	5.17×10^{-5}	$<4.79 \times 10^{-5}$
Mean (10^{-18} μ Ci/mL)	1.83	<0.83	<1.01	<0.85	1.03	<0.96
Std dev (10^{-18} μ Ci/mL)	1.68	>0.63	>0.57	>0.71	0.53	>0.64
²³⁸U						
Mean (10^{-5} μ g/m ³)	7.27	6.11	8.42	4.92	4.52	7.17
Std dev (10^{-5} μ g/m ³)	5.16	3.60	3.84	2.55	2.28	3.23
Fraction of DCG ^d	2.42×10^{-4}	2.04×10^{-4}	2.81×10^{-4}	1.64×10^{-4}	1.51×10^{-4}	2.39×10^{-4}
²³⁵U						
Mean (10^{-7} μ g/m ³)	5.21	4.32	6.17	3.55	3.25	5.09
Std dev (10^{-7} μ g/m ³)	3.77	2.63	2.75	1.89	1.66	2.29
Fraction of DCG ^e	1.11×10^{-5}	9.20×10^{-6}	1.31×10^{-5}	7.55×10^{-6}	6.92×10^{-6}	1.08×10^{-5}

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 4-1 for sample locations.

^b Problems with the analysis of these samples occurred (see text).

^c DCG = 7.4×10^{-10} Bq/mL for ²³⁹Pu activity in air (2×10^{-14} μ Ci/mL).

^d DCG = 0.3 μ g/m³ for ²³⁸U activity in air.

^e DCG = 0.047 μ g/m³ for ²³⁵U activity in air.

Table 4-4. Plutonium-239 activity on air filters (in 10^{-13} Bq/mL), 1992.

Month	Sampling location ^a	
	B531	CRED
Jan.	0.98 ± 0.30	0.26 ± 0.13
Feb.	0.77 ± 0.26	0.21 ± 0.19
Mar.	0.14 ± 0.03	0.35 ± 0.17
Apr.	1.99 ± 0.61	0.18 ± 0.11
May	3.92 ± 0.54	0.26 ± 0.16
June	4.44 ± 0.84	0.32 ± 0.16
July	2.82 ± 0.60	0.46 ± 0.23
Aug.	3.16 ± 0.46	0.40 ± 0.18
Sept.	9.99 ± 0.80	0.47 ± 0.22
Oct.	3.51 ± 0.61	<0.41
Nov.	1.12 ± 0.25	<0.01
Dec.	<0.02	<0.01
Mean	<2.74	<0.28
Std dev	>2.73	— ^b
Fraction of DCG ^c	$<3.70 \times 10^{-4}$	$<3.76 \times 10^{-5}$
[$\mu\text{Ci/mL}$]		
Mean ($\mu\text{Ci/mL}$)	$<7.40 \times 10^{-18}$	$<7.52 \times 10^{-19}$
Std dev ($\mu\text{Ci/mL}$)	$>7.38 \times 10^{-18}$	— ^b

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 4-1 for sample locations.

^b No measure of dispersion calculated; see Quality Assurance chapter.

^c DCG = 7.4×10^{-10} Bq/mL for ^{239}Pu activity in air (2×10^{-14} $\mu\text{Ci/mL}$).

4. Air Monitoring

Table 4-5. Tritium in air (in 10^{-7} Bq/mL), Livermore-site perimeter, 1992.

Month	Sampling location ^a			
	SALV	MESQ	CAFE	MET
Jan.	1.31 ± 0.11	0.11 ± 0.08	2.09 ± 0.14	1.01 ± 0.11
	0.70 ± 0.11	0.08 ± 0.08	0.18 ± 0.09	1.93 ± 0.14
Feb.	1.92 ± 0.18	2.58 ± 0.19	3.32 ± 0.21	1.98 ± 0.19
	1.35 ± 0.12	1.77 ± 0.18	3.17 ± 0.20	0.94 ± 0.12
Mar.	2.86 ± 0.18	2.15 ± 0.21	2.98 ± 0.19	1.46 ± 0.14
	1.99 ± 0.19	1.80 ± 0.19	2.29 ± 0.19	0.99 ± 0.16
Apr.	3.85 ± 0.22	1.17 ± 0.16	1.70 ± 0.16	0.63 ± 0.20
	1.67 ± 0.18	— ^b	1.74 ± 0.18	0.43 ± 0.14
May	2.83 ± 0.20	1.07 ± 0.15	1.98 ± 0.17	0.85 ± 0.14
	1.72 ± 0.17	0.67 ± 0.14	1.58 ± 0.17	0.53 ± 0.13
June	2.28 ± 0.16	0.20 ± 0.10	0.54 ± 0.13	0.29 ± 0.26
	2.26 ± 0.20	0.15 ± 0.12	0.42 ± 0.13	0.14 ± 0.12
July	2.11 ± 0.24	0.24 ± 0.18	0.43 ± 0.17	<0.17
	2.14 ± 0.22	0.61 ± 0.18	1.13 ± 0.19	0.33 ± 0.16
	3.43 ± 0.31	<0.19	0.50 ± 0.19	<0.16
Aug.	3.61 ± 0.25	0.75 ± 0.18	1.40 ± 0.19	0.74 ± 0.17
	3.34 ± 0.23	1.85 ± 0.20	3.20 ± 0.24	— ^b
Sept.	2.73 ± 0.25	1.04 ± 0.19	1.05 ± 0.19	0.43 ± 0.17
	2.37 ± 0.15	1.11 ± 0.20	1.64 ± 0.21	0.70 ± 0.13
Oct.	1.47 ± 0.19	4.03 ± 0.26	3.04 ± 0.23	1.47 ± 0.12
	2.05 ± 0.22	1.91 ± 0.19	2.67 ± 0.32	1.12 ± 0.17
Nov.	— ^b	0.95 ± 0.18	2.63 ± 0.25	1.90 ± 0.32
	2.05 ± 0.16	9.69 ± 0.28	5.29 ± 0.22	3.01 ± 0.19
Dec.	1.30 ± 0.14	1.61 ± 0.15	2.14 ± 0.14	1.24 ± 0.13
	1.46 ± 0.15	0.64 ± 0.16	2.23 ± 0.20	0.73 ± 0.17
	1.53 ± 0.19	0.83 ± 0.15	1.77 ± 0.17	0.95 ± 0.17
Mean ^c	2.17	<1.49	1.97	<0.97
Std dev	0.80	>1.94	1.16	>0.69
Fraction of DCG ^d	5.88×10^{-5}	$<4.02 \times 10^{-5}$	5.31×10^{-5}	$<2.61 \times 10^{-5}$
Dose (mSv) ^e	4.7×10^{-5}	$<3.2 \times 10^{-5}$	4.2×10^{-5}	$<2.1 \times 10^{-5}$
[$\mu\text{Ci/mL}$]				
Mean	5.88×10^{-12}	$<4.02 \times 10^{-12}$	5.31×10^{-12}	$<2.61 \times 10^{-12}$
Std dev	2.17×10^{-12}	$>5.25 \times 10^{-12}$	3.14×10^{-12}	$>1.87 \times 10^{-12}$
Dose (mrem) ^e	4.7×10^{-3}	$<3.2 \times 10^{-3}$	4.2×10^{-3}	$<2.1 \times 10^{-3}$

...continued

Table 4-5. Tritium in air (in 10^{-7} Bq/mL), Livermore-site perimeter, 1992
(concluded).

Month	Sampling location ^a		
	VIS	COW	POOL
Jan.	1.61 ± 0.15	1.27 ± 0.13	3.89 ± 0.21
	0.31 ± 0.10	0.32 ± 0.09	0.10 ± 0.09
Feb.	2.11 ± 0.18	1.00 ± 0.08	5.11 ± 0.27
	1.67 ± 0.19	0.96 ± 0.17	3.74 ± 0.23
Mar.	1.95 ± 0.14	2.53 ± 0.18	5.66 ± 0.30
	1.68 ± 0.20	1.37 ± 0.19	5.00 ± 0.27
Apr.	1.32 ± 0.17	0.95 ± 0.13	4.07 ± 0.26
	1.49 ± 0.19	0.88 ± 0.14	1.76 ± 0.17
May	1.44 ± 0.16	0.93 ± 0.14	2.28 ± 0.21
	1.61 ± 0.18	0.91 ± 0.14	2.00 ± 0.19
June	1.90 ± 0.15	0.87 ± 0.10	1.30 ± 0.12
	1.41 ± 0.18	0.51 ± 0.12	1.12 ± 0.15
July	1.96 ± 0.25	1.01 ± 0.19	1.38 ± 0.30
	1.95 ± 0.22	1.04 ± 0.17	2.57 ± 0.27
Aug.	1.64 ± 0.22	0.75 ± 0.17	1.47 ± 0.30
	2.18 ± 0.21	1.05 ± 0.16	2.38 ± 0.21
Sept.	2.60 ± 0.22	1.42 ± 0.17	3.41 ± 0.24
	1.73 ± 0.21	0.57 ± 0.15	3.89 ± 0.38
Oct.	1.54 ± 0.13	1.18 ± 0.10	2.49 ± 0.23
	0.80 ± 0.19	0.61 ± 0.10	6.33 ± 0.32
Nov.	1.74 ± 0.22	1.07 ± 0.17	4.29 ± 0.27
	2.24 ± 0.26	1.55 ± 0.29	4.59 ± 0.33
Dec.	1.39 ± 0.14	— ^b	9.55 ± 0.34
	0.74 ± 0.11	0.68 ± 0.11	3.14 ± 0.17
	1.62 ± 0.19	0.92 ± 0.19	2.14 ± 0.18
	1.11 ± 0.15	1.06 ± 0.16	1.91 ± 0.16
Mean ^c	1.61	1.02	3.29
Std dev	0.49	0.43	2.01
Fraction of DCG ^d	4.34×10^{-5}	2.75×10^{-5}	8.89×10^{-5}
Dose (mSv) ^e	3.4×10^{-5}	2.2×10^{-5}	7.1×10^{-5}
	[$\mu\text{Ci/mL}$]		
Mean	4.34×10^{-12}	2.75×10^{-12}	8.89×10^{-12}
Std dev	1.32×10^{-12}	1.15×10^{-12}	5.42×10^{-12}
Dose (mrem) ^e	3.4×10^{-3}	2.2×10^{-3}	7.1×10^{-3}

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 4-1 for sampling locations.

^b No data; see Quality Assurance chapter.

^c Livermore-site perimeter overall average = 1.8×10^{-7} Bq/mL.

^d DCG = 3.7×10^{-3} Bq/mL (1×10^{-7} $\mu\text{Ci/mL}$).

^e This dose is the effective dose equivalent.

4. Air Monitoring

Table 4-6. Tritium in air (in 10^{-7} Bq/mL), special study, 1992.

Month	Sampling location ^a			
	B292	B331	B514	B624
Jan.	0.33 ± 0.09	0.21 ± 0.09	0.14 ± 0.09	19.02 ± 0.36
	0.21 ± 0.08	<0.08	0.33 ± 0.08	0.55 ± 0.09
Feb.	— ^b	4.81 ± 0.22	3.47 ± 0.22	32.15 ± 0.58
	— ^b	7.62 ± 0.38	3.03 ± 0.20	28.64 ± 0.54
Mar.	49.58 ± 0.74	8.36 ± 0.30	3.08 ± 0.21	20.39 ± 0.43
	62.53 ± 0.94	4.11 ± 0.21	2.76 ± 0.20	19.24 ± 0.42
Apr.	67.34 ± 0.81	6.92 ± 0.28	2.05 ± 0.17	25.27 ± 0.45
	53.28 ± 0.80	5.18 ± 0.23	1.39 ± 0.15	22.64 ± 0.43
May	40.70 ± 0.61	7.99 ± 0.28	2.04 ± 0.17	33.26 ± 0.50
	251.60 ± 1.51	6.25 ± 0.25	1.51 ± 0.16	31.86 ± 0.54
June	66.23 ± 2.65	9.36 ± 0.43	0.98 ± 0.13	46.25 ± 1.85
	33.19 ± 0.50	5.66 ± 0.22	0.83 ± 0.12	8.47 ± 0.28
July	97.68 ± 1.07	8.14 ± 0.33	1.05 ± 0.19	10.25 ± 0.38
	10.14 ± 0.36	101.38 ± 1.12	1.72 ± 0.20	17.46 ± 0.47
	50.32 ± 0.70	9.99 ± 0.35	0.87 ± 0.15	7.44 ± 0.29
Aug.	122.47 ± 1.10	12.80 ± 0.37	1.57 ± 0.17	8.58 ± 0.30
	29.38 ± 0.50	— ^b	2.72 ± 0.22	9.25 ± 0.29
Sept.	15.98 ± 0.64	6.11 ± 0.27	1.47 ± 0.18	5.96 ± 0.26
	26.34 ± 1.03	9.07 ± 0.34	2.65 ± 0.22	8.92 ± 0.32
Oct.	36.70 ± 0.59	6.77 ± 0.28	2.86 ± 0.21	15.36 ± 0.40
	33.12 ± 0.63	15.36 ± 0.63	2.11 ± 0.18	11.43 ± 0.37
Nov.	14.21 ± 0.45	7.22 ± 0.32	3.30 ± 0.38	9.14 ± 0.36
	22.05 ± 0.42	5.07 ± 0.21	2.99 ± 0.17	7.92 ± 0.24
Dec.	13.51 ± 0.31	3.63 ± 0.18	2.47 ± 0.16	6.44 ± 0.23
	— ^b	4.74 ± 0.27	3.16 ± 0.20	10.66 ± 0.39
	— ^b	2.23 ± 0.15	2.52 ± 0.17	— ^b
Mean ^c	49.86	<10.36	2.04	16.66
Std dev	54.25	>19.27	0.96	11.09
Fraction of DCG ^d	1.35×10^{-3}	$<2.80 \times 10^{-4}$	5.52×10^{-5}	4.50×10^{-4}
Dose (mSv) ^e	1.1×10^{-3}	$<2.2 \times 10^{-4}$	4.4×10^{-5}	3.6×10^{-4}
[μCi/mL]				
Mean	1.35×10^{-10}	$<2.80 \times 10^{-11}$	5.52×10^{-12}	4.50×10^{-11}
Std dev	1.47×10^{-10}	$>5.21 \times 10^{-11}$	2.60×10^{-12}	3.00×10^{-11}
Dose (mrem) ^e	1.1×10^{-1}	$<2.2 \times 10^{-2}$	4.4×10^{-3}	3.6×10^{-2}

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 4-1 for sampling locations.

^b No data; see Quality Assurance chapter.

^c Special study overall average = 19.7×10^{-7} Bq/mL.

^d DCG = 3.7×10^{-3} Bq/mL (1×10^{-7} μCi/mL).

^e This dose is the effective dose equivalent.

Table 4-7. Tritium in air (in 10^{-7} Bq/mL), Livermore Valley, 1992.

Month	Sampling location ^a		
	ZON7	ALTA	LCCY
Jan.	0.67 ± 0.12	0.25 ± 0.12	0.37 ± 0.10
	1.17 ± 0.13	0.38 ± 0.11	0.14 ± 0.09
Feb.	1.26 ± 0.16	0.42 ± 0.18	1.12 ± 0.25
	1.16 ± 0.13	0.44 ± 0.14	1.11 ± 0.23
Mar.	1.36 ± 0.19	0.81 ± 0.19	0.72 ± 0.18
	0.91 ± 0.16	0.68 ± 0.17	0.61 ± 0.18
Apr.	0.93 ± 0.15	0.67 ± 0.15	0.15 ± 0.13
	0.68 ± 0.15	0.51 ± 0.17	0.19 ± 0.16
May	0.98 ± 0.14	0.67 ± 0.15	0.28 ± 0.12
	0.68 ± 0.13	0.33 ± 0.13	0.15 ± 0.15
June	1.23 ± 0.12	0.25 ± 0.09	<0.67
	0.88 ± 0.16	0.28 ± 0.15	0.15 ± 0.15
July	1.07 ± 0.20	0.39 ± 0.19	0.23 ± 0.16
	1.08 ± 0.19	0.48 ± 0.18	<0.15
	1.24 ± 0.21	<0.19	<0.18
Aug.	1.18 ± 0.20	<0.17	<0.18
	1.40 ± 0.17	0.61 ± 0.15	0.26 ± 0.17
Sept.	0.82 ± 0.10	0.26 ± 0.11	0.38 ± 0.29
	1.02 ± 0.13	0.39 ± 0.12	<0.14
Oct.	0.55 ± 0.15	0.64 ± 0.20	0.55 ± 0.16
	1.02 ± 0.21	0.42 ± 0.19	0.60 ± 0.17
Nov.	1.30 ± 0.24	0.62 ± 0.30	0.48 ± 0.20
	0.65 ± 0.11	0.50 ± 0.11	1.01 ± 0.12
Dec.	0.38 ± 0.12	— ^b	0.39 ± 0.12
	0.67 ± 0.14	0.28 ± 0.21	0.15 ± 0.12
	0.78 ± 0.18	0.24 ± 0.16	0.24 ± 0.10
Mean ^c	0.97	<0.43	<0.41
Std dev	0.27	>0.18	— ^d
Fraction of DCG ^e	2.61×10^{-5}	$<1.17 \times 10^{-5}$	$<1.10 \times 10^{-5}$
Dose (mSv) ^f	2.1×10^{-5}	$<9.3 \times 10^{-6}$	$<8.8 \times 10^{-6}$
[$\mu\text{Ci/mL}$]			
Mean	2.61×10^{-12}	$<1.17 \times 10^{-12}$	$<1.10 \times 10^{-12}$
Std dev	7.38×10^{-13}	$>4.83 \times 10^{-13}$	— ^d
Dose (mrem) ^f	2.1×10^{-3}	$<9.3 \times 10^{-4}$	$<8.8 \times 10^{-4}$

...continued

4. Air Monitoring

Table 4-7. Tritium in air (in 10^{-7} Bq/mL), Livermore Valley, 1992 (*concluded*).

Month	Sampling location ^a		
	FIRE	XRDS	VET
Jan.	0.67 ± 0.12	0.81 ± 0.14	1.10 ± 0.13
	0.58 ± 0.10	1.62 ± 0.15	0.67 ± 0.11
Feb.	0.95 ± 0.15	1.45 ± 0.22	2.59 ± 0.22
	0.77 ± 0.15	0.79 ± 0.19	1.53 ± 0.18
Mar.	0.97 ± 0.18	1.31 ± 0.21	1.61 ± 0.20
	0.57 ± 0.15	0.73 ± 0.18	1.44 ± 0.19
Apr.	0.20 ± 0.12	0.50 ± 0.16	0.65 ± 0.15
	0.22 ± 0.14	0.45 ± 0.18	0.35 ± 0.15
May	0.45 ± 0.15	0.87 ± 0.15	0.94 ± 0.15
	<0.13	0.34 ± 0.14	0.53 ± 0.14
June	0.24 ± 0.13	0.63 ± 0.13	0.28 ± 0.13
	0.21 ± 0.13	0.47 ± 0.15	<0.13
July	<0.17	0.61 ± 0.20	<0.18
	0.27 ± 0.17	0.60 ± 0.18	0.27 ± 0.16
	<0.16	0.37 ± 0.17	<0.54
Aug.	0.27 ± 0.15	0.51 ± 0.17	0.51 ± 0.16
	0.59 ± 0.15	1.05 ± 0.16	1.27 ± 0.17
Sept.	0.31 ± 0.08	0.32 ± 0.08	0.45 ± 0.09
	0.19 ± 0.11	0.58 ± 0.12	0.37 ± 0.12
Oct.	0.93 ± 0.16	0.36 ± 0.14	1.56 ± 0.18
	0.94 ± 0.19	0.67 ± 0.19	1.39 ± 0.29
Nov.	0.87 ± 0.23	0.71 ± 0.24	0.97 ± 0.23
	1.62 ± 0.14	0.45 ± 0.10	2.06 ± 0.16
Dec.	— ^b	0.27 ± 0.10	0.96 ± 0.13
	0.25 ± 0.17	0.20 ± 0.16	0.68 ± 0.15
	0.53 ± 0.13	0.50 ± 0.16	1.13 ± 0.14
Mean ^c	<0.52	0.66	<0.93
Std dev	>0.37	0.36	>0.62
Fraction of DCG ^e	<1.41 × 10 ⁻⁵	1.78 × 10 ⁻⁵	<2.51 × 10 ⁻⁵
Dose (mSv) ^f	<1.1 × 10 ⁻⁵	1.4 × 10 ⁻⁵	<2.0 × 10 ⁻⁵
	[μCi/mL]		
Mean	<1.41 × 10 ⁻¹²	1.78 × 10 ⁻¹²	<2.51 × 10 ⁻¹²
Std dev	>1.00 × 10 ⁻¹²	9.66 × 10 ⁻¹³	>1.67 × 10 ⁻¹²
Dose (mrem) ^f	<1.1 × 10 ⁻³	1.4 × 10 ⁻³	<2.0 × 10 ⁻³

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 4-2 for sampling locations.

^b No data; see Quality Assurance chapter.

^c Livermore Valley overall average = 6.6×10^{-8} Bq/mL.

^d No measure of dispersion calculated; see Quality Assurance chapter.

^e DCG = 3.7×10^{-3} Bq/mL (1×10^{-7} μCi/mL).

^f This dose is the effective dose equivalent.

Table 4-8. Beryllium on air filters (in pg/m^3), Livermore-site perimeter, 1992.

Month	Sampling location ^a					
	SALV	MESQ	CAFE	MET	VIS	COW
Jan.	16.8	22.5	42.5	14.3	15.0	18.2
Feb.	15.2	17.5	31.0	15.7	12.3	20.5
Mar.	10.9	10.6	20.2	10.0	9.5	15.5
Apr.	30.8	24.7	27.9	11.8	12.9	19.4
May	37.5	28.8	35.4	23.3	22.0	39.7
June	8.1	<5.4	<5.4	<5.8	<5.4	<7.2
July	42.9	24.6	28.1	20.5	18.5	27.0
Aug.	33.1	34.7	43.7	32.6	27.3	39.4
Sept.	57.5	56.9	45.8	36.1	30.8	65.9
Oct.	23.7	22.5	25.6	21.9	17.4	21.9
Nov.	41.8	23.3	24.2	17.2	31.2	18.4
Dec.	8.3	9.9	13.6	6.3	13.2	13.7
Mean ^b	27.2	<23.5	<28.6	<18.0	<18.0	<25.6
Std dev	15.9	>13.4	>12.2	>9.5	>8.3	>15.9

Note: The monthly ambient concentration guide (ACG) set by the BAAQMD is $10,000 \text{ pg}/\text{m}^3$.

To determine the fraction each value is of the monthly standard, divide the reported value for the month by 10,000; e.g., $35.0 \div 10,000 = 0.000350$.

^a See Fig 4-1 for sampling locations.

^b Livermore-site perimeter overall annual average is $23.5 \text{ pg}/\text{m}^3$.

4. Air Monitoring

Table 4-9. Gamma activity on air filters, Site 300, 1992.^a

Month	[10 ⁻⁹ Bq/mL]	[10 ⁻¹² Bq/mL]		
	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na
Jan.	1.79 ± 0.03	<3.97	<0.13	<0.14
Feb.	3.33 ± 0.06	<5.03	<0.16	0.45 ± 0.38
Mar.	3.73 ± 0.07	<3.98	<0.15	0.58 ± 0.39
Apr.	5.50 ± 0.12	<6.69	<0.16	0.70 ± 0.35
May	7.27 ± 0.17	22.51 ± 11.53	<0.20	0.98 ± 0.58
June	4.06 ± 0.07	<4.13	<0.16	0.64 ± 0.37
July	5.48 ± 0.09	<3.27	<0.12	0.55 ± 0.29
Aug.	7.64 ± 0.17	19.04 ± 10.39	<0.16	0.63 ± 0.34
Sept.	5.47 ± 0.11	27.33 ± 13.88	0.79 ± 0.61	<0.26
Oct.	5.57 ± 0.09	15.55 ± 9.64	0.39 ± 0.29	0.38 ± 0.30
Nov.	5.30 ± 0.08	<5.20	<0.18	<0.21
Dec.	3.57 ± 0.07	<5.11	<0.19	<0.21
Median	4.89 ^b	<5.15	<0.16	<0.48
MAD	1.67 ^c	— ^d	— ^d	>0.25
DCG	1.5 × 10 ⁻³	3.3 × 10 ⁻⁵	1.5 × 10 ⁻⁵	3.7 × 10 ^{-5b}
Fraction of DCG	3.3 × 10 ⁻⁶	<1.6 × 10 ⁻⁷	<1.1 × 10 ⁻⁸	<1.3 × 10 ^{-8c}
[μCi/mL]				
Median	1.3 × 10 ^{-13b}	<1.4 × 10 ⁻¹⁶	<4.4 × 10 ⁻¹⁸	<1.3 × 10 ^{-17b}
MAD	4.5 × 10 ^{-14c}	— ^d	— ^d	>6.7 × 10 ^{-18c}
DCG	4 × 10 ⁻⁸	9 × 10 ⁻¹⁰	4 × 10 ⁻⁹	1 × 10 ⁻⁹

..continued

Table 4-9. Gamma activity on air filters, Site 300, 1992.^a (*concluded*).

Month	[10 ⁻¹² Bq/mL]		
	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Jan.	<0.29	<0.65	<0.31
Feb.	<0.35	<0.75	<0.41
Mar.	<0.30	1.85 ± 1.56	<0.36
Apr.	1.04 ± 0.69	<0.70	<0.45
May	<1.22	<0.85	<0.57
June	1.00 ± 0.59	<0.64	0.83 ± 0.53
July	0.92 ± 0.54	1.32 ± 0.83	0.93 ± 0.58
Aug.	0.89 ± 0.64	2.22 ± 1.21	<0.47
Sept.	2.01 ± 0.80	<1.04	1.39 ± 0.96
Oct.	1.14 ± 0.56	<0.69	<0.41
Nov.	<0.40	<0.84	<0.48
Dec.	<0.37	<0.84	<0.47
Median	<0.90	<0.84	<0.47
MAD	— ^d	— ^d	— ^d
DCG	3.7 × 10 ⁻⁸	1.1 × 10 ⁻⁷	1.5 × 10 ⁻⁹
Fraction of DCG	<2.4 × 10 ⁻⁵	<7.7 × 10 ⁻⁶	<3.1 × 10 ⁻⁴
	[μCi/mL]		
	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Median	<2.4 × 10 ⁻¹⁷	<2.3 × 10 ⁻¹⁷	<1.3 × 10 ⁻¹⁷
MAD	— ^d	— ^d	— ^d
DCG	1 × 10 ⁻¹²	3 × 10 ⁻¹²	4 × 10 ⁻¹⁴

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a All Site 300 perimeter samples composited.

^b Mean value reported because of QA requirements; see Quality Assurance chapter.

^c Standard deviation reported because of QA requirements; see Quality Assurance chapter.

^d No measure of dispersion calculated; see Quality Assurance chapter.

4. Air Monitoring

Table 4-10. Plutonium and uranium activity on air filters, Site 300, 1992.^a

Month	[10 ⁻¹³ Bq/mL]	[10 ⁻⁵ µg/m ³]	[10 ⁻⁷ µg/m ³]	[10 ⁻³]
	²³⁹ Pu	²³⁸ U	²³⁵ U	^{235/238} U
Jan.	0.02 ± 0.01	4.36	2.03	4.7
Feb.	0.04 ± 0.03	2.04	1.33	6.5
Mar.	0.06 ± 0.05	1.98	1.37	6.9
Apr.	0.30 ± 0.19	24.80	17.00	6.9
May	0.31 ± 0.05	7.36	5.25	7.1
June	0.05 ± 0.03	5.20	3.53	6.8
July	0.05 ± 0.02	5.04	3.33	6.6
Aug.	0.06 ± 0.03	7.00	4.76	6.8
Sept.	0.14 ± 0.07	10.60	7.37	6.9
Oct.	0.09 ± 0.03	11.10	6.47	5.8
Nov.	0.03 ± 0.02	5.77	4.07	7.1
Dec.	0.06 ± 0.03	1.92	1.32	6.9
Mean	0.10	7.26	4.82	
Std dev	0.10	6.30	4.33	
Fraction of DCG	1.4 × 10 ^{-5b}	2.4 × 10 ^{-4c}	1.0 × 10 ^{-5d}	
[µCi/mL]				
Mean	2.7 × 10 ⁻¹⁹			
Std dev	2.7 × 10 ⁻¹⁹			

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a Composite of all Site 300 samples. See Fig. 4-3 for sample locations.

^b DCG = 7.4 × 10⁻¹⁰ Bq/mL for ²³⁹Pu activity in air (2 × 10⁻¹⁴ µCi/mL).

^c DCG = 0.3 µg/m³ for ²³⁸U activity in air.

^d DCG = 0.047 µg/m³ for ²³⁵U activity in air.

Table 4-11. Beryllium on air filters (in pg/m³), Site 300, 1992.

Month	Sampling location ^a								
	EOBS	ECP	WCP	LIN	GOLF	TFIR ^b	NPS	WOBS	801E
Jan.	6.6	<4.4	<4.4	<4.4	<4.3	14.1	<4.3	<4.4	<4.4
Feb.	13.1	11.7	18.7	9.2	8.5	22.1	9.1	9.2	5.2
Mar.	10.9	16.3	13.5	9.5	17.6	17.4	11.2	9.4	8.1
Apr.	20.5	26.1	30.4	22.9	23.8	29.6	17.4	16.9	14.1
May	43.3	40.4	38.0	44.2	24.1	41.7	29.4	27.9	12.1
June	37.1	18.9	33.9	8.1	<5.4	<5.4	18.9	18.8	6.8
July	34.6	41.0	35.2	28.2	44.4	35.3	29.6	304.9	30.6
Aug.	28.9	20.8	33.5	31.6	108.4	25.2	31.7	32.2	20.9
Sept.	48.0	38.9	60.7	40.2	90.7	73.8	47.2	43.3	43.9
Oct.	29.3	18.6	21.7	20.8	38.8	30.9	23.7	25.5	29.2
Nov.	16.2	13.6	16.2	18.4	36.6	38.7	11.8	16.8	15.0
Dec.	13.5	9.8	6.2	5.0	12.4	24.8	6.2	5.2	6.2
Mean ^c	25.2	<21.7	<26.0	<20.2	<34.6	<29.9	<20.0	<42.9	<16.4
Std dev	13.6	>12.4	>15.8	>13.6	>33.3	>17.3	>12.7	>83.3	>12.4

Note: The monthly ambient concentration guide (ACG) set by the BAAQMD is 10,000 pg/m³. To determine the fraction each value is of the monthly standard, divide the reported value for the month by 10,000; e.g., 14.1 ÷ 10,000 = 0.00141.

^a See Fig. 4-3 for sampling locations.

^b Location TFIR is in the city of Tracy.

^c Site 300 overall annual average is 26.3 pg/m³.

4. Air Monitoring

Table 4-12. Radioactive airborne effluent releases from the Livermore site, 1981 through 1992.

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

Table 4-13. Nonradioactive air emissions, Livermore site and Site 300, 1992.

Pollutant	Estimated releases [metric tons/day]	
	Livermore site	Site 300
Carbon monoxide	0.01632	0.00288
Chlorofluorocarbons	0.02886	0.00212
Organic compounds	0.01284	0.00126
Oxides of nitrogen	0.07905	0.00653
Oxides of sulfur	0.00219	0.00035
Particulates	0.00336	0.00054

Brian K. Balke

Introduction

The Livermore site discharges approximately 1.1 million liters per day of wastewater to the City of Livermore sewer system, an amount that constitutes less than 7% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories, California (SNL/CA), which is discharged to the LLNL collection system, and combines with LLNL sewage before it is released at a single point to the municipal collection system. The wastewater contains sanitary sewage and industrial effluent and is discharged in accordance with permit requirements and the City of Livermore Municipal Code.

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

LLNL receives water from two suppliers. During the summer months, June through August, deliveries are taken primarily from the Alameda County Flood Control and Water Quality Conservation District Zone 7. This water is a mixture of ground water and water from the South Bay Aqueduct of the State Water Project. For the remainder of the year, LLNL's water usually is supplied from the Hetch-Hetchy Aqueduct. Water quality parameters for these sources are obtained from the suppliers and are used to evaluate compliance with the discharge permit conditions that limit changes in water quality between receipt and discharge.

Administrative and engineering controls at the Livermore site prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Waste generators receive training on proper waste handling. Environmental Protection Department personnel review facility procedures and inspect processes for inappropriate discharges. Retention tanks are used to collect wastewater from processes that might release large quantities of contaminants (to validate the integrity of this equipment, LLNL undertook an extensive evaluation, completed in 1993, of drain connections from buildings to the sanitary and storm sewer systems). Finally, to verify that training and control equipment function properly, wastewaters are sampled and analyzed both at the point of generation and at the point of discharge to the municipal sewer system.

5. Sewage Monitoring

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

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

In 1991, LLNL completed construction of a diversion system that is automatically activated when unacceptable conditions are detected by the monitoring system. The diversion system ensures that all but the first few minutes of the affected wastewater is retained at LLNL, thereby protecting the LWRP and minimizing any required cleanup. Up to 775,000 liters of potentially contaminated sewage can be held pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer, shipped for off-site disposal, or treated at LLNL's Hazardous Waste Management Facility.

LLNL has also implemented a system of satellite monitoring stations that operates in conjunction with the sewer monitoring system (Figure 5-1). The satellite monitoring stations are positioned at strategic locations within the main sewer system to help pinpoint the area on site from which a spill has originated. Each station consists of an automatic sampler that collects samples on a time-proportional basis. In the event of a spill, these samples are analyzed.

Methods

A 24-hr composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for 4 s for every 3875 L of effluent. Aliquots of this composite are

transferred to plastic bottles and submitted for analysis. Treated effluent from LWRP is collected daily by LWRP employees. Aliquots are placed in 500-mL polyethylene bottles, which are retained for weekly collection by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge three times a week.

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

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the Livermore-site and LWRP effluents is analyzed for ^{137}Cs and ^{239}Pu . Weekly composites of LLNL effluent are analyzed for metals. In addition, composite samples from the LWRP digesters are analyzed monthly for gross radioactivity and metals; composites of the monthly samples are analyzed quarterly for plutonium and cesium content and for gamma-emitting radionuclides.

5. Sewage Monitoring

Water quality parameters and organic compounds are also monitored. Once each month, a 24-hr composite sample and an instantaneous grab sample of the LLNL sewage effluent are subjected to an extensive set of analyses. These analyses include parameters specified on LWRP's National Pollutant Discharge Elimination System permit, including metals, nutrients, pesticides, and priority pollutants. The federal priority pollutants are measured using EPA Methods 624 and 625 to establish baseline information for these parameters.

Quarterly samples also are collected at the point of discharge of specified metal finishing and electrical (and electronic) component processes to assure compliance with EPA discharge limits for those processes. LLNL reports the results of these analyses semiannually to the LWRP, the agency delegated by EPA to implement those regulations. The results are not reported here.

For those samples analyzed for gross alpha and beta activity, about 25 mL of an 80%/20% mixture of HNO_3 and HClO_4 is added to an aliquot (350 mL if the sample is from Livermore site, 100 mL if from LWRP), and the liquid is evaporated from the mixture. The residue is taken up in 10 mL of HNO_3 and 5 mL of 5% H_2O_2 . The volume is reduced to 3 to 5 mL on a hotplate, transferred to 5-cm-diameter planchets, and counted. The alpha yield is calibrated with ^{239}Pu , and the beta yield is calibrated with ^{90}Sr .

For tritium analyses, a 5-mL aliquot of distilled sewage sample is added to 15 mL of Packard Instagel in a 25-mL, screw-cap polyethylene bottle. Another 15 mL of Instagel is used as a control blank. Both the sample and the blank are placed in the refrigerated detection chamber of the scintillation counter for a 1-hr temperature equilibration prior to counting. Each sample is counted for 100 min.

Plutonium is separated by coprecipitation with manganese dioxide (MnO_2). The MnO_2 then is ashed and dissolved in HNO_3 and H_2O_2 . Plutonium is purified by ion exchange, electroplated onto a stainless steel disk, and submitted for alpha spectroscopy.

Cesium is separated by ion exchange with ammonium molybdophosphate (AMP). The AMP crystals are transferred to a counting vial with concentrated HCl , which then is submitted for gamma spectroscopy.

Weekly composites of Livermore-site sewage effluent are analyzed for arsenic, cadmium, chromium, copper, iron, lead, nickel, silver, aluminum, beryllium, and zinc. The weekly composite sample is prepared by combining 500-mL daily samples. A solution of HNO_3 (80%) and HClO_4 (20%) is added to the first 500-mL daily sample of the month, and the mixture is reduced in volume to about 100 mL. Each subsequent day, the daily sample is added and the total volume is reduced to about 100 mL. After the 500-mL aliquot from the last day has been added, the combined volume is reduced to about 50 mL. When the solution is cool, about 50 mL of deionized water is added, and the liquid is filtered through Whatman-40 paper. The paper is placed in a platinum crucible and digested with about 5 mL of HF , 16 mL of HNO_3 , and 4 mL of HClO_4 to a residue of about 4 to 5 mL. Water is added and the liquid is refiltered; the residue is discarded. The filtrates are combined, transferred to a 100-mL volumetric flask, and brought to volume with deionized water. The metal content is determined by means of inductively coupled plasma (ICP) mass spectrometry. The required calibration standards are prepared by dilution of a 1000-ppm, NIST-traceable stock solution.

For mercury analysis, 25 mL is taken from the daily sample and transferred to a glass bottle with a ground-glass stopper. Prior to analysis, 100 mL of the solution is reduced with 5 mL of H_2SO_4 and 5 mL of HNO_3 (80%). Potassium permanganate then is added to eliminate sulfides and chlorides. The sample is heated in a water bath for 2 hr at 95°C. After cooling, 6 mL of sodium chloride-hydroxylamine sulfate reduces the excess permanganate, after which 5 mL of stannous sulfate is added. The resulting solution is analyzed by cold-vapor atomic absorption. The analysis is performed twice a month, to avoid exceeding EPA-prescribed holding times on the weekly samples. Each time the analysis is performed, standards are run to calibrate the method, as described above.

Results

Radioactivity in Sewage

Determination of the total radioactivity released as tritium, alpha emitters, and beta emitters is based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever is higher (see **Table 5-1**). The combined releases of tritium, alpha, and beta radiation—8.0 GBq (GBq = 10^9 Bq), or 0.22 Ci—were 22% of the California Title 17 limit, which is 37 GBq (**Table 5-2** summarizes regulatory limits applied to the discharge of radionuclides in LLNL sewage). The total is based on the results shown in **Table 5-1**, reduced by reported SNL/CA tritium releases of 2.2 GBq (0.06 Ci). **Figure 5-2** shows the daily concentration of tritium for 1992. The concentrations of ^{239}Pu , ^{137}Cs , and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 5-3**. During 1992, there were no inadvertent releases that exceeded any discharge limits for release of radioactive materials to the sanitary sewer system.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 0.019 Bq/mL (0.7 pCi/mL), about 0.0037% (that is, 0.000037) of the DOE Derived Concentration Guide (DCG) to a public sewer system that, if exceeded, requires the application of best available technology, or BAT (facilities that exceed the DOE DCG over the course of a month must evaluate the need to implement additional control measures to reduce effluent concentrations). The daily concentration presented in **Figure 5-2** was multiplied by the volume of sewage released on that day and then summed to determine the total radiation released in the form of tritium, as given in **Table 5-1**. The annual average concentration of ^{137}Cs was 5.4 $\mu\text{Bq/mL}$ (1.4×10^{-4} pCi/mL), only 0.0000045 of the DOE DCG. The annual average ^{239}Pu concentration was 5.2 $\mu\text{Bq/mL}$ (1.4×10^{-4} pCi/mL), which was 0.000014 of the DOE DCG. **Figure 5-3** shows the average monthly plutonium and cesium concentrations in sewage since 1973.

5. Sewage Monitoring

Figure 5-2. LLNL tritium concentration in sewage effluent, 1992. Values below the level of sensitivity are possibly due to analytical uncertainty rather than the presence of tritium.

Nonradioactive Pollutants in Sewage

Table 5-4 presents monthly average metal concentrations in LLNL's sanitary sewer effluent. At the bottom of the table, the annual average concentration for each metal is compared to the discharge limit. The metals that approached closest to the discharge limits were mercury, lead and copper at 14%, 13%, and 8%, respectively, of the discharge concentrations. Results of monthly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent are provided in Table 5-5. With the exception of the oil and grease results, the results are all well below the pollutant limitations stipulated in the discharge permit. The oil and grease results are discussed in the following section.

5. Sewage Monitoring

Environmental Impact

Radioactivity in Sewage

To prevent discharges of radioactive materials to the sanitary sewer, LLNL limits the use of those materials and implements engineering controls to prevent the release of radioactivity to the environment. When a process does not lend itself to such controls, or when an extra measure of security is warranted, liquid effluents with potential for containing radioactive materials are not discharged directly into the sanitary sewer but are routed to retention tanks. The retention tanks collect potentially contaminated liquids until a thorough characterization can be performed. When a retention tank becomes full, a sample of the liquid is analyzed to determine pollutant concentrations. If necessary, the wastewater can be treated at LLNL's Hazardous Waste Management Facility to filter out radioactivity to the lowest levels reasonably achievable, and well below discharge limits. Once treated and below acceptable limits (verified by resampling and analysis), the liquid waste is discharged to the City of Livermore sanitary sewer system.

DOE requires that radiological releases to the sanitary sewer comply with local and state regulations. The most stringent of these limits is applied by 17 CCR. Furthermore, DOE has established criteria for the application of BAT to protect public health adequately and minimize degradation of the environment.

Table 5-6 summarizes the radioactivity in liquid effluent released over the past nine years. During 1992, a total of 8.0 GBq (0.22 Ci) of tritium was discharged to the sanitary sewer. This is the combined release from the Livermore site and from SNL/CA, whose records account for 2.2 GBq (0.06 Ci) of this amount; LLNL therefore released 5.8 GBq (0.16 Ci), an amount that is well within environmental protection standards established by DOE and is less than the range reported in the past.

In 1992, the total LLNL releases, in the form of alpha and beta emitters (including tritium), were 16% of the 17 CCR limit, which is 37 GBq. For specific isotopes, the average tritium concentration was 0.0000037 of the DOE DCG, while the average ^{239}Pu and ^{137}Cs discharges were 0.000014 and 0.0000045 of the DOE DCG.

Figure 5-3 summarizes the ^{239}Pu monitoring data since 1973. The historical levels observed since 1981 are approximately 0.37 Bq/mL (1×10^{-5} pCi/mL), with the exception of a peak in 1987. Even this peak is well below the applicable DOE DCG. Historically, levels generally are one-millionth (0.000001) of that limit. The greatest part of the plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge, which is dried and disposed of at a landfill. The plutonium concentration observed in 1992 sludge, 15.2 mBq/dry g

(0.56 pCi/dry g), is 30 times lower than the proposed EPA guideline for unrestricted use of soil (480 mBq/dry g).

As first discussed in the *Environmental Report for 1991* (Gallegos et al. 1992a), concentrations of plutonium and cesium remain slightly elevated over the lowest values seen historically. As was established in 1991, the overall upward trend is related to sewer cleaning with new, more effective equipment. Cleaning activity around the site was extensive during 1992, as utilities personnel worked to complete their assessment of the condition of the sewer system.

Along with this observation, however, the measured plutonium activities were further elevated during the months of January through March. For those three months, the data show an increase of a factor of 10 above values seen during 1991 and the other months of 1992. The effects of this discharge are visible in the activities measured in LWRP process streams (effluent and sludge). The highest activities observed in LWRP sludge are more than 10 times below the proposed EPA guideline for the unrestricted use of soil, and the levels observed in LLNL effluent are 20 times below the most applicable drinking water standard (for alpha radiation). Because of the longer retention times in the LWRP sludge digesters (roughly 30 days), slightly higher activities were seen in LWRP sludge through the second quarter of the year.

LLNL has investigated possible causes for the elevated levels, including inadvertent releases from LLNL operations, releases from retention tanks and sewer cleaning operations. No definite determination of the cause could be made. Retention tank releases could account for, at most, 10% of the plutonium discharged. Sewer cleaning was scattered across the LLNL site during this period, but only one location was cleaned during all three months. The cleaning at that location was necessitated by pipe degradation, and that section of the sewerage was replaced in April 1992. The higher levels could also be related to elevated levels of alpha radioactivity detected in LLNL's effluent on several days during the first quarter of 1992.

Small releases of alpha radiation are observed in LLNL sewage several times each year, but do not usually correlate with any increase in plutonium. However, in order to better understand occasional discharges of alpha-emitting radioactivity above routine levels, a protocol has been developed for further analysis when higher levels are seen. The information obtained—the specific radioisotopes detected in a release—will be used to achieve a greater understanding of these discharges. Should any specific radioisotope be commonly observed in alpha radiation releases, LLNL personnel will be able to focus their efforts to decrease future discharges of that type. The program of extended evaluation of alpha radiation releases was initiated in 1993, but LLNL will analyze archived samples held from the first quarter of 1992.

5. Sewage Monitoring

Nonradioactive Liquid Effluents

For the year as a whole, the monitoring data reflect the success of LLNL's discharge control program in preventing any significant impact on the operations of the City's treatment plant. LLNL was issued a single Notice of Violation during 1992, for elevated concentrations of oil and grease seen in the monthly grab sample taken in May. Examination of the historical record indicates that oil and grease concentrations in sanitary sewage began to rise in the summer of 1990. This correlates with improvements to the sewer maintenance program, which led to the liberation of historical residue in the sewers. In addition, evaluations by discharge control personnel have identified deficiencies in the design of grease abatement measures in use at LLNL cafeterias. Improvements have been designed and scheduled for implementation.

As a result of this incident, the LWRP suggested changes to LLNL's sampling procedure for oil and grease monitoring. The LWRP was concerned that a single grab sample would not adequately characterize the average concentration of oil and grease in LLNL effluent. Because the LWRP is primarily concerned with controlling the total daily inflow to the plant, they requested that LLNL institute a more comprehensive sampling protocol for oil and grease. In response, LLNL now collects four oil and grease samples at 4-hour intervals, beginning at 6 a.m. and ending at 6 p.m. The sampling times are distributed so that periods of peak and low flow are represented proportionately in the total volume of wastewater discharged during each period. The results for the four samples can therefore be averaged to produce a measure of the average daily oil and grease discharge.

Table 5-7 summarizes the incidents during 1992 when LLNL's continuous monitoring system identified instantaneous excursions of pollutant concentrations above alarm limits. A total of ten incidents was reported to the LWRP and DOE during 1992. For incidents that lasted more than 5 minutes, the Sewer Diversion Facility was activated to contain the remainder of the release. In all cases, later analysis of the diverted effluent showed that the average concentration of the contaminant was sufficiently low to allow release of the wastewater back to the sanitary sewer. In no case did an incident represent a threat to the integrity of operations at the LWRP.

Examination of the list of incidents reveals a marked difference between the first and second halves of the year. During the first six months of 1992, the recorded incidents were quite similar to the kinds of releases that dominated the list of events in 1991. During April, it was determined that the bulk of the zinc discharges was probably caused by use of a common household cleaner that contained zinc in high concentrations as an artifact of the manufacturing process. The second most frequent type of alarm—brief releases of silver—ceased recurring in June. Continued reviews of silver processing operations by environmental operations analysts, identification of potential sources during a

comprehensive inventory and evaluation of sanitary sewer connections, a poster campaign targeted to reduce silver discharges, and a general laboratory information campaign successfully sensitized personnel as to the importance of controlling silver discharges.

In addition to showing success in controlling zinc and silver discharges, the list in **Table 5-7** indicates that the magnitude and seriousness of the releases decreased in the second half of the year. The instantaneous concentrations observed were only marginally higher than the discharge guidelines. More than the absolute numerical reduction in the number of events (down from 14 observed during 1991), the decrease in the significance of the incidents indicates the responsiveness of LLNL programs and personnel to the need to control the discharge of pollutants to the sanitary sewer.

5. Sewage Monitoring

Table 5-1. Estimated total radioactivity in sanitary sewer effluent, LLNL, 1992.

Radioactive emitter	Estimate based on effluent concentration [GBq] ^a	Limit of sensitivity [GBq] ^a
Tritium	7.9 ^{b,c}	3.7
Alpha radiation	0.026	0.041 ^b
Beta radiation	0.26 ^b	0.06

^a GBq = 10⁹ Bq, or 0.028 pCi.

^b Used for determination of the total radiation release because it is the more conservative value.

^c 7.9 GBq includes 5.7 GBq from LLNL plus 2.2 GBq from SNL/CA.

Table 5-2. Sewer discharge release limits for tritium (³H), ¹³⁷Cs, and ²³⁹Pu.

		³ H	¹³⁷ Cs	²³⁹ Pu
CA Title 17 concentrations used to establish release limits		3.7 × 10 ³ Bq/mL	15 Bq/mL	30 Bq/mL
CA Title 17	daily	37 GBq ^a	16 GBq ^a	32 GBq ^a
	monthly	37 GBq ^b	37 GBq ^b	37 GBq ^b
	yearly	37 GBq ^a	37 GBq ^a	37 GBq ^a
DOE annualized discharge limit for application of BAT^c		370 Bq/mL	0.55 Bq/mL	0.37 Bq/mL

^a CA Title 17 regulations impose a 37-GBq combined limit on the total of all radiation released, i.e., the total release of all isotopes must not exceed 37 GBq. If a total of 37 GBq of a particular isotope was released during the year, this would require that no other isotopes be released.

^b Limits similar to those applied to daily releases except total releases for the month must not exceed these quantities.

^c The DOE annualized discharge limit for application of Best Available Technology is five times the DCG (ingested water) for each radionuclide released.

Table 5-3. Various radionuclides in sanitary sewer effluents (in 10^{-6} Bq/mL), LLNL and LWRP, 1992.

Month	³ H (mBq/mL)		¹³⁷ Cs (μBq/mL)		²³⁹ Pu (μBq/mL)		²³⁹ Pu (mBq/gm)
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge ^a
Jan.	<8.7	<9.3	3.3 ± 0.7	0.4 ± 0.1	30 ± 1	0.087 ± 0.023	
Feb.	21 ± 3	<7.9	12.6 ± 0.9	1.2 ± 0.5	5.2 ± 0.2	0.25 ± 0.04	
Mar.	14 ± 2	<8.5	6.9 ± 0.8	0.5 ± 0.2	16 ± 1	0.062 ± 0.019	29.7 ± 1.3
Apr.	10 ± 2	<8.6	3.4 ± 0.6	<0.4	2.5 ± 0.1	0.021 ± 0.009	
May	38 ± 3	<9.2	22 ± 3	<1.1	1.4 ± 0.2	0.013 ± 0.013	
June	47 ± 4	<9.6	4.2 ± 0.6	<3.9	1.8 ± 0.2	<0.037	20.9 ± 0.8
July	20 ± 3	<10.1	1.1 ± 0.3	<0.2	0.8 ± 0.1	<0.013	
Aug.	12 ± 2	<10.0	1.3 ± 0.3	<0.4	0.59 ± 0.09	<0.020	
Sept.	<8.6	<8.3	1.0 ± 0.3	<0.7	0.37 ± 0.07	<0.016	6.0 ± 0.5
Oct.	31 ± 3	<8.0	6.5 ± 0.8	0.6 ± 0.4	1.4 ± 0.2	<0.023	
Nov.	<9.1	<8.6	0.16 ± 0.05	<0.4	1.1 ± 0.1	<0.016	
Dec.	9 ± 2	<8.7	2.7 ± 0.5	<0.2	1.6 ± 0.1	<0.012	4.1 ± 0.2
Mean	18	<8.7 ^b	5.4	<0.5 ^b	5.2	<0.021 ^b	15.2
Std dev	27		12		17.7		24.5
	pCi/mL						pCi/dry g
Mean	0.49	<0.24 ^b	145 × 10 ⁻⁶	<14 × 10 ⁻⁶	140 × 10 ⁻⁶	<0.6 × 10 ⁻⁶	0.41
Std dev	0.71		331 × 10 ⁻⁶		480 × 10 ⁻⁶		0.66
Annual total discharges by radioisotope							
	³ H		¹³⁷ Cs		²³⁹ Pu		
Bq/y	5.7 × 10 ⁹ ^c		2.2 × 10 ⁶		1.9 × 10 ⁶		
Ci/y	0.15		6.0 × 10 ⁻⁵		5.1 × 10 ⁻⁵		
Fraction of Limit							
DOE	0.000036		0.0000045		0.0000141		
Title 17	15 ^d						

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a Sludge from LWRP digesters is dried prior to analysis. The resulting data indicate the plutonium concentration in the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

^b Due to the large number of nondetects, the median rather than the mean is presented, and the standard deviation from the mean is omitted. See Quality Assurance chapter.

^c Not including discharges of 2.2×10^9 Bq (0.06 Ci).

^d Including ^{137}Cs and ^{239}Pu .

5. Sewage Monitoring

Table 5-4. Metals discharged to sanitary sewer system (in mg/L), 1992 summary.

Month	Ag	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
Jan.	0.022	0.58	<0.002	<0.0002	0.0014	0.033	0.05	1.14	<0.0015	0.014	<0.014	0.31
Feb.	0.012	1.75	<0.002	<0.0001	0.0013	0.030	<0.012	1.60	0.0020	0.016	<0.08	0.25
Mar.	0.010	0.37	<0.004	<0.0001	0.0011	0.061	0.10	1.03	0.0037	0.016	<0.019	0.36
Apr.	0.014	0.62	<0.002	<0.0001	0.0012	0.045	0.14	1.18	0.0015	0.017	0.066	0.30
May	0.010	0.39	<0.002	<0.0001	0.0008	0.028	0.08	0.89	<0.0008	0.005	0.016	0.22
June	0.017	0.32	<0.002	<0.0001	0.0009	0.025	0.08	1.14	0.0006	0.005	0.019	0.18
July	0.009	0.24	<0.002	<0.0001	0.0012	0.020	0.05	0.65	<0.0005	0.004	0.023	0.11
Aug.	0.011	0.30	<0.002	<0.0001	0.0007	0.022	0.05	0.67	0.0006	0.004	0.017	0.15
Sep.	0.010	0.27	<0.002	<0.0001	0.0015	0.024	0.06	0.77	<0.0005	0.004	0.016	0.15
Oct.	0.013	0.37	<0.004	<0.0001	0.0007	0.030	0.07	1.05	0.0010	0.005	0.016	0.13
Nov.	0.016	1.00	<0.003	<0.0001	0.0012	0.028	0.08	3.07	0.0009	0.015	0.017	0.15
Dec.	0.013	0.54	<0.002	<0.0001	0.0006	0.034	0.07	1.1	0.0015	0.010	0.011	0.22
Mean	0.013	0.57	<0.002	<0.0001	0.0010	0.031	0.08	1.19	0.0014	0.009	0.025	0.21
SDM	0.005	0.87	— ^a	— ^a	0.0007	0.019	0.03	1.2	0.0014	0.007	0.013	0.09
DCL ^b	0.2	— ^c	0.06	— ^c	0.14	0.62	1.0	— ^c	0.01	0.62	0.2	3.0
Fraction of DCL	0.065	— ^c	<0.03	— ^c	0.007	0.05	0.08	— ^c	0.14	0.014	0.13	0.07

^a The number presented as a mean is the median of the annual values. Due to the large number of nondetects, the standard deviation could not be calculated for these analytes. See Quality Assurance chapter.

^b DCL is Discharge Concentration Limit (City of Livermore Ordinance 13.32).

^c No established limit for analyte.

Table 5-5. Positively detected parameters in LLNL sanitary sewer effluent, 1992.

Positively detected parameter	Detection ^a frequency	Minimum	Maximum	Mean ^b	Std dev ^b
Physical and chemical (mg/L)					
Biochemical oxygen demand	12/12	58	630	177	152
Chemical oxygen demand	12/12	70	560	300	132
Settleable solids (mL/L)	5/12	<0.1	17	<0.1	
Total dissolved solids	12/12	160	660	328	134
Total solids	12/12	260	630	412	115
Total suspended solids	12/12	38	300	80	73
Volatile solids	12/12	26	294	163	66
Ammonia nitrogen (as N)	12/12	18	43	34	7
Chloride	12/12	2	220	56	54
Cyanide	0/12	<0.01	<0.02		
Nitrate plus nitrite (as N)	4/12	<0.1	5.9	<0.1	
Nitrate plus nitrite (as NO ₃)	4/12	<0.4	26	<0.4	
Nitrite nitrogen (as N)	7/12	<0.01	1.6	0.16	0.45
Nitrite nitrogen (as NO ₂)	7/12	<0.01	5.3	0.53	1.5
Sulfate	12/12	15	130	49	39
Bicarbonate alkalinity (as CaCO ₃)	12/12	120	210	184	30
Total Kjeldahl nitrogen (as N)	12/12	22	54	40	8
Total phosphorus (as P)	12/12	2.8	8.2	5.6	1.4
Arsenic	5/12	<0.002	0.0064	<0.002	
Boron	10/12	<0.2	0.54	0.33	0.12
Cadmium	11/12	<0.0005	0.0015	0.0008	0.0003
Calcium	12/12	10	35	18	8
Chromium	12/12	0.014	0.18	0.045	0.048
Copper	12/12	0.044	0.26	0.083	0.059
Lead	12/12	0.006	0.019	0.014	0.004
Magnesium	12/12	2.2	7.9	4.9	2.4
Mercury	11/12	<0.0002	0.0021	0.0008	0.0006
Nickel	9/12	<0.005	0.032	0.009	0.008
Potassium	12/12	10	25	17	4
Silver	12/12	0.008	0.031	0.015	0.007
Sodium	12/12	26	200	59	47
Zinc	12/12	0.11	0.52	0.21	0.12
Organic compounds (mg/L)					
Oil and grease	12/12	13	300	79	93
Phenolics	12/12	0.01	0.12	0.05	0.03
Total organic carbon	12/12	23	84	48	21

...continued

5. Sewage Monitoring

Table 5-5. Positively detected parameters in LLNL sanitary sewer effluent, 1992 (concluded) .

Positively detected parameter	Detection ^a frequency	Minimum	Maximum	Mean ^b	Std dev ^b
Organochloride pesticides (EPA Method 608, µg/L)^c					
Aldrin	1/9	<0.04	0.12	<0.04	
BHC, beta isomer	1/9	<0.03	0.042	<0.03	
BHC, delta isomer	1/9	<0.03	0.13	<0.03	
Endrin	1/12	<0.05	0.062	<0.05	
Purgeable-extractable pollutants (EPA Methods 624/625, µg/L)					
1,1,1-Trichloroethane	3/12	<0.5	1	<0.5	
1,1-Dichloroethane	1/12	<0.5	32	<0.5	
1,2-Dichlorobenzene	2/12	<0.5	5.4	<0.5	
1,4-Dichlorobenzene	5/12	<0.5	8.8	<0.5	
2-Butoxyethanol	1/12	—	600 ^d	—	
4-Methylphenol	8/12	<4	70	30	21
Acetone	7/12	<5	1900	173	544
Benzene acetic acid	1/12	—	100 ^d	—	
Benzoic acid	8/12	<10	750	340	275
Benzyl alcohol	5/12	<10	200	<100	
Bis(2-ethylhexyl)phthalate	4/12	<4	23	<23	
Bromodichloromethane	1/12	<0.5	0.7	<0.5	
Butoxy ethanol phosphate	3/12	—	700 ^d	—	
Butylbenzylphthalate	1/12	<3	4	<12	
Butyl carbitol	1/12	—	80 ^d	—	
Carbon disulfide	1/12	<0.5	180	<0.5	
Chloroform	12/12	4.5	32	19	6.5
Cholesterol	10/12	—	1000 ^d	438	309
Cholesterol-3-ol	10/12	—	700 ^d	375	232
Diethylphthalate	1/12	<3	10	<15	
Freon-113	4/12	<0.5	150	<0.5	
Methylene chloride	3/12	1.3	100	<2.3	
Phenol	2/11	<5	8	<14	
Tetrachloroethene	1/12	<0.5	0.63	<0.5	
Thiobismethane	3/12	—	8	—	
Toluene	7/12	<0.5	51	5.2	14
Total xylene isomers	1/12	<0.5	1	<0.5	
Trichloroethene	1/12	<0.5	0.5	<0.5	
Trichlorofluoromethane	2/12	<0.5	2.7	<0.5	

^a 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).

^b Where the detection frequency is less than 50%, the median is presented and the standard deviation from the mean is omitted.

^c The samples were analyzed for the full range of EPA Method 608 organochloride compounds. Concentrations of all these compounds except those listed were below detection limits.

^d Semiquantified result. The analytical laboratory does not usually report a result for this compound, and no detection limit has been established.

Table 5-6. Radioactive liquid effluent releases from the Livermore site, 1983–1992.

Year	Liquid effluents (GBq)	
	³ H (LLNL and SNL/CA)	²³⁹ Pu
1983	63	2.5×10^{-4}
1984	63	1.2×10^{-4}
1985	133	1.8×10^{-4}
1986	74	5.5×10^{-4}
1987	52	2.6×10^{-2}
1988	56	8.1×10^{-4}
1989	59	1.8×10^{-4}
1990	25	2.3×10^{-4}
1991	32	6.1×10^{-4}
1992	8	1.9×10^{-3}

Table 5-7. Summary of contaminant releases detected by the sewer monitoring system, 1992.

Date	Contaminant	Estimated duration (min)	Instantaneous concentration (mg/L)	Discharge standard ^a (mg/L)
3/19	Ag	5	5.6	0.2
4/2	Zn	20	12.6	3.0
4/11	Zn	5	8.8	3.0
4/13	Zn	30	19.7	3.0
6/11	Ag	15	22.2	0.2
6/30	Pb	— ^b	1.0	0.2
7/11	Pb	— ^b	0.58	0.2
9/25	Pb	10	0.33	0.2
10/7	Cr	30	0.99	0.62
12/1	Cu	40	1.73	1.0

^a If a release lasted as long as 24 hours, concentrations above this level would likely result in disruption of treatment plant operations, or cause the treated wastewater to exceed allowable concentration limits for discharge to the San Francisco Bay.

^b Due to fouling of the monitoring equipment by the contaminant, no estimate can be made of the duration of the incident.

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Introduction

Lawrence Livermore National Laboratory performs surveillance monitoring of waters at the Livermore site, in surrounding regions of the Livermore Valley, and at Site 300 in the Altamont Hills. The waters monitored at the first two locations include reservoirs and ponds, the LLNL swimming pool, rainfall, tap water, storm water runoff, drinking water production wells, and ground water monitoring wells. Surveillance monitoring at Site 300 encompasses on-site and off-site production wells and monitoring wells, spring-fed creeks, and rainfall. Water samples are analyzed for radionuclides and a large range of non-radioactive constituents.

A small fraction of treated effluent from the City of Livermore Water Reclamation Plant (LWRP) is used to irrigate nearby municipal land. This effluent contains low levels of tritium from natural sources and from permitted operational releases to the sanitary sewer system by LLNL and Sandia National Laboratories, California (SNL/CA). [Total radionuclides in liquid effluents are limited to 1 curie (3.7×10^{10} Bq) per year.] Rainfall and storm water runoff in the Livermore Valley also contain small amounts of tritium from natural sources, from past atmospheric tests of nuclear weapons, and from atmospheric emissions by LLNL and SNL/CA. Since 1977, annual tritium measurements have been made on water samples collected from monitoring wells and drinking water wells throughout the Livermore Valley to determine the extent of tritium migration into the ground from the LWRP irrigation water, from tritium washed out of the atmosphere by rain, and from tritium in storm water runoff that flows through the Arroyo Las Positas to Alameda Creek and thence to San Francisco Bay.

LLNL has monitored storm water runoff at the Livermore site since 1975. The original monitoring network was designed to detect pesticides. This monitoring was expanded in 1990 to cover new locations and additional water quality parameters, including radioactivity, metals, and numerous organic compounds. Storm water runoff monitoring now provides a broad measure of the efficacy of LLNL operational procedures that prevent, or contain and remediate, inadvertent spills of hazardous wastes or products onto the ground within the Livermore site.

6. Surveillance Water Monitoring

The *Environmental Report for 1989* (Sims et al. 1990) first reported elevated tritium in storm water samples collected during a March 1989 rain storm at the Livermore site. Although tritium emissions at LLNL are closely monitored, the sampling of rain was expanded in 1990 to understand better the relationship between emissions, rainfall, and storm runoff.

As described in Chapter 7 on Ground Water Protection, LLNL performs additional monitoring at Site 300 to evaluate ground water contaminants originating from historical operations.

Methods

Livermore Water Reclamation Plant

Nineteen wells near and at some distance from LWRP are sampled annually for tritium measurement to determine the extent of tritium migration into the ground water (Figure 6-1). Wells used only for monitoring of reclaimed irrigation water are 1H3, 1P2,

Figure 6-1. Ground water well sampling locations, Livermore Valley, 1992.

1P3, 1R2, 2R1, 7C2, 7P3, 11B1, 12A2, and 12G1. Sampled potable water supply wells serving the City of Livermore are 8F1, 8P1, 9Q1, and 16B1. City of Pleasanton supply wells, which are sampled annually for tritium measurements, are 9M2, 16L7, 16L5, 18A1 and 18A5.

Livermore Valley

LLNL samples both surface water and drinking water in the vicinity of the Livermore site and in the Livermore Valley (Figure 6-2). Locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water sources. The locations GAS, PALM, and ORCH are drinking water outlets. Samples from these locations are taken quarterly and are measured for gross alpha, gross beta, and tritium. Water samples are obtained with a tethered pail from surface sources. Other locations are sampled directly from the outfall. Samples for tritium analysis are collected in 500-mL, argon-flushed glass containers fitted with ground-glass stoppers. Samples for other radiological analyses are collected in 1000-mL polyethylene bottles.

Livermore Site

The on-site swimming pool and on-site drinking water (POOL, TAP; Figure 6-2) are measured for gross alpha, gross beta, and tritium. The pool is sampled monthly and the drinking water is sampled quarterly.

Rain samples from 19 locations, including 7 on-site, are collected after each major rainstorm and are measured for tritium (Figure 6-3).

The storm water runoff monitoring network includes ten locations (Figure 6-4) that are sampled during active surface water flow following the first major storm of the rainy season.

Beginning in January 1993, subsequent to the first major storm, monthly sampling of runoff and dry weather observations will be performed at both the Livermore site and at Site 300. This is required by a National Pollutant Discharge Elimination System (NPDES)

6. Surveillance Water Monitoring

General Industrial Activities Storm Water Permit for both sites. This monitoring will supplement the routine surveillance storm water monitoring.

Approximately one-fourth of the storm water runoff generated within the LLNL site drains into the centrally located Central Drainage Basin (CDB; **Figure 6-4**). The remainder drains either directly, or via a system of storm sewers and ditches, into two arroyos. The arroyos generally drain from east to west. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas has been diverted from its natural course to follow the northeastern and northern boundaries of the Livermore site. Several long on-site ditches, established to channel storm water runoff, drain from south to north across the site into the Arroyo Las Positas. Of the ten storm water sampling locations at LLNL, five were selected to characterize storm waters either entering the site (influent water) or exiting the site (effluent water). Influent locations are ALPE, GRNE, and ASS2. Effluent

Figure 6-3. Rain sampling locations, Livermore site and Livermore Valley, 1992.

locations are WPDC for the Arroyo Las Positas, and ASW for the Arroyo Seco. Location CDB measures runoff from the southeastern quadrant of the Livermore site where it enters the Central Drainage Basin. Location ALPN measures outflow from the drainage basin at its confluence point with the Arroyo Las Positas. Location ALPW measures on-site runoff from a ditch along Avenue A where it enters the Arroyo Las Positas. Location 4THA samples runoff from the on-site Plutonium and Tritium Facilities. Location B438 measures storm water runoff from the shops area and the Hazardous Waste Management facilities.

Site 300

Quarterly surface water samples are collected off site, downstream from Site 300 in the Corral Hollow Creek (GEOCRK) and on site in a small, spring-fed creek near Bunker 812 (812CRK; Figure 6-5). Volatile samples are collected directly from surface flows.

6. Surveillance Water Monitoring

[Samples to be analyzed for tritium are collected in 500-mL, argon-flushed glass containers. Samples for gross alpha and beta measurements are collected in 1000-mL polyethylene bottles. Rainfall at one location (RAIN; Figure 6-5) is composited each month and analyzed for tritium.]

Nineteen ground water wells are monitored at Site 300 as part of the ground water surveillance program. There are seven on-site wells: Well 01, Well 18, Well 20, NC2-11D, NC7-61, NC7-69, and W-7A (Figure 6-5). Well 01 supplies fire-suppression water to the Site 300 Fire Department. During 1992, this well was sampled quarterly for certain metals, radioactivity, and organic compounds. Well 20 is the potable water supply well for Site 300. Well 18 is currently inactive and is maintained as a backup for Well 20. Both these wells are sampled quarterly for certain metals and radioactivity, and monthly for organic compounds. Wells NC2-11D, NC7-61, NC7-69, and W-7A are sampled quarterly for beryllium, chromium, copper, and lead; for organic compounds; and for radioactivity. Additionally, wells NC7-61 and NC7-69 are sampled quarterly for isotopes of uranium.

Twelve off-site water supply wells were sampled and analyzed in 1992. Six were sampled quarterly. Of these, CARNRW1 and CON2 were sampled for organic compounds only, while CARNRW2, CDF1, CON1, and GALLO1 were sampled for a large suite of inorganic and organic compounds (GALLO1 was unavailable for sampling during the third and fourth quarters of 1992). The remaining six wells, MUL1, MUL2, STN, VIE1, VIE2, and W35A-04, are sampled annually for a large suite of inorganic and organic compounds.

Ground water monitoring wells are purged of stagnant water prior to sampling. All sampling equipment is maintained so that it does not contaminate the water sample. Containers and preservatives are used according to established protocols for the analytes of interest. Table 6-1 lists the standard EPA methods used to measure contaminants in water.

Results

Livermore Site/Livermore Valley, Radioactivity in Water

Mean gross alpha and gross beta in surface and domestic water sampled during 1992 were very low, averaging less than 11% and 13% of the drinking water maximum contaminant levels (MCLs), respectively (Tables 6-2 and 6-3). One storm water location showed elevated gross alpha and gross beta [0.77 Bq/L (20.8 pCi/L) and 3.82 Bq/L (103.2 pCi/L), respectively]. This sample was taken from the outflow stream of the Central Drainage Basin where it enters the Arroyo Las Positas (location ALPN, Figure 6-4). However, contemporaneous measurements made downstream in the arroyo at location ALPW showed typically low values of gross alpha (0.04 Bq/L, or 1 pCi/L) and gross beta (0.23 Bq/L, or 6 pCi/L).

Tritium. Mean tritium activity collected from surface and drinking water locations in the Livermore Valley was less than 1% of the drinking water MCL [surface water average = 1.55 Bq/L (41.9 pCi/L); drinking water average =

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0.90 Bq/L (24.3 pCi/L); **Table 6-3**]. The LLNL swimming pool water had the highest mean value and the highest individual measurement. The mean tritium value for water in the swimming pool for 1992 was 16.96 Bq/L (458 pCi/L), still only 2% of the drinking water MCL. The highest single observation for location POOL was 22.98 Bq/L (621 pCi/L; 3% of MCL; see **Table 6-3**).

Rainfall samples were collected at 19 locations from 20 storms in 1992. The mean rainfall tritium concentration for 1992 was 13.3 Bq/L (359 pCi/L) (**Figure 6-3** and **Table 6-4**), less than 2% of the drinking water MCL. The highest rainfall tritium activity measured in 1992 was 115.81 Bq/L (3130 pCi/L; 16% of MCL) at the on-site location B291. This rain sampling location is adjacent to an extensively studied subsurface soil zone where tritium-bearing wastewater leaked from a pipe connecting to an underground storage tank. Vegetation above the zone draws small quantities of tritium upwards by capillary action and transpires it directly to the atmosphere.

Storm water runoff was collected at ten on-site locations during 18 rainstorms in 1992 (some storms produced sufficient rainfall for sampling, but did not generate sufficient runoff for sampling). Tritium levels in storm water runoff were low, averaging 10.55 Bq/L (285 pCi/L), less than 2% of the drinking water MCL (**Table 6-2**). The highest tritium activity measured in storm water runoff during 1992 was 61.79 Bq/L (1670 pCi/L) at influent location ASS2, less than 10% of the drinking water MCL.

Well water was collected at 19 locations in the Livermore Valley (**Table 6-5**). Tritium levels in these wells were at background levels, averaging 2.83 Bq/L (76.5 pCi/L), less than 1% of the MCL for drinking water. As in previous years, the highest tritium measurement, 16.95 Bq/L (458 pCi/L), was from Well 11B1. However, tritium activity in this well, which is used only for monitoring, has decreased since 1990 and 1991, when it measured 24.1 Bq/L (652 pCi/L) and 23.41 Bq/L (633 pCi/L), respectively.

Livermore Site/Livermore Valley, Nonradioactive Pollutants in Water

LLNL measures inorganic and organic contaminants in storm water runoff entering and exiting the site (**Table 6-6**). Of 813 measurements made for potential inorganic contaminants in 1992, only one 450-ppm sulfate value, from influent location ALPE, exceeded the secondary standard (250 ppm) set by the State of California for drinking water. The most commonly detected metals in storm water runoff were arsenic, barium, cadmium, chromium, and lead. During 1992, these metals were found at levels less than the corresponding drinking water MCLs. Other metals, such as beryllium, mercury, selenium, and silver, were observed three or fewer times in storm water runoff. All were found at levels below their respective drinking water MCL.

Of the nearly 6000 measurements made in 1992 for potential organic contaminants in storm water runoff (Table 6-6), only three measurements of bis(2-ethylhexyl)phthalate exceeded the drinking water MCL (4 ppb). The three are from locations ASS2 (37 ppb), ASW (99 ppb), and CDB (23 ppb). The source of this organic compound is unknown. It is a light oil commonly used in the manufacture of PVC plastic. The measurements are suspect since this compound is known to be introduced during laboratory analytical procedures. Other detected organic pollutants include 1,1,1-trichloroethane (4 observations), acetone (6), chloroform (1), Freon-113 (10), toluene (5), trichloroethene (3), and oil and grease (20). A single observation of the herbicide 2,4-D is associated with storm water entering the site at ALPE. Five observations of the pesticide Endrin are associated with runoff from a storm that occurred on February 10, 1992. This pesticide is not used at LLNL and its source is unknown. The concentrations measured are all below the 0.2-ppb MCL for drinking water.

Site 300, Radioactivity in Surface Water

No measured value of radioactivity in rain or surface water at Site 300 exceeded drinking water MCLs for gross alpha, gross beta, or tritium (Table 6-7). Mean gross alpha and gross beta values at the two surface water locations, GEOCRK and 812CRK, are less than 43% of the MCL. Mean tritium activity in the two surface water locations and in rain at Site 300 was very low, less than 1% of the MCL.

Site 300, Radioactivity in Ground Water

No measurement of gross alpha or gross beta in water samples taken from on-site and off-site wells exceeded drinking water MCLs (Tables 6-8 to 6-10). The highest measured value of gross alpha is 0.434 Bq/L (11.7 pCi/L) in off-site production well STN (78% of the MCL). The highest measured gross beta value, 0.336 Bq/L (9.1 pCi/L), was from off-site production well CARNRW2 (18% of the drinking water MCL). Tritium levels in all but one surveillance well, NC7-61, were far below the drinking water MCL of 740 Bq/L (20,000 pCi/L). Mean tritium activity for the on-site monitoring well NC7-61 was about 9000 Bq/L (243,000 pCi/L) for 1992, about 12 times the drinking water MCL. This well is located east and downgradient of the Building 850 Area, a known source of tritium (see Chapter 7 on Ground Water Protection for a further discussion).

Site 300, Nonradioactive Pollutants in Water

On-Site Inactive Ground Water Production Wells. The compound 1,1,1-trichloroethane was detected at 0.6 ppb in a ground water sample collected from Well 01 (Table 6-10). No other organic compounds of concern were detected in this sample. Lead was found in two of four measurements at concentrations of 2 and 3 ppb in Well 01. These are within the historical range of

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lead values observed in the well (1 to 6 ppb), and considerably below the MCL of 50 ppb for drinking water.

Sample data from Well 18 (the backup drinking water well) did not exceed any MCL or State Action Level (SAL). Three metals were detected at extremely low concentrations: chromium in Well 18 at 6 ppb (MCL = 50 ppb); copper at 11 ppb (secondary MCL = 1000 ppb); and lead in two samples at concentrations of 3 and 4.4 ppb (MCL = 50 ppb).

In 1991, trichloroethene (TCE) was detected in Well 18 at a concentration of 1 ppb (MCL = 5 ppb). Of twelve monthly samples taken from Well 18 in 1992, ten samples contained TCE from 0.5 to 1.1 ppb (Table 6-10). The source(s) of these trace levels of TCE is under investigation. Toluene was detected in one of twelve monthly samples at a concentration of 2 ppb. Surveillance monitoring of Well 18 continues on a monthly basis.

On-Site Active Water Supply Well 20. Lead was detected at 2 ppb in one of the quarterly samples of water collected from Well 20, the primary potable water supply well at Site 300. The primary MCL for lead in drinking water is 50 ppb. Although several organic compounds were detected at extremely low concentrations in Well 20 in 1991, the 1992 data reveal no constituents of concern above the detection limits (Table 6-10).

Other On-Site Surveillance Wells. Chromium was detected at 5 ppb in a quarterly sample taken from well NC7-61. Lead was detected at 7.1 ppb in one of four measurements of water from well NC7-69. Beryllium, chromium, copper, and lead were tested for, but not detected, in samples from wells NC2-11D and W-7A.

TCE was detected in all quarterly samples taken from Well W-7A at concentrations ranging from 0.6 to 1.4 ppb. Cis-1,2-dichloroethene, a potential product of TCE decomposition, was also detected in one of the quarterly samples taken from well W-7A. This well derives water from the lower water-bearing zone of the Neroly Formation, which serves as the regional aquifer beneath the General Services Area at Site 300. Causes of the low-level TCE contamination are being examined in the continuing *Draft Site-Wide Remedial Investigation* (SWRI; Webster-Scholten 1993).

Off-Site Water Supply Wells. No primary inorganic compounds of concern were detected above safe drinking water limits in any of the 12 off-site monitoring wells (Table 6-10). Three wells, STN, CON1, and MUL2, exceeded the California Department of Health Services (DHS) secondary (aesthetic) drinking water standards for sulfate, a naturally occurring ground water contaminant in the Altamont Hills. Two wells, CON1 and MUL2, exceeded the secondary standard of 0.05 ppm set for manganese. Manganese is also a naturally occurring ground water contaminant in the Altamont Hills.

Wells CARNRW1 and CON2 were sampled once in 1992 and analyzed for organic compounds only. Because no compounds of concern were detected, these data are omitted from Table 6-10.

Five trihalomethane (THM) compounds were detected in well CARNRW2 during 1992. These findings result from collecting the sample from a chlorinated water supply rather than from untreated well water. This situation has been corrected by installing a sampling tap at the wellhead. Other organic compounds of concern were detected in CARNRW2 at extremely low levels, including 1,2-dichloroethane, 1,2-dichloropropane, 1,4-dichlorobenzene, ethylbenzene, and xylene isomers (Table 6-10). These contaminants may be associated with well maintenance and chlorination.

Two halocarbon compounds, bromochloromethane and bromoform, were detected in surface water taken from the VIE1 artesian well. The origin of these compounds is unknown. However, the water sampled passed through a surface pool that is highly susceptible to external contamination.

TCE was observed at the lowest possible detection level in two quarterly water samples from surveillance well GALLO1 in January and May 1992. These detections were made after changing the analytical method from EPA 601 to EPA 524.2, which has lower detection levels. The method of analysis was changed because EPA 524.2 is the more common method of analysis for drinking water production wells. The concentrations in both samples, 0.2 ppb, were at the EPA 524.2 method detection limit. GALLO1 was not available for sampling during the third and fourth quarters of 1992.

A single detection of TCE at an extremely low concentration of 0.3 ppb occurred in a water sample taken from surveillance well CDF1. This is the first such observation for this well and resulted from changing analytical methods. However, subsequent analyses have failed to confirm TCE in this well. Another detection unique to the sample taken from well CDF1 was carbon disulfide at an extremely low concentration of 0.65 ppb.

Environmental Impact

Livermore Site

Storm water runoff contained low levels of bis(2-ethylhexyl)phthalate and other organic compounds at various locations, but very few contaminants were detected. Except for bis(2-ethylhexyl)phthalate, nonradiological pollutants above regulatory limits for drinking water were not observed in any storm water samples. Although not all constituents of concern were monitored, storm water runoff from the Livermore site meets the water quality objectives for fresh waters as outlined in the September 9, 1992, amendments to the *Water Quality Control Plan—San Francisco Bay Region* (California Regional Water Quality Control Board 1991). The detection of the pesticide Endrin at extremely low concentrations in

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runoff has prompted an investigation as to its source. Endrin is not used at the Livermore site and has not previously been detected in soils or in storm water runoff from the site.

The effective dose equivalent (EDE) from tritium is estimated based on the highest tritium activity measured in an off-site water sample. The method used to calculate dose is presented in Appendix B. Of all off-site waters measured, the maximum tritium activity, 53.3 Bq/L (1440 pCi/L), occurred in rain sampled at station AQUE during one storm (Table 6-4). The EDE to an adult who ingested two liters of this rain water per day for one year would be 0.0007 mSv (0.007 mrem), which is less than 1% of the EPA standard allowable dose of 0.1 mSv/yr (10 mrem). All other off-site waters, if ingested at the 2-liter-per-day rate, would result in even lower EDEs. The water data collected during 1992 and the estimated potential maximal dose demonstrates a minimal impact of LLNL operations on Valley waters resulting from releases of tritium to the atmosphere and to the sanitary sewer.

Site 300

The major nonradiological constituents of concern in Site 300 ground waters are the organic solvents, such as TCE, and their decomposition products. These were observed at least once during 1992 in Well 01. In backup water supply Well 18, TCE was observed in ten of twelve monthly samples, with the highest concentration measured at 1.1 ppb. This value is 22% of the 5-ppb MCL. The implementation of a different method of analysis resulted in the detection of solvents in water samples from off-site production wells CDF1 and GALLO1 at concentrations of 0.3 and 0.2 ppb. These detections, which are below the previous detection limit of 0.5 ppb, have not been substantiated by subsequent analyses. Investigations as to the extent and sources of organic solvents in Site 300 ground water are discussed in the SWRI (Webster-Scholten 1993).

Halomethane compounds were detected in water samples taken from the off-site active water supply wells CARNRW2 and VIE1. In CARNRW2, they are a result of sampling chlorinated water. No such association can be made for the VIE1 artesian well, but external contamination is likely.

Tritium concentrations in the on-site water supply Well 20 and ten off-site water supply wells were all indistinguishable from background levels and all were less than 1% of the MCL for drinking water. Mean tritium activity in well NC7-61 decreased 10% from the previous year (10,000 Bq/L to 9000 Bq/L). This decrease is double the amount expected from natural decay of tritium and suggests that dilution is occurring within the contaminated zone. Conversely, tritium continues to increase in Well 01, which is near the leading edge of a tritium-bearing ground water plume that has traveled eastward about 1 kilometer from its origin near Building 850. Tritium activities have increased

from 190 Bq/L (5135 pCi/L) in 1991 to 222 Bq/L (6000 pCi/L) in 1992, which is equal to 30% of the drinking water MCL. This well is no longer used as a source of drinking water at Site 300.

The surveillance monitoring data demonstrate that the off-site radiological and nonradiological impact of LLNL operations at Site 300 are minimal. LLNL is, however, continuing investigations of several areas of ground water contamination within the site.

Special Studies

Tritium

Historically LLNL has exhibited elevated tritium levels in both rainfall and storm water runoff. Elevated storm water tritium associated with a rainfall in March 1989 was reported in the *Environmental Report for 1989* (Sims et al. 1990). Rain water monitoring was subsequently expanded to 19 locations and the storm water monitoring system was extended to 10 locations to better assess the migration of tritium through the environment.

Tritium in Rain and Storm Water. Tritium levels in rain and storm water dropped significantly during the October 1990 through December 1992 special study period. These observations may be directly related to substantial reductions in the emission of tritiated water vapor (HTO) into the atmosphere by LLNL and SNL/CA (Figure 6-6). In 1989, the total atmospheric HTO emission from these two sources was 82 terabecquerels (TBq). Of this amount, LLNL released 58 TBq (1560 Ci) and SNL/CA released 24 TBq (656 Ci). In 1990, annual emissions were reduced to 35 TBq. Of this amount, LLNL released 26 TBq (700 Ci) and SNL/CA released 9 TBq (244 Ci). A small increase in annual HTO emissions, to 38 TBq, occurred in 1991. Of this amount, LLNL released 25 TBq (678 Ci) and SNL/CA released 13 TBq (352 Ci). This was followed by another marked reduction in 1992 when HTO emissions totaled 9 TBq. Of this amount, LLNL released 4 TBq (101 Ci) and SNL/CA released 5 TBq (134 Ci).

Reductions of tritium emissions by LLNL and SNL/CA appear to have resulted in reductions of tritium precipitated in rain throughout the Livermore Valley (Figure 6-6; note that this figure uses relative units, that is, the 10 Bq/L unit used for rain, runoff, and LLNL pool is a trillion times lower than the 10 TBq unit used for emission). The mean of tritium activity measurements in rain for 1990 was 58.9 Bq/L (1590 pCi/L); for 1991 the mean was 42.9 Bq/L (1160 pCi/L); and for 1992 the mean was 13.3 Bq/L (360 pCi/L). This represents more than a fourfold decrease over the past three years.

The mean value of tritium activity in storm water runoff sampled in 1989 was 129 Bq/L (3486 pCi/L). The mean value dropped to 31.3 Bq/L (846 pCi/L) in 1991, and to 10.6 Bq/L (286 pCi/L) in 1992 (Figure 6-6). This more than tenfold

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decrease in the tritium content of storm water runoff is directly related to the decreased tritium content of rainfall in the Livermore Valley.

Tritium in Other Waters. Other waters, both at the surface and underground, show decreasing tritium activity during the period of this special study (Figure 6-6). Tritium concentrations in the LLNL swimming pool, like those in rain and storm water runoff, appears to have decreased with decreasing emissions from nearby sources. Mean tritium activity of the LLNL pool water decreased from 42 Bq/L (1140 pCi/L) in 1990 to 39 Bq/L (1050 pCi/L) in 1991 and to 17 Bq/L (459 pCi/L) in 1992. The 1992 level is about 2% of the MCL for drinking water. Surface waters and drinking waters ("other waters" in Figure 6-6) and wells in the Livermore Valley exhibit very low and consistently decreasing values of tritium activity, equal to approximately one-tenth the values observed for rain and surface runoff. Tritium activities in these waters are below 1% of the MCL for drinking water. The general decrease observed in all the various waters sampled appears to reflect both the long-term reduction in tritium emissions and the radioactive decay of tritium to helium (half-life equals

12.3 years). If no increase in tritium emission occurs, tritium activity will continue to decrease from its present low levels in waters within and beneath the Livermore Valley.

Central Drainage Basin

The Central Drainage Basin was lined as part of the Livermore site remedial activities. Remedial action studies had indicated that infiltration of storm water from the basin was a cause of increased dispersal of ground water contaminants. Basin lining was completed in March 1992 and LLNL adopted the Drainage Retention Basin Management Plan.

The focus of the Plan was to implement long-term biological monitoring and to address water quality problems through reduction of nutrient loading and bioremediation. Water quality objectives would be met through use of submersed plants to maintain water quality and rooted aquatic plants in the shallow portions of the basin to remove urban runoff pollutants and control erosion of the basin lining cover.

The Plan identified two sources of water to fill and maintain the level of the retention basin. The primary source would be water generated from the ground water treatment units and discharged to the basin through the existing storm water collection system. The second source would be storm water collected during the rainy season. During 1992, storm water runoff was the primary source of basin water, augmented by discharge from a ground water treatment unit.

Regulatory Requirements. The San Francisco Bay Regional Water Quality Control Board (RWQCB) regulates discharge from the basin. The RWQCB issued Waste Discharge Requirements (WDRs) for discharging treated ground water from remedial activities. WDR Order No. 90-091 regulates discharge from Treatment Facility A to help fill the basin. The discharge limitations in this permit, in turn, regulate discharges from the basin into the Livermore-site storm drain. In 1992, LLNL agreed to sample any discharge from the basin monthly and report the results to the RWQCB. In subsequent years, LLNL agreed to sample the initial and one subsequent discharge.

The National Pollution Discharge Elimination System (NPDES) permit CA0029829 for the ground water treatment facility regulates discharges from the basin. Sampling of basin discharge to satisfy requirements of this permit is collected at the basin outfall.

Sampling Program. Sampling is performed to provide information necessary for basin maintenance and to document the effectiveness of nutrient removal. During 1992, the basin was monitored for a suite of management parameters (Table 6-11). Results of sampling performed for NPDES requirements are shown in Table 6-12.

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Sampling Results. During 1992, nitrogen, phosphorus, and chemical oxygen demand (COD) levels exceeded both management objectives and action levels (Table 6-11). Elevated levels of nitrogen were due to high natural levels of nitrate in ground water used to fill the basin. This practice of using ground water in the basin was halted in Fall 1992 and by the end of the year, following fall rains, one of the two measures of nitrogen, ammonia, and nitrate plus nitrite had begun to decline in the basin.

No parameter exceeded any NPDES discharge limit based on three 1992 sampling events (Table 6-12). However, the analytical detection limits for two parameters, copper and thallium, are currently higher than the permitted discharge limits. We will work with our contract analytical labs during 1993 to lower the analytical detection limits for these two parameters to below the discharge limits.

Impacts. There were no significant environmental impacts from the drainage basin. Elevated nutrient levels in the basin were primarily due to use of nitrogen-laden ground water and startup problems with the submersed plants (they died once and were replaced). There were no detected discharges from the basin that exceeded our discharge limits. For two parameters, copper and thallium, there were no detectable amounts in the discharge. Our current detection limit for copper is one-sixth the drinking water MCL. During 1993, the monitoring program will be expanded to assess the efficiency of the retention basin to remediate storm water pollutants.

Table 6-1. EPA standard methods for water sampling.

Analyte	EPA method	Analyte	EPA method
Metals			
Antimony	6010, 200.7, 204.1	Manganese	6010, 200.7, 243.1
Arsenic	7060, 206.2	Mercury	7470, 245.1
Barium	6010, 200.7, 208.2	Molybdenum	246.1
Beryllium	7091, 210.2	Nickel	249.2
Cadmium	7131, 213.2	Selenium	7740, 270.2
Chromium	7191, 218.2	Silver	7760, 272.2
Chromium, hexavalent	7196	Sodium	6010, 273.1
Cobalt	219.1	Thallium	6010, 200.7, 279.1
Copper	7210, 6010, 200.7, 220.2	Vanadium	6010, 286.1
Iron	6010, 200.7, 236.1	Zinc	6010, 200.7, 289.1
Lead	7421, 239.2		
Nonmetallic inorganic compounds			
Total dissolved solids	160.1	Nitrate	353.2
Total suspended solids	160.2	Nitrite	354.1
Total Kjeldahl nitrogen	351.3	Fluoride	340.2
Ammonia nitrogen (as N)	350.3	Chloride	325.3
All alkalinities	310.2	Phosphorus	365.2
Boron	212.3	Sulfate	375.4
Organic compounds			
Volatile organic compounds		Low level phenolic compounds	420.1
Purgeable halocarbons	601	Total organic halide (TOX)	9020
Purgeable priority pollutants	524.2, 624	Total organic carbon (TOC)	415.1, 9060
Title 22 organic compounds	509B, 608	Oil and grease	413.1
Extractable priority pollutants	625	Chemical oxygen demand (COD)	410.4
Radioactivity			
Gross alpha/beta	900.0

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Table 6-2. Radioactivity in storm water runoff (in Bq/L), 1992.

Location ^a	Tritium	Gross alpha	Gross beta	Location	Tritium	Gross alpha	Gross beta
ALPE	2.18 ± 1.56	0.06 ± 0.05	0.10 ± 0.06	4THA	1.48 ± 1.48	0.03 ± 0.04	0.05 ± 0.06
	2.38 ± 1.65	0.00 ± 0.03	0.16 ± 0.07		20.13 ± 2.25	0.00 ± 0.03	0.11 ± 0.06
	25.35 ± 1.93				2.40 ± 1.65		
	2.58 ± 1.06				25.12 ± 1.91		
	7.36 ± 1.83				8.73 ± 1.88		
	2.42 ± 1.37	0.21 ± 0.29	0.32 ± 0.25		18.61 ± 1.58	0.02 ± 0.03	0.07 ± 0.06
	1.67 ± 0.97				4.48 ± 1.07		
	3.81 ± 1.07				3.44 ± 3.26		
	4.07 ± 1.48	0.05 ± 0.05	0.09 ± 0.07		6.36 ± 1.13	0.02 ± 0.03	0.05 ± 0.07
	7.36 ± 1.13				1.70 ± 0.96		
	14.50 ± 1.42				5.55 ± 1.69		
	5.44 ± 2.84				44.03 ± 2.60		
	18.91 ± 2.23				26.42 ± 1.90		
	1.75 ± 1.75	0.00 ± 0.42	0.22 ± 0.15		3.74 ± 1.83	0.03 ± 0.37	0.15 ± 0.16
	18.28 ± 2.52				9.69 ± 2.28	0.10 ± 0.06	0.22 ± 0.05
GRNE	12.14 ± 2.39			ALPW	1.92 ± 1.92		
	10.73 ± 2.33				1.98 ± 1.98		
					1.91 ± 1.91		
	4.63 ± 1.66	0.10 ± 0.08	0.21 ± 0.07		2.96 ± 1.59	0.04 ± 0.06	0.23 ± 0.07
	2.14 ± 1.65	0.04 ± 0.05	0.06 ± 0.06		11.03 ± 1.91	0.04 ± 0.04	0.06 ± 0.07
	16.47 ± 2.11				3.56 ± 1.70		
	4.37 ± 1.58				21.39 ± 1.78		
	5.11 ± 2.28				14.87 ± 2.07		
	3.51 ± 3.51	0.03 ± 0.16	0.49 ± 0.27		34.63 ± 2.22	0.08 ± 0.07	0.19 ± 0.08
	1.25 ± 1.23				10.95 ± 1.74		
	4.74 ± 1.52				5.33 ± 1.15		
	3.57 ± 1.00	0.00 ± 0.06	0.10 ± 0.07		12.28 ± 1.34	0.05 ± 0.04	0.08 ± 0.06
	6.62 ± 1.15				1.34 ± 0.97		
	11.91 ± 1.76				7.73 ± 1.17		
	3.35 ± 1.05				5.00 ± 1.05		
B438	8.40 ± 1.22				26.64 ± 2.45		
	5.00 ± 2.12	0.07 ± 0.09	0.52 ± 0.06		15.24 ± 2.21	0.24 ± 0.44	0.46 ± 0.16
	4.81 ± 2.06				14.47 ± 2.44	0.00 ± 0.03	0.16 ± 0.05
	2.25 ± 2.05				5.33 ± 2.08	0.07 ± 0.06	0.20 ± 0.05
	4.66 ± 2.11				7.14 ± 2.22		
					14.02 ± 2.44		
	19.54 ± 2.11	-0.01 ± 0.02	0.08 ± 0.06	WPDC	9.92 ± 1.82	0.06 ± 0.04	0.09 ± 0.07
	2.86 ± 1.67	0.02 ± 0.04	0.08 ± 0.06		10.95 ± 1.96	0.03 ± 0.04	0.09 ± 0.07
	23.87 ± 3.25				8.55 ± 2.56		
	10.92 ± 1.33				8.95 ± 1.28		
	13.25 ± 2.03				8.14 ± 1.86		
	10.25 ± 1.63	-0.01 ± 0.03	0.14 ± 0.07		24.20 ± 1.84	0.01 ± 0.03	0.09 ± 0.06
	6.18 ± 1.16				12.51 ± 1.38		
	6.11 ± 1.11				1.27 ± 0.97		
	10.21 ± 1.26	-0.02 ± 0.02	0.09 ± 0.06		14.32 ± 1.45	0.00 ± 0.03	0.07 ± 0.07
	10.55 ± 1.32				4.00 ± 1.52		
	32.93 ± 2.50				8.70 ± 1.79		
	17.09 ± 1.54				2.52 ± 1.38		
	44.03 ± 2.60				34.11 ± 2.18		
	11.66 ± 2.11	0.15 ± 0.46	0.37 ± 0.17		11.21 ± 2.11	0.31 ± 0.43	0.40 ± 0.17
	23.42 ± 2.69				2.48 ± 1.97		
	3.62 ± 2.00				10.21 ± 2.26		
	5.37 ± 2.14				11.77 ± 2.35		

...continued

Table 6-2. Radioactivity in storm water runoff (in Bq/L), 1992 (concluded).

Location ^a	Tritium	Gross alpha	Gross beta	Location	Tritium	Gross alpha	Gross beta	
CDB	3.61 ± 1.49	−0.01 ± 0.02	0.08 ± 0.06	ASS2	8.29 ± 1.78	0.00 ± 0.04	0.22 ± 0.09	
	13.62 ± 1.47				14.73 ± 2.09	0.04 ± 0.05	0.12 ± 0.06	
	9.32 ± 1.75				2.00 ± 1.63			
	19.50 ± 2.20	0.01 ± 0.11	−0.14 ± 0.22		61.79 ± 3.46			
	5.33 ± 1.11				1.56 ± 1.56			
	13.54 ± 1.41				7.62 ± 1.57	0.03 ± 0.04	0.13 ± 0.06	
	11.77 ± 1.40	0.00 ± 0.04	0.12 ± 0.06		1.88 ± 1.01			
	13.14 ± 1.38				13.28 ± 1.45			
	28.64 ± 1.95				3.85 ± 1.43	0.05 ± 0.04	0.12 ± 0.07	
	8.33 ± 1.20	0.01 ± 0.34	0.25 ± 0.16		0.89 ± 0.89			
	14.21 ± 1.46				16.02 ± 2.05			
	44.03 ± 2.86				28.75 ± 2.01			
	11.77 ± 2.11	0.05 ± 0.04	0.19 ± 0.04		48.84 ± 2.78			
	8.73 ± 2.25				1.75 ± 1.75	0.06 ± 0.34	0.19 ± 0.15	
	10.40 ± 2.27				10.77 ± 2.33	0.06 ± 0.04	0.25 ± 0.05	
	4.03 ± 2.13				3.10 ± 2.01			
3.17 ± 2.05			2.02 ± 2.02					
			1.98 ± 1.98					
ALPN	9.55 ± 1.80	0.07 ± 0.09	3.82 ± 0.18	ASW	9.03 ± 1.80	0.00 ± 0.04	0.16 ± 0.07	
	12.25 ± 1.90	0.06 ± 0.05	0.11 ± 0.06		23.38 ± 2.34	0.02 ± 0.03	0.12 ± 0.06	
	1.62 ± 1.62	0.01 ± 0.04	0.08 ± 0.06		3.48 ± 1.69			
	18.46 ± 2.18				29.60 ± 2.04			
	2.06 ± 1.05				2.19 ± 2.19			
	2.56 ± 1.66	0.07 ± 0.07	0.17 ± 0.08		8.92 ± 1.26	0.01 ± 0.04	0.27 ± 0.07	
	5.29 ± 1.12				1.38 ± 0.96			
	6.18 ± 1.54				0.95 ± 0.95			
	8.62 ± 1.26	0.06 ± 0.04	0.08 ± 0.06		3.39 ± 1.38	0.06 ± 0.05	0.01 ± 0.07	
	4.77 ± 1.07				2.31 ± 1.30			
	4.51 ± 1.07				6.73 ± 1.74			
	3.17 ± 1.60				56.24 ± 3.04			
	1.35 ± 0.96				1.75 ± 1.75	0.06 ± 0.35	0.31 ± 0.16	
	22.53 ± 1.76	−0.07 ± 0.30	0.17 ± 0.16		18.35 ± 2.55	0.01 ± 0.04	0.23 ± 0.04	
	12.28 ± 2.13				5.07 ± 2.09			
	6.33 ± 2.16				2.02 ± 2.02			
	10.62 ± 2.27	0.77 ± 0.35	0.79 ± 0.17		2.47 ± 2.02			
	6.77 ± 2.21							
8.36 ± 2.27								
Mean	10.55	0.06	0.24					
Std dev	10.09	0.11	0.50					

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

Gross alpha and gross beta sampled quarterly; quality assurance duplicates also reported. For very low counts, subtraction of background count may yield a negative number for gross alpha and gross beta (see U.S. Department of Energy 1991).

^a See Fig. 6-4 for sampling locations.

6. Surveillance Water Monitoring

Table 6-3. Radioactivity in water, Livermore Valley (in Bq/L), 1992.

Location ^a	Tritium	Gross alpha	Gross beta
DEL	1.41 ± 0.11	0.00 ± 0.08	0.15 ± 0.07
	0.90 ± 0.09	0.00 ± 0.08	0.04 ± 0.06
	0.94 ± 0.13	0.00 ± 0.08	0.07 ± 0.06
	1.05 ± 0.13	0.00 ± 0.07	0.07 ± 0.06
ZON7	0.94 ± 0.08	-0.16 ± 0.09	9.70 ± 0.28
	0.66 ± 0.07	0.03 ± 0.06	0.06 ± 0.10
	0.25 ± 0.08	0.00 ± 0.10	0.24 ± 0.08
	0.87 ± 0.14	0.01 ± 0.08	0.08 ± 0.05
DUCK	2.82 ± 0.18	0.42 ± 0.39	0.17 ± 0.17
	2.67 ± 0.20	0.03 ± 0.27	0.07 ± 0.16
	1.67 ± 0.14	-0.21 ± 0.30	0.45 ± 0.30
CAL	0.92 ± 0.08	0.03 ± 0.07	0.07 ± 0.06
	0.61 ± 0.07	0.03 ± 0.05	0.08 ± 0.08
	0.75 ± 0.11	-0.07 ± 0.06	0.04 ± 0.06
ALAG	0.92 ± 0.13	0.00 ± 0.05	0.05 ± 0.05
	1.00 ± 0.09	0.01 ± 0.09	0.11 ± 0.07
	1.15 ± 0.10	0.00 ± 0.09	-0.01 ± 0.08
	0.94 ± 0.12	0.02 ± 0.05	0.00 ± 0.07
SHAD	1.17 ± 0.15	0.05 ± 0.08	0.10 ± 0.05
	3.67 ± 0.23	0.09 ± 0.13	0.13 ± 0.07
	3.39 ± 0.23	0.01 ± 0.15	0.11 ± 0.08
	3.08 ± 0.18	0.02 ± 0.14	0.08 ± 0.06
POOL	3.89 ± 0.22	0.09 ± 0.20	-0.01 ± 0.10
	20.94 ± 2.18	0.05 ± 0.13	0.16 ± 0.08
	21.39 ± 1.78	-0.15 ± 0.31	0.46 ± 0.26
	22.72 ± 1.75	-0.06 ± 0.10	0.06 ± 0.08
	22.57 ± 1.74	-0.09 ± 0.11	0.14 ± 0.09
	22.98 ± 1.79	0.02 ± 0.14	0.13 ± 0.07
	19.20 ± 2.15	0.01 ± 0.31	0.37 ± 0.15
	17.43 ± 2.09	-0.05 ± 0.14	0.15 ± 0.08
	15.47 ± 2.09	-0.69 ± 0.43	0.39 ± 0.28
	10.99 ± 2.21	0.10 ± 0.30	0.48 ± 0.15
	7.81 ± 1.09	0.08 ± 0.29	0.16 ± 0.13
	9.36 ± 1.47	-0.01 ± 0.30	0.61 ± 0.17
	12.62 ± 1.99	— ^b	— ^b

...continued

6. Surveillance Water Monitoring

Table 6-3. Radioactivity in water, Livermore Valley (in Bq/L), 1992 (*concluded*).

Location ^a	Tritium	Gross alpha	Gross beta
GAS	1.66 ± 0.12	0.43 ± 0.19	7.43 ± 0.25
	0.75 ± 0.08	0.01 ± 0.06	0.09 ± 0.06
	1.33 ± 0.15	-0.02 ± 0.10	-0.02 ± 0.13
	1.48 ± 0.15	0.06 ± 0.12	0.04 ± 0.04
TAP^c	1.05 ± 0.08	0.00 ± 0.03	0.01 ± 0.08
	0.97 ± 0.14		
	0.23 ± 0.05	-0.01 ± 0.04	-0.01 ± 0.06
	0.83 ± 0.10		
	0.61 ± 0.11	0.03 ± 0.04	0.04 ± 0.07
	0.72 ± 0.13		
	1.02 ± 0.13	0.01 ± 0.02	0.00 ± 0.02
	0.90 ± 0.16		
PALM	0.97 ± 0.09	-0.02 ± 0.08	0.04 ± 0.06
	0.64 ± 0.08	-0.08 ± 0.05	0.04 ± 0.09
	0.68 ± 0.12	0.07 ± 0.11	0.09 ± 0.08
	0.58 ± 0.11	0.00 ± 0.07	0.10 ± 0.05
BELL	0.93 ± 0.10	-0.01 ± 0.05	0.09 ± 0.06
	0.95 ± 0.63	-0.04 ± 0.06	0.10 ± 0.07
	0.98 ± 0.13	0.01 ± 0.10	0.08 ± 0.14
	1.08 ± 0.13	-0.02 ± 0.06	0.07 ± 0.05
ORCH	1.20 ± 0.10	-0.01 ± 0.24	0.09 ± 0.13
	0.94 ± 0.09	0.05 ± 0.20	0.06 ± 0.16
	0.49 ± 0.10	0.20 ± 0.18	0.08 ± 0.07
	0.51 ± 0.11	-0.01 ± 0.18	0.11 ± 0.12
Mean	4.42	0.005	0.12
Std dev	6.88	0.14	0.14
Mean without POOL	1.22	0.02	0.08
Std dev	0.86	0.11	0.08
Mean of POOL	16.96	-0.07	0.28
Std dev	5.56	0.22	0.18

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

For very low counts, subtraction of background values may yield a negative number for gross alpha and gross beta (see U.S. Department of Energy 1991).

^a See Fig. 6-2 for sampling locations.

^b Sample not taken; see Quality Assurance chapter.

^c Tritium sample twice as frequently as gross alpha and gross beta.

6. Surveillance Water Monitoring

Table 6-4. Tritium in rain, Livermore site and Livermore Valley (in Bq/L), 1992.

Date	Sampling location ^a						
	B343	CDB	B291	VIS	SALV	MET	COW
Jan. 7	46.99 ± 2.73	— ^b	25.16 ± 2.24	11.77 ± 1.88	19.39 ± 2.09	2.30 ± 1.57	15.39 ± 2.00
Jan. 30	36.70 ± 2.68	— ^b	13.14 ± 2.04	2.66 ± 1.65	5.29 ± 1.77	15.61 ± 2.11	3.85 ± 1.62
Feb. 5	79.18 ± 3.88	— ^b	54.76 ± 3.23	17.09 ± 1.57	40.70 ± 2.44	10.66 ± 1.81	16.69 ± 2.14
Feb. 8	30.49 ± 2.10	— ^b	26.90 ± 1.94	12.58 ± 1.86	20.05 ± 1.62	6.03 ± 1.78	6.44 ± 1.80
Feb. 11	44.40 ± 2.75	— ^b	34.00 ± 2.52	8.21 ± 1.76	6.33 ± 1.68	13.02 ± 1.93	3.50 ± 1.01
Feb. 12	31.12 ± 2.49	9.07 ± 1.87	13.58 ± 2.01	5.40 ± 1.73	8.70 ± 1.79	7.59 ± 1.81	3.47 ± 1.57
Feb. 18	— ^b	33.67 ± 2.15	29.23 ± 2.05	9.92 ± 1.77	20.87 ± 1.69	2.31 ± 1.63	14.43 ± 2.05
Feb. 19	42.92 ± 2.75	15.32 ± 2.01	35.74 ± 2.57	7.88 ± 1.76	16.50 ± 2.03	3.53 ± 1.59	3.20 ± 1.59
Feb. 20	48.47 ± 2.91	35.96 ± 2.63	115.81 ± 4.05	23.24 ± 2.32	13.14 ± 2.02	1.59 ± 1.59	23.68 ± 1.80
Mar. 3	40.70 ± 2.73	86.58 ± 3.64	35.48 ± 2.63	19.54 ± 2.21	48.84 ± 2.93	9.92 ± 1.92	29.86 ± 2.48
Mar. 6	78.44 ± 3.45	27.12 ± 2.39	21.05 ± 2.21	5.96 ± 1.76	10.25 ± 1.90	4.55 ± 1.71	13.73 ± 1.98
Mar. 17	53.28 ± 2.98	43.29 ± 2.77	51.06 ± 2.91	22.09 ± 2.21	37.74 ± 2.60	1.47 ± 1.47	12.25 ± 1.92
Mar. 26	24.75 ± 1.86	12.47 ± 1.35	26.38 ± 1.90	8.18 ± 1.24	17.09 ± 2.02	14.87 ± 1.96	4.81 ± 1.71
Apr. 13	23.27 ± 2.33	22.16 ± 2.28	21.76 ± 2.28	20.31 ± 1.63	19.80 ± 2.22	6.22 ± 1.13	11.47 ± 1.33
Jun. 30	41.81 ± 2.76	14.91 ± 2.07	110.63 ± 3.98	10.77 ± 1.95	24.24 ± 2.33	1.52 ± 1.52	3.52 ± 1.61
Oct. 21	40.33 ± 3.15	30.64 ± 3.00	74.00 ± 4.00	11.06 ± 2.39	22.83 ± 2.79	1.99 ± 1.99	10.88 ± 2.37
Nov. 2	49.95 ± 3.50	50.69 ± 3.50	95.09 ± 4.47	21.57 ± 2.76	23.13 ± 2.80	3.28 ± 2.14	24.16 ± 2.75
Dec. 4	12.06 ± 1.99	3.69 ± 1.93	9.66 ± 2.93	4.26 ± 1.72	4.85 ± 1.97	6.14 ± 1.79	4.88 ± 1.74
Dec. 10	73.26 ± 3.88	35.26 ± 3.03	22.76 ± 2.71	26.79 ± 2.81	21.68 ± 2.67	4.81 ± 2.10	19.83 ± 2.62
Dec. 15	59.94 ± 3.66	28.49 ± 2.05	16.95 ± 2.32	11.84 ± 2.38	33.93 ± 3.05	6.14 ± 1.44	11.66 ± 2.11
Mean	45.16	29.95	41.66	13.06	20.77	6.18	11.88
Std dev	18.12	20.42	32.32	7.06	11.97	4.47	7.96

...continued

6. Surveillance Water Monitoring

Table 6-4. Tritium in rain, Livermore site and Livermore Valley (in Bq/L), 1992 (*continued*).

Date	Sampling location ^a					
	ESAN	AQUE	ZON7	GTES	BVA	VINE
Jan. 7	— ^b	8.29 ± 1.77	— ^b	1.71 ± 1.55	1.52 ± 1.52	1.52 ± 1.52
Jan. 30	— ^b	6.51 ± 1.81	3.11 ± 1.67	4.92 ± 1.74	8.03 ± 1.86	4.00 ± 1.69
Feb. 5	— ^b	16.35 ± 2.11	18.32 ± 2.20	4.96 ± 1.45	9.62 ± 1.74	15.84 ± 2.12
Feb. 8	— ^b	16.10 ± 1.53	8.03 ± 1.20	36.30 ± 2.25	25.75 ± 1.91	7.03 ± 2.50
Feb. 11	— ^b	4.74 ± 1.63	4.44 ± 1.46	2.11 ± 1.52	6.51 ± 1.70	0.93 ± 0.92
Feb. 12	— ^b	12.32 ± 1.97	3.50 ± 1.57	8.51 ± 1.85	4.37 ± 1.71	1.85 ± 1.51
Feb. 18	— ^b	14.54 ± 1.92	6.99 ± 2.46	2.01 ± 1.32	2.38 ± 1.64	4.66 ± 1.71
Feb. 19	— ^b	11.88 ± 1.90	5.22 ± 1.66	33.86 ± 2.51	11.14 ± 1.86	13.73 ± 1.95
Feb. 20	— ^b	27.60 ± 2.43	14.32 ± 1.43	3.85 ± 2.27	1.87 ± 1.65	0.93 ± 0.93
Mar. 3	11.66 ± 1.28	19.68 ± 2.22	17.58 ± 2.14	1.37 ± 1.23	10.73 ± 2.62	2.85 ± 1.68
Mar. 6	26.34 ± 2.37	9.44 ± 1.87	3.61 ± 1.62	8.47 ± 1.84	1.57 ± 1.57	1.52 ± 1.52
Mar. 17	37.00 ± 2.59	53.28 ± 2.98	12.91 ± 1.94	1.52 ± 1.52	2.30 ± 1.56	2.18 ± 1.55
Mar. 26	21.02 ± 1.72	11.21 ± 1.33	5.96 ± 1.75	12.69 ± 1.84	6.51 ± 1.16	10.40 ± 1.90
Apr. 13	28.82 ± 2.48	18.61 ± 2.20	9.51 ± 1.26	17.58 ± 2.16	8.44 ± 1.26	6.33 ± 1.15
Jun. 30	51.43 ± 2.98	26.34 ± 2.40	6.88 ± 1.75	— ^b	1.52 ± 1.52	1.71 ± 1.55
Oct. 21	29.56 ± 2.96	30.86 ± 2.99	8.03 ± 2.29	— ^b	2.03 ± 2.03	— ^b
Nov. 2	33.86 ± 2.74	20.02 ± 2.72	7.03 ± 2.21	1.87 ± 1.81	1.92 ± 1.92	— ^b
Dec. 4	34.71 ± 2.95	5.92 ± 1.79	1.61 ± 1.61	1.85 ± 1.85	6.88 ± 1.83	6.48 ± 1.79
Dec. 10	24.86 ± 2.76	17.80 ± 2.54	13.73 ± 2.40	2.04 ± 2.04	1.94 ± 1.94	1.98 ± 1.98
Dec. 15	63.27 ± 3.73	26.53 ± 2.04	12.25 ± 1.58	5.51 ± 2.14	3.13 ± 2.06	3.50 ± 2.07
Mean	32.96	17.90	8.58	8.40	5.91	4.86
Std dev	14.19	11.26	4.95	10.65	5.74	4.43

...continued

6. Surveillance Water Monitoring

Table 6-4. Tritium in rain, Livermore site and Livermore Valley (in Bq/L), 1992 (*concluded*).

Date	Sampling location ^a					
	PATT	FCC	SLST	ALTA	DEL7	PARK
Jan. 7	1.53 ± 1.53	— ^b	1.49 ± 1.49	3.44 ± 1.61	1.50 ± 1.50	1.48 ± 1.48
Jan. 30	1.70 ± 1.62	2.93 ± 1.67	2.77 ± 1.67	1.62 ± 1.62	3.58 ± 1.69	3.81 ± 1.70
Feb. 5	1.28 ± 1.28	2.58 ± 1.66	4.33 ± 1.15	2.58 ± 1.04	2.55 ± 1.06	2.73 ± 1.08
Feb. 8	5.88 ± 5.88	3.92 ± 2.35	15.87 ± 1.48	4.63 ± 1.07	3.01 ± 1.02	7.03 ± 2.41
Feb. 11	1.46 ± 1.46	0.93 ± 0.93	1.44 ± 1.44	1.45 ± 1.45	1.07 ± 0.97	1.17 ± 1.17
Feb. 12	1.64 ± 1.60	1.44 ± 1.44	2.34 ± 1.63	2.42 ± 1.63	1.59 ± 1.59	1.89 ± 1.60
Feb. 18	0.95 ± 0.95	1.59 ± 1.59	1.59 ± 1.59	20.13 ± 1.67	1.60 ± 1.60	2.09 ± 1.62
Feb. 19	2.51 ± 1.55	1.51 ± 1.51	2.19 ± 1.54	1.51 ± 1.51	2.58 ± 1.56	2.25 ± 1.55
Feb. 20	3.15 ± 1.02	1.58 ± 1.58	1.54 ± 1.54	2.71 ± 1.00	1.43 ± 0.94	1.62 ± 1.62
Mar. 3	3.96 ± 1.03	5.99 ± 1.80	4.88 ± 1.76	1.41 ± 1.25	2.18 ± 2.18	1.57 ± 1.57
Mar. 6	2.63 ± 1.64	1.52 ± 1.52	1.58 ± 1.58	1.59 ± 1.59	1.47 ± 1.47	1.58 ± 1.58
Mar. 17	3.62 ± 1.62	1.48 ± 1.48	1.66 ± 1.54	4.40 ± 1.64	1.82 ± 1.57	1.52 ± 1.52
Mar. 26	1.23 ± 1.23	2.58 ± 1.63	5.25 ± 1.11	4.44 ± 1.07	3.70 ± 1.06	0.94 ± 0.94
Apr. 13	2.27 ± 2.27	2.62 ± 2.62	2.92 ± 1.04	2.56 ± 1.67	4.63 ± 3.19	3.19 ± 1.32
Jun. 30	1.64 ± 1.64	1.55 ± 1.55	4.07 ± 1.77	— ^b	2.79 ± 1.66	1.49 ± 1.49
Oct. 21	2.51 ± 2.10	2.20 ± 2.07	2.30 ± 2.03	— ^b	2.04 ± 2.04	1.98 ± 1.98
Nov. 2	1.72 ± 1.72	1.99 ± 1.99	2.00 ± 2.00	3.92 ± 1.83	2.93 ± 2.12	1.98 ± 1.98
Dec. 4	2.00 ± 2.00	1.61 ± 1.61	3.32 ± 1.69	1.96 ± 1.96	1.56 ± 1.56	2.45 ± 1.65
Dec. 10	2.03 ± 2.03	2.00 ± 2.00	1.93 ± 1.93	2.75 ± 2.07	1.95 ± 1.95	2.92 ± 2.69
Dec. 15	2.33 ± 1.27	1.91 ± 1.91	1.64 ± 1.64	5.11 ± 1.89	1.95 ± 1.95	1.24 ± 1.24
Mean	2.30	2.21	3.26	3.81	2.30	2.25
Std dev	1.15	1.15	3.20	4.25	0.92	1.34

Note: Results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 6-3 for sampling locations.

^b Sample unavailable; 6 samples had insufficient volume, and 18 could not be taken due to missing sample buckets (see Quality Assurance chapter).

6. Surveillance Water Monitoring

Table 6-5. Tritium activity in wells, Livermore Valley (in Bq/L), 1992.

Location ^a	Activity
1H3	0.39 ± 0.11
1P2	4.92 ± 0.27
1P3	0.73 ± 0.11
1R2	2.95 ± 0.18
2R1	6.51 ± 0.31
7C2	4.22 ± 0.22
7P3	0.06 ± 0.06
7P3 duplicate	0.08 ± 0.07
8F1	1.35 ± 0.13
8P1	2.29 ± 0.19
9M2	1.59 ± 0.14
9M2 duplicate	1.24 ± 0.18
9Q1	0.62 ± 0.10
11B1	16.95 ± 0.54
12A2	2.59 ± 0.21
12G1	No sample provided
16L5	1.41 ± 0.15
16L7	0.96 ± 0.14
16L7 duplicate	0.90 ± 0.12
18A1	0.92 ± 0.12
18A5	No sample provided
16B1	1.60 ± 0.15
Mean	2.83
Std dev	3.91
	pCi/L
Mean	76.5
Std dev	105.7

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 6-1 for sampling locations.

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992.

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Inorganic chemicals (mg/L)										
Alkalinity (Total, as CaCO ₃)	10	30	20	30	30	20	10	10	40	20
(Bicarbonate = Total)	10	30	20	20	30	30	20	20	40	20
	20	220	80	30	30	50	20	20	150	40
	10	40	20	30	20	20	20	20	100	20
	16	47	16	31	19	26	22	15	57	23
	15		26	15	22	17				
Arsenic	0.003	0.002	0.02	0.002		0.0028	0.003	0.0044	0.005	0.003
	0.002	0.005					0.011	0.0021	0.003	0.002
	0.0024									0.0049
	0.002									
	38 nondetections at <0.002 ppm.									
Barium		0.10	0.1	0.055					0.1	0.05
									0.05	
	49 nondetections at <0.05 ppm.									
Beryllium	16 nondetections at <0.2 ppb and forty at <0.5 ppb.									
Cadmium	0.0007	0.0012				0.0008	0.0006	0.0006	0.0008	
	0.0028						0.0016			
	47 nondetections at <0.5 ppb.									
Chemical oxygen demand	25	25	25	25	25	25	25		30	25
	50	110	70	80	150	110	110	75	170	75
	40	130	40	45	40	90	90	30	100	50
	50	60	90	50	110	85	50	80	40	50
	150	140	80	180	90	210	160	120	80	130
	70		50	40	40	30		40		
Chloride	1.2	6	12	18	1.2	1	1	1	9	15
		13	1	13		15			13	4
		240		4.7					150	1.9
		24							84	
		9							30	
	31 nondetections at <1 ppm.									
Chromium	0.0061	0.0056	0.016	0.0068		0.005	0.0071	0.023		0.0083
		0.005	0.0061					0.0067		
	42 nondetections at <0.005 ppm.									
Fluoride	0.1	0.9		0.1	0.1				0.2	
		0.1		0.12					0.2	
		0.15							0.6	0.1
									0.4	
	41 nondetections at <0.1 ppm.									
									0.16	

...continued

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992 (*continued*).

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Lead	0.0059		0.0025	0.0036		0.0048	0.002	0.003		0.003
							0.011	0.0025		0.0051
	43 nondetections at <0.002 ppm, and one at <0.2 ppm.									
Mercury	52 nondetections at <0.2 ppb.									
Nitrate plus nitrite (as NO ₃)	1.6	7.4	2.1	2	3.1	2.3	1.2		9.2	2.9
	4	5	6.1	4.9	4.2	4.7	2.4	3.2	27	5.3
	0.4	4.2	1.4	2.8	1	1.7	0.3	2.7	1.9	0.7
	4.2	6.6	6.6	3.9	3.2	2	1.6	2.4	5.3	2.2
	14	16	4.9	11	1.9	4.8	5.7	5.4		8.2
	3.2		2.9	3	4.8	2.8		4.4	8.2	
Selenium	52 nondetections at <2 ppb.									
Silver				0.0012			0.0046			
	53 nondetections at <0.5 ppb.									
Sulfate	5	3	7	5	9	5	3	4	13	7
	8	9	7	8	12	8	9	8	23	8
	5	450	31	25	5	27	8	5	130	25
	8	22	6	14			5		52	5
									20	
	17 nondetections at <2 ppm.									
VOC (EPA 624, µg/L)										
1,1,1-Trichloroethane			0.5				0.5	0.9		0.6
	51 nondetections at <0.5 ppb.									
1,1,2,2-Tetrachloroethane	55 nondetections at <0.5 ppb.									
1,1,2-Trichloroethane	55 nondetections at <0.5 ppb.									
1,1-Dichloroethane	55 nondetections at <0.5 ppb.									
1,1-Dichloroethene	55 nondetections at <0.5 ppb.									
1,2-Dichlorobenzene	55 nondetections at <0.5 ppb.									
1,2-Dichloroethane	55 nondetections at <0.5 ppb.									
1,2-Dichloroethene (total)	55 nondetections at <0.5 ppb.									
1,2-Dichloropropane	55 nondetections at <0.5 ppb.									
1,3-Dichlorobenzene	55 nondetections at <0.5 ppb.									
1,4-Dichlorobenzene	55 nondetections at <0.5 ppb.									
2-Chloroethylvinylether	16 nondetections at <2 ppb and 39 at <0.5 ppb.									
2-Hexanone	55 nondetections at <0.5 ppb.									
4-Methyl-2-pentanone	16 nondetections at <2 ppb and 39 at <0.5 ppb.									

...continued

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992 (*continued*).

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Acetone	5.3	9.2		5.9		17	5.2			6.9
	49 nondetections at <5 ppb.									
Acrolein	16 nondetections at <10 ppb and 39 at <5 ppb.									
Acrylonitrile	55 nondetections at <5 ppb.									
Benzene	55 nondetections at <0.5 ppb.									
Bromodichloromethane	55 nondetections at <0.5 ppb.									
Bromoform	55 nondetections at <0.5 ppb.									
Bromomethane	55 nondetections at <0.5 ppb.									
Carbon disulfide	55 nondetections at <0.5 ppb.									
Carbon tetrachloride	55 nondetections at <0.5 ppb.									
Chlorobenzene	55 nondetections at <0.5 ppb.									
Chloroethane	7 nondetections at <1 ppb and 48 at <0.5 ppb.									
Chloroform				1.4						
	54 nondetections at <0.5 ppb.									
Chloromethane	55 nondetections at <0.5 ppb.									
cis-1,2-Dichloroethene	55 nondetections at <0.5 ppb.									
cis-1,3-Dichloropropene	55 nondetections at <0.5 ppb.									
Dibromochloromethane	55 nondetections at <0.5 ppb.									
Ethylbenzene	55 nondetections at <0.5 ppb.									
Freon-113	1.9	0.7	1.5			1.5	0.8	0.7	0.7	2.1
							0.5		0.6	
	16 nondetections at <1 ppb and 29 at <0.5 ppb.									
Methyl ethyl ketone	16 nondetections at <5 ppb and 39 at <10 ppb.									
Methylene chloride	16 nondetections at <0.5 ppb, 20 at <2 ppb, and 19 at <3 ppb.									
Styrene	55 nondetections at <0.5 ppb.									
Tetrachloroethene	55 nondetections at <0.5 ppb.									
Toluene			0.8		1.3	1.5				0.6
					0.8					
	50 nondetections at <0.5 ppb.									
Total xylene isomers			1.4							
	54 nondetections at <0.5 ppb.									
trans-1,2-Dichloroethylene	55 nondetections at <0.5 ppb.									
trans-1,3-Dichloropropene	55 nondetections at <0.5 ppb.									
Trichloroethene				0.5						
				0.7						
				1.6						
	52 nondetections at <0.5 ppb.									

...continued

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992 (*continued*).

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Trichlorofluoromethane	55 nondetections at <0.5 ppb.									
Vinyl acetate	55 nondetections at <0.5 ppb.									
Vinyl chloride	55nondetections at <0.5 ppb.									
Semi-VOC (EPA 625, µ/L)										
1,2,4-Trichlorobenzene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
1,2-Dichlorobenzene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
1,2-Diphenylhydrazine	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
1,3-Dichlorobenzene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
1,4-Dichlorobenzene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2,4,5-Trichlorophenol	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
2,4,6-Trichlorophenol	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2,4-Dichlorophenol	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2,4-Dimethylphenol	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
2,4-Dinitrophenol	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
2,4-Dinitrotoluene	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
2,6-Dinitrotoluene	52 nondetections at <2 ppb, and due to dilutions, one at <10 ppb and two at <20 ppb.									
2-Chloronaphthalene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2-Chlorophenol	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
2-Methyl phenol	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2-Methyl-4,6-dinitrophenol	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2-Methylnaphthalene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
2-Nitroaniline	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
2-Nitrophenol	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
3,3'-Dichlorobenzidine	52 nondetections at <20 ppb, and due to dilutions, one at <100 ppb and two at <200 ppb.									
3-Nitroaniline	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
4-Bromophenylphenylether	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
4-Chloro-3-methylphenol	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
4-Chloroaniline	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
4-Chlorophenylphenylether	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
4-Methyl phenol	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
4-Nitroaniline	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
4-Nitrophenol	52 nondetections at <30 ppb, and due to dilutions, one at <200 ppb and two at <300 ppb.									
Acenaphthene	52 nondetections at <5 ppb, and due to dilutions, one at <30 ppb and two at <50 ppb.									
Acenaphthylene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Aniline	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Anthracene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									

...continued

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992 (*continued*).

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Benzidine	52 nondetections at <50 ppb, and due to dilutions, one at <300 ppb and two at <500 ppb.									
Benzo(a)anthracene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Benzo(a)pyrene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Benzo(b)fluoranthene	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Benzo(g,h,i)perylene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Benzo(k)fluoranthene	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Benzoic acid	49.00									
Benzyl alcohol	51 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
	21.00									
	51 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Bis(2-chloroethoxy)methane	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Bis(2-chloroethyl)ether	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Bis(2-chloroisopropyl)ether	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Bis(2-ethylhexyl)phthalate	37 99 23									
	34 nondetections at <4 ppb, and due to dilutions, 15 at <10 ppb, one at <20 ppb, and two at <40 ppb.									
Butylbenzylphthalate	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Chrysene	52 nondetections at <2 ppb, and due to dilutions, one at <10 ppb and two at <20 ppb.									
Di-n-octylphthalate	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Dibenzo(a,h)anthracene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Dibenzofuran	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Dibutylphthalate	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Diethylphthalate	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Dimethylphthalate	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Fluoranthene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Fluorene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Hexachlorobenzene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Hexachlorobutadiene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Hexachlorocyclopentadiene	52 nondetections at <20 ppb, and due to dilutions, one at <100 ppb and two at <200 ppb.									
Hexachloroethane	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
Indeno(1,2,3-c,d)pyrene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Isophorone	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
N-Nitrosodi-n-propylamine	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									
N-Nitrosodimethylamine	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
N-Nitrosodiphenylamine	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Naphthalene	52 nondetections at <3 ppb, and due to dilutions, one at <20 ppb and two at <30 ppb.									

...continued

6. Surveillance Water Monitoring

Table 6-6. LLNL storm water runoff, nonradioactive parameters, 1992 (*concluded*).

Parameter	Sampling location ^a									
	4THA	ALPE	ALPN	ALPW	ASS2	ASW	B438	CDB	GRNE	WPDC
Nitrobenzene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Pentachlorophenol	52 nondetections at <10 ppb, and due to dilutions, one at <50 ppb and two at <100 ppb.									
Phenanthrene	52 nondetections at <4 ppb, and due to dilutions, one at <20 ppb and two at <40 ppb.									
Phenol	52 nondetections at <5 ppb, and due to dilutions, one at <30 ppb and two at <50 ppb.									
Pyrene	52 nondetections at <2 ppb, and due to dilutions, one at <10 ppb and two at <20 ppb.									
Herbicides (EPA 509B, µg/L)										
2,4,5-TP (Silvex)	55 nondetections at <1 ppb.									
2,4-D	8.50									
	54 nondetections at <5 ppb.									
Pesticides (EPA 608, µg/L)										
BHC, gamma isomer (Lindane)	0.05									
	39 nondetections at <0.4 ppb and fifteen at <0.03 ppb.									
Endrin	0.05		0.03			0.04	0.05			0.05
	8 nondetections at <0.01 ppb, 22 at <0.05 ppb, 10 at <0.1 ppb, and 10 at <0.2 ppb.									
Methoxychlor	39 nondetections at <10 ppb and 16 at <0.2 ppb.									
Toxaphene	16 nondetections at <1 ppb, 34 at <0.5 ppb, and five at <0.1 ppb.									
Total organic carbon (mg/L)	8.0	8.6	4.4	7.2	6.0	5.6	6.2		6.6	6.6
	12.0	10.0	10.0	12.0	13.0	19.0	16.0	12.0	9.3	11.0
	9.0	29.0	8.6	12.0	6.7	13.0	8.7	8.8	19.0	8.8
	13.0	7.5	8.3	8.4	4.9	5.2	10.0	9.5	8.4	5.1
	42.0	29.0	15.0	40.0	18.0	48.0	31.0	22.0		31.0
	13.0		8.0	10.0	9.5	8.5		9.6	26.0	
Oil and grease (mg/L)	10	10	10	9	10	10	9	5	9	9
	7	6	7	6	5	8	10			
		5				5	6			
	35 nondetections at <5 ppm.									

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 6-4 for sampling locations.

6. Surveillance Water Monitoring

Table 6-7. Quarterly radioactivity in surface water (in Bq/L), Site 300, 1992.

	Sampling location ^a		
	GEO	RAIN	812 CREEK
Tritium			
1st Quarter	0.95 ± 0.08	0.46 ± 0.11 0.97 ± 0.12	0.34 ± 0.20
2nd Quarter	0.98 ± 0.12	1.20 ± 0.11 0.40 ± 0.10 3.60 ± 0.77	0.33 ± 0.08
3rd Quarter	0.89 ± 0.14		0.37 ± 0.07
4th Quarter	1.17 ± 0.16	0.47 ± 0.12 0.61 ± 0.61 0.56 ± 0.10 0.71 ± 0.09	0.48 ± 0.12
Gross alpha			
1st Quarter	0.07 ± 0.31		0.26 ± 0.16
2nd Quarter	0 ± 0.24		0.12 ± 0.18
3rd Quarter	0.06 ± 0.31		0.16 ± 0.17
4th Quarter	0.24 ± 0.34		0.42 ± 0.30
Gross beta			
1st Quarter	0.17 ± 0.13		0.38 ± 0.08
2nd Quarter	0.19 ± 0.14		0.47 ± 0.09
3rd Quarter	0.24 ± 0.15		0.29 ± 0.08
4th Quarter	0.24 ± 0.16		0.48 ± 0.14

Note: Results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 6-5 for sampling locations.

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992.

Parameter	Well ^a				
	STN	CARNRW2	CDF1	CON1	GALLO1 ^b
Inorganic chemicals (mg/L)					
Total alkalinity (as CaCO ₃)	310	210	230	200	
Bicarbonate alk (as CaCO ₃)	310	190	150	1160	
Carbonate alk (as CaCO ₃)	<1	20	80	40	
Arsenic	<0.002	<0.002	0.003	<0.002	
Barium	<0.05	<0.05	<0.05	<0.05	
Beryllium	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005
		<0.0005	<0.0005	<0.0005	<0.0005
		<0.0005	<0.0005	<0.0005	
		<0.0005	<0.0002	<0.0002	
		<0.0002	<0.0005	<0.0005	
Cadmium	<0.0005	<0.0005	<0.0005	<0.0005	
Calcium	170	23	68	46	
Chloride	170	100	120	180	
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005
		<0.005	<0.005	<0.005	<0.05
		<0.005	<0.005	<0.005	
		<0.005	<0.005	0.005	
		<0.005			
Copper	<0.05	<0.005	0.006	<0.005	<0.05
		<0.05	<0.05	<0.05	<0.05
		0.008	<0.05	<0.05	
		<0.05	<0.05	<0.05	
		<0.05			
Fluoride	0.37	0.4	0.4	0.4	
Iron	<0.1	<0.1	<0.1	<0.1	
Lead	<0.002	0.003	<0.002	<0.002	<0.002
		<0.002	<0.002	<0.002	0.003
		<0.002	<0.002	<0.002	
		<0.002	<0.002	<0.002	
		<0.002	0.004	0.003	
Low level phenolics	<0.005	<0.005	<0.005	<0.005	
Magnesium	83	4.9	29	7.8	
Manganese	<0.05	<0.05	<0.05	0.16	
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	
Nitrate plus nitrite (as NO ₃)	8.6	<0.4	10	<0.4	
pH	7.2	8.4	8.2	8.2	
Potassium	5.8	8.4	6	10	
Selenium	<0.002	<0.002	0.004	<0.002	
Silver	<0.0005	<0.0005	<0.0005	<0.0005	
Sodium	200	190	150	420	
Specific conductance (µmhos/cm)	50	990	1300	2070	

...continued

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	VIE1	VIE2	MUL1	MUL2	W35A-04
Inorganic chemicals (mg/L)					
Total alkalinity (as CaCO ₃)	250	280	200	180	250
Bicarbonate alk (as CaCO ₃)	210	240	200	180	250
Carbonate alk (as CaCO ₃)	40	40	<1	<1	<1
Arsenic	0.016	<0.002	0.0027	<0.002	<0.002
Barium	0.051	<0.05	0.062	<0.05	0.053
Beryllium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002
Cadmium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Calcium	39	140	71	170	100
Chloride	76	85	46	66	140
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	0.62	0.64	0.72	0.72	0.37
Iron	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	<0.002	0.0029	0.003	<0.002	<0.002
Low level phenolics	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	21	18	31	56	48
Manganese	<0.05	<0.05	<0.05	0.18	<0.05
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nitrate plus nitrite (as NO ₃)	6.1	13	5.4	9.4	22
pH	8.4	8.4	7.5	7.1	7.5
Potassium	8.4	<5	6	7.5	<5.0
Selenium	0.0046	0.0065	0.0031	0.0075	0.0031
Silver	<0.0005	<0.0005	0.0014	<0.0005	<0.0005
Sodium	110	66	78	130	150
Specific conductance (μmhos/cm)	770	930	780	1480	1410

...continued

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	STN	CARNRW2	CDF1	CON1	GALLO1 ^b
Sulfate	710	230	320	770	
Total dissolved solids (TDS)	1600	740	880	1500	
Zinc	0.077	<0.05	<0.05	<0.05	
Organic chemicals^c					
EPA Method 524.2 (µg/L)					
1,1,1,2-Tetrachloroethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
1,1,1-Trichloroethane	1 n.d. <0.2	4 n.d. <0.2	3 n.d. <0.2	3 n.d. <0.2	2 n.d. <0.2
		1 n.d. <0.3	1 n.d. <0.3	1 n.d. <0.3	
1,1,2,2-Tetrachloroethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
1,1,2-Trichloroethane	1 n.d. <0.2	4 n.d. <0.2	3 n.d. <0.2	3 n.d. <0.2	2 n.d. <0.2
		1 n.d. <0.3	1 n.d. <0.3	1 n.d. <0.3	
1,1-Dichloroethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
1,1-Dichloroethene	Same as above.				
1,1-Dichloropropene	Same as above.				
1,2,3-Trichlorobenzene	Same as above.				
1,2,3-Trichloropropane	Same as above.				
1,2,4-Trichlorobenzene	Same as above.				
1,2,4-Trimethylbenzene	Same as above.				
1,2-Dibromo-3-chloropropane	1 n.d. <2	4 n.d. <2	3 n.d. <2	3 n.d. <2	2 n.d. <0.2
		1 n.d. <0.5	1 n.d. <0.5	1 n.d. <0.5	
1,2-Dibromoethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
1,2-Dichlorobenzene	Same as above.				
1,2-Dichloroethane	1 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
		1			
1,2-Dichloropropane	1 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
		0.4			
1,3,5-Trimethylbenzene	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
1,3-Dichlorobenzene	Same as above.				
1,3-Dichloropropane	Same as above.				
1,4-Dichlorobenzene	1 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
		0.5			
2,2-Dichloropropane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
2-Chlorotoluene	Same as above.				
4-Chlorotoluene	Same as above.				
Benzene	Same as above.				
Bromobenzene	Same as above.				
Bromochloromethane	Same as above.				
Bromodichloromethane	1 n.d. <0.2	3 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
		0.8			
		4.2			

...continued

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	VIE1	VIE2	MUL1	MUL2	W35A-04
Sulfate	110	200	240	660	430
Total dissolved solids (TDS)	590	730	580	1200	1100
Zinc	<0.05	0.057	0.051	<0.05	<0.05
Organic chemicals^c					
EPA Method 524.2 (µg/L)					
1,1,1,2-Tetrachloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,1,1-Trichloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,1,2,2-Tetrachloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,1,2-Trichloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,1-Dichloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,1-Dichloroethene	Same as above.				
1,1-Dichloropropene	Same as above.				
1,2,3-Trichlorobenzene	Same as above.				
1,2,3-Trichloropropane	Same as above.				
1,2,4-Trichlorobenzene	Same as above.				
1,2,4-Trimethylbenzene	Same as above.				
1,2-Dibromo-3-chloropropane	1 n.d. <2	1 n.d. <2	1 n.d. <2	1 n.d. <2	1 n.d. <2
1,2-Dibromoethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,2-Dichlorobenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,2-Dichloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,2-Dichloropropane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,3,5-Trimethylbenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
1,3-Dichlorobenzene	Same as above.				
1,3-Dichloropropane	Same as above.				
1,4-Dichlorobenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
2,2-Dichloropropane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
2-Chlorotoluene	Same as above.				
4-Chlorotoluene	Same as above.				
Benzene	Same as above.				
Bromobenzene	Same as above.				
Bromochloromethane	0.4				
Bromodichloromethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
	0.4				

...continued

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	STN	CARNRW2	CDF1	CON1	GALLO1 ^b
Bromoform	1 n.d. <0.2	3 n.d. <0.2 2.8 23	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Bromomethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Carbon tetrachloride	1 n.d. <0.2	4 n.d. <0.2 1 n.d. <0.3	3 n.d. <0.2 1 n.d. <0.3	3 n.d. <0.2 1 n.d. <0.3	2 n.d. <0.2
Chlorobenzene	1 n.d. <0.2	4 n.d. <0.2 0.4	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Chloroethane	1 n.d. <0.2	4 n.d. <0.2 1 n.d. <0.3	3 n.d. <0.2 1 n.d. <0.3	3 n.d. <0.2 1 n.d. <0.3	2 n.d. <0.2
Chloroform	1 n.d. <0.2	3 n.d. <0.2 0.6 1.9	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Chloromethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
cis-1,2-Dichloroethene	Same as above.				
cis-1,3-Dichloropropene	1 n.d. <0.2	4 n.d. <2 1 n.d. <0.5	3 n.d. <2 1 n.d. <0.5	3 n.d. <2 1 n.d. <0.5	2 n.d. <0.2
Dibromochloromethane	1 n.d. <0.2	3 n.d. <0.2 1.6 9.8	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Dibromomethane	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Dichlorodifluoromethane	1 n.d. <0.2	2 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Ethylbenzene	1 n.d. <0.2	4 n.d. <0.2 0.5	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Hexachlorobutadiene	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Isopropylbenzene	Same as above.				
m- and p-Xylene isomers	1 n.d. <0.2	4 n.d. <0.2 0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Methylene chloride	1 n.d. <1	4 n.d. <1 1 n.d. <0.2	3 n.d. <1 1 n.d. <0.2	3 n.d. <1 1 n.d. <0.2	2 n.d. <1
n-Butylbenzene	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
n-Propylbenzene	Same as above.				
Naphthalene	Same as above.				
o-Xylene	Same as above.				
p-Isopropyl toluene	Same as above.				
sec-Butylbenzene	Same as above.				
Styrene	Same as above.				
tert-Butylbenzene	Same as above.				
Tetrachloroethene	Same as above.				
Toluene	Same as above.				
trans-1,2-Dichloroethylene	Same as above.				
trans-1,3-Dichloropropene	Same as above.				

...continued

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	VIE1	VIE2	MUL1	MUL2	W35A-04
Bromoform	0.8	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Bromomethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Carbon tetrachloride	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Chlorobenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Chloroethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Chloroform	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Chloromethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
cis-1,2-Dichloroethene	Same as above.				
cis-1,3-Dichloropropene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Dibromochloromethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Dibromomethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Dichlorodifluoromethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Ethylbenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Hexachlorobutadiene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Isopropylbenzene	Same as above.				
m- and p-Xylene isomers	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Methylene chloride	1 n.d. <1	1 n.d. <1	1 n.d. <1	1 n.d. <1	1 n.d. <1
n-Butylbenzene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
n-Propylbenzene	Same as above.				
Naphthalene	Same as above.				
o-Xylene	Same as above.				
p-Isopropyl toluene	Same as above.				
sec-Butylbenzene	Same as above.				
Styrene	Same as above.				
tert-Butylbenzene	Same as above.				
Tetrachloroethene	Same as above.				
Toluene	Same as above.				
trans-1,2-Dichloroethylene	Same as above.				
trans-1,3-Dichloropropene	Same as above.				

...continued

Table 6-8. Analyses of water from supply wells near Site 300, 1992
(continued).

Parameter	Well ^a				
	STN	CARNRW2	CDF1	CON1	GALLO1 ^b
Trichloroethene	1 n.d. <0.2	5 n.d. <0.2	3 n.d. <0.2 0.3	4 n.d. <0.2	0.2 0.2
Trichlorofluoromethane	1 n.d. <0.2	4 n.d. <0.2 1 n.d. <1	3 n.d. <0.2 1 n.d. <1	3 n.d. <0.2 1 n.d. <1	2 n.d. <0.2
Vinyl chloride	1 n.d. <0.2	5 n.d. <0.2	4 n.d. <0.2	4 n.d. <0.2	2 n.d. <0.2
Explosive compounds (µg/L)					
HMX	<20 for each well, except GALLO1 unavailable for sampling.				
RDX	<30 for each well, except GALLO1 unavailable for sampling.				
TNT	<30 for each well, except GALLO1 unavailable for sampling.				
Pesticides and herbicides (µg/L) EPA Methods 608, 509B					
2,4,5-TP (Silvex)	<1 for each well, except GALLO1 unavailable for sampling.				
2,4-D	<5 for each well, except GALLO1 unavailable for sampling.				
BHC, gamma isomer (Lindane)	<0.03 for each well, except GALLO1 unavailable for sampling.				
Endrin	<0.05 for each well, except GALLO1 unavailable for sampling.				
Methoxychlor	<0.2 for each well, except GALLO1 unavailable for sampling.				
Toxaphene	<1 for each well, except GALLO1 unavailable for sampling.				
Radioactivity (Bq/L)^d					
Gross alpha	0.43	0.00 -0.13 0.01 0.05	0.01 0.00 -0.02 0.02	-0.05 0.04 0.10 0.03	-0.03 -0.09
Gross beta	0.16	0.32 0.34 0.26 0.26	0.32 0.16 0.28 0.24	0.30 0.29 0.18 0.25	0.09
Tritium	1.30	0.10 0.58 0.17 0.10 0.03	0.41 0.70 0.73 0.51	0.19 0.08 0.18 0.12	0.22 0.02

...continued

6. Surveillance Water Monitoring

Table 6-8. Analyses of water from supply wells near Site 300, 1992 (*concluded*).

Parameter	Well ^a				
	VIE1	VIE2	MUL1	MUL2	W35A-04
Trichloroethene	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Trichlorofluoromethane	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Vinyl chloride	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2	1 n.d. <0.2
Explosive compounds (µg/L)					
HMX	<20 for each well.				
RDX	<30 for each well.				
TNT	<30 for each well.				
Pesticides and herbicides (µg/L) EPA Methods 608, 509B					
2,4,5-TP (Silvex)	<1 for each well.				
2,4-D	<5 for each well.				
BHC, gamma isomer (Lindane)	<0.03 for each well.				
Endrin	<0.05 for each well.				
Methoxychlor	<0.2 for each well.				
Toxaphene	<1 for each well.				
Radioactivity (Bq/L)^d					
Gross alpha	0.11	0.26	0.14	-0.01	0.07
Gross beta	0.29	0.06	0.15	0.15	0.19
Tritium	0.14	1.02	0.17	0.12	1.39

Notes: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

The abbreviation "n.d." stands for nondetection.

^a See Fig. 6-5 for sampling locations.

^b Inaccessible for sampling in third and fourth quarters.

^c Less sensitive EPA Methods 601 and 624 were run in addition to EPA Method 524.2 on duplicate samples from wells STN, CDF1, and CON1. All measurements were below detection limits except for carbon disulfide (0.65 ppb) in well CDF1 and chloroform (1.4 ppb) in well STN.

^d For very low counts, subtraction of background count may yield a negative number for gross alpha and gross beta (see U.S. Department of Energy 1991).

6. Surveillance Water Monitoring

Table 6-9. Quarterly analyses of water from surveillance monitoring wells, Site 300, 1992.

Parameter	Well ^a			
	NC2-11D	NC7-61	NC7-69	W-7A
Inorganic (mg/L)				
Beryllium	Three nondetections per well at <0.0005 and one per well at <0.0002.			
Chromium	Three nondetections per well at <0.005. 0.005			
Copper	Four nondetections per well at <0.05.			
Lead	Four nondetections per well at <0.002, except NC7-69 with three. 0.0071			
Organic, EPA Method 601 (µg/L)				
1,1,1-Trichloroethane	Four nondetections per well at <0.5 ppb.			
1,1,2,2-Tetrachloroethane	Four nondetections per well at <0.5 ppb.			
1,1,2-Trichloroethane	Four nondetections per well at <0.5 ppb.			
1,1-Dichloroethane	Four nondetections per well at <0.5 ppb.			
1,1-Dichloroethene	Four nondetections per well at <0.5 ppb.			
1,2-Dichlorobenzene	Four nondetections per well at <0.5 ppb.			
1,2-Dichloroethane	Four nondetections per well at <0.5 ppb.			
1,2-Dichloropropane	Four nondetections per well at <0.5 ppb.			
1,3-Dichlorobenzene	Four nondetections per well at <0.5 ppb.			
1,4-Dichlorobenzene	Four nondetections per well at <0.5 ppb.			
2-Chloroethylvinylether	Four nondetections per well at <0.5 ppb.			
Bromodichloromethane	Four nondetections per well at <0.5 ppb.			
Bromoform	Four nondetections per well at <0.5 ppb.			
Bromomethane	Four nondetections per well at <0.5 ppb.			
Carbon tetrachloride	Four nondetections per well at <0.5 ppb.			
Chlorobenzene	Four nondetections per well at <0.5 ppb.			
Chloroethane	Four nondetections per well at <0.5 ppb.			
Chloroform	Four nondetections per well at <0.5 ppb.			
Chloromethane	Four nondetections per well at <0.5 ppb.			
cis-1,2-Dichloroethene (total)	Four nondetections per well at <0.5 ppb, except W-74 with three.			2.4
cis-1,3-Dichloropropene	Four nondetections per well at <0.5 ppb.			
Dibromochloromethane	Four nondetections per well at <0.5 ppb.			
Dichlorodifluoromethane	Four nondetections per well at <0.5 ppb.			
Freon-113	Four nondetections per well at <0.5 ppb.			
Methylene chloride	Four nondetections per well at <0.5 ppb.			
Tetrachloroethene	Four nondetections per well at <0.5 ppb.			
trans-1,2-Dichloroethylene	Four nondetections per well at <0.5 ppb.			
trans-1,3-Dichloropropene	Four nondetections per well at <0.5 ppb.			
Trichloroethene	Four nondetections per well at <0.5 ppb.			
Trichlorofluoromethane	Four nondetections per well at <0.5 ppb.			
Vinyl chloride	Four nondetections per well at <0.5 ppb.			
Organic, EPA Method 602 (µg/L)				
1,2-Dichlorobenzene	Four nondetections per compound, well W-7A only.			
1,3-Dichlorobenzene	Four nondetections per compound, well W-7A only.			
1,4-Dichlorobenzene	Four nondetections per compound, well W-7A only.			

...continued

6. Surveillance Water Monitoring

Table 6-9. Quarterly analyses of water from surveillance monitoring wells, Site 300, 1992
(concluded).

Parameter	Well ^a			
	NC2-11D	NC7-61	NC7-69	W-7A
Organic, EPA Method 602 (µg/L)				
Benzene	Four nondetections per compound, well W-7A only.			
Chlorobenzene	Four nondetections per compound, well W-7A only.			
Ethylbenzene	Four nondetections per compound, well W-7A only.			
Toluene	Four nondetections per compound, well W-7A only.			
Total xylene isomers	Four nondetections per compound, well W-7A only.			
Radioactivity (Bq/L)				
Gross alpha	0.12 ± 0.13	0.10 ± 0.11	0.02 ± 0.08	0.00 ± 0.07
	0.05 ± 0.11	0.14 ± 0.13	0.0004 ± 0.10	0.00 ± 0.15
	0.20 ± 0.13	0.06 ± 0.13	-0.02 ± 0.08.	0.04 ± 0.19
	0.19 ± 0.13	0.09 ± 0.16	0.00 ± 0.08	0.00 ± 0.15
Gross beta	0.11 ± 0.07	0.16 ± 0.08	0.13 ± 0.08	0.19 ± 0.07
	0.15 ± 0.09	0.12 ± 0.07	0.09 ± 0.08	0.22 ± 0.07
	0.12 ± 0.07	0.19 ± 0.07	0.11 ± 0.07	0.22 ± 0.07
	0.20 ± 0.05	0.21 ± 0.08	0.18 ± 0.06	0.30 ± 0.11
Radium-226	0.002 ± 0.017			
Tritium	69.56 ± 4.17	9509.00 ± 48	0.05 ± 0.04	0.17 ± 0.06
	67.71 ± 1.63	9102.00 ± 36	0.06 ± 0.06	0.02 ± 0.02
		8917.00 ± 36	0.15 ± 0.05	0.10 ± 0.06
		8510.00 ± 306	0.13 ± 0.08	0.10 ± 0.10
Uranium-233, -234		0.11 ± 0.02	0.0004 ± 0.002	
		0.10 ± 0.01	0.002 ± 0.002	
		0.17 ± 0.01	0.08 ± 0.01	
		0.10 ± 0.01	0.01 ± 0.00	
Uranium-235		0.005 ± 0.003	0.0004 ± 0.0009	
		0.002 ± 0.002	-0.0004 ± 0.0009	
		0.003 ± 0.001	0.0003 ± 0.0009	
		0.00 ± 0.00	0.00 ± 0.00	
Uranium-238		0.07 ± 0.01	0.00 ± 0.0007	
		0.07 ± 0.01	0.001 ± 0.002	
		0.09 ± 0.01	0.0009 ± 0.0007	
		0.08 ± 0.01	0.00 ± 0.00	

Note: Results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 6-5 for sampling locations.

6. Surveillance Water Monitoring

Table 6-10. Analyses of water from supply wells, Site 300, 1992.

Parameter	Well ^a		
	Well 01	Well 18	Well 20
Inorganic chemicals (mg/L)			
Total alkalinity (as CaCO ₃)			230
			220
Bicarbonate alk (as CaCO ₃)			200
			220
Carbonate alk (as CaCO ₃)			30
			<1
Beryllium	<0.0005	<0.0005	<0.0005
	<0.0005	<0.0005	<0.0005
	<0.0002	<0.0002	<0.0002
	<0.0005	<0.0005	<0.0005
Calcium			6.2
			6.2
Chloride			78
			74
Chromium	<0.005	<0.005	<0.005
	<0.005	<0.005	<0.005
	<0.005	0.006	<0.005
	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	<0.005
	<0.05	<0.05	<0.05
	<0.05	<0.05	<0.05
	<0.05	<0.05	<0.05
		<0.05	<0.05
		0.011	<0.005
Iron			<0.1
			0.4
Lead	<0.002	<0.002	0.002
	0.002	0.0044	<0.002
	<0.002	0.003	<0.002
	0.003	<0.002	<0.002
Magnesium			<0.5
			<0.5
Manganese			<0.05
			<0.05
Nitrate plus nitrite (as NO ₃)			2.7
			<0.4
Potassium			8.1
			8
Sodium			220
			230
Sulfate			200
			190
Total dissolved solids (TDS)			720
			730

...continued

6. Surveillance Water Monitoring

Table 6-10. Analyses of water from supply wells, Site 300, 1992 (*continued*).

Parameter	Well ^a		
	Well 01	Well 18	Well 20
Zinc			<0.05
			<0.05
Specific conductance (µmhos/cm)			990
			1080
pH			8.4
			8.3
Organic chemicals EPA Method 524.2 (µg/L)			
1,1,1,2-Tetrachloroethane	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,1,1-Trichloroethane	0.6	6 n.d. <0.5	3 n.d. <0.3
	1 n.d. <0.3	6 n.d. <0.2	7 n.d. <0.2
1,1,2,2-Tetrachloroethane	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,1,2-Trichloroethane	1 n.d. <0.2	6 n.d. <0.5	3 n.d. <0.3
	1 n.d. <0.3	6 n.d. <0.2	7 n.d. <0.2
1,1-Dichloroethane	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,1-Dichloroethene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,1-Dichloropropene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2,3-Trichlorobenzene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2,3-Trichloropropane	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2,4-Trichlorobenzene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2,4-Trimethylbenzene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2-Dibromo-3-chloropropane	1 n.d. <2	6 n.d. <0.5	3 n.d. <0.5
	1 n.d. <0.5	6 n.d. <2.0	7 n.d. <2.0
1,2-Dibromoethane	2 n.d. <0.2	6 n.d. <0.2	10 n.d. <0.2
1,2-Dichlorobenzene	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2-Dichloroethane	2 n.d. <0.2	6 n.d. <0.5	10 n.d. <0.2
		6 n.d. <0.2	
1,2-Dichloroethene (total)	2 n.d. <0.2	6 n.d. <0.5	

...continued

6. Surveillance Water Monitoring

Table 6-10. Analyses of water from supply wells, Site 300, 1992 (*continued*).

Parameter	Well ^a		
	Well 01	Well 18	Well 20
1,2-Dichloropropane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
1,3,5-Trimethylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
1,3-Dichlorobenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
1,3-Dichloropropane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
1,4-Dichlorobenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
2,2-Dichloropropane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
2-Chlorotoluene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
4-Chlorotoluene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Benzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Bromobenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Bromochloromethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Bromodichloromethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	11 n.d. <0.2
Bromoform	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	11 n.d. <0.2
Bromomethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Carbon tetrachloride	1 n.d. <0.2 1 n.d. <0.3	6 n.d. <0.5 6 n.d. <0.2	3 n.d. <0.3 7 n.d. <0.2
Chlorobenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Chloroethane	1 n.d. <0.2 1 n.d. <0.3	6 n.d. <0.5 6 n.d. <0.2	3 n.d. <0.3 7 n.d. <0.2
Chloroform	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	11 n.d. <0.2

...continued

6. Surveillance Water Monitoring

Table 6-10. Analyses of water from supply wells, Site 300, 1992 (*continued*).

Parameter	Well ^a		
	Well 01	Well 18	Well 20
	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
cis-1,2-Dichloroethene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
cis-1,3-Dichloropropene	1 n.d. <0.2 1 n.d. <0.5	6 n.d. <0.5 6 n.d. <0.2	3 n.d. <0.5 7 n.d. <0.2
Dibromochloromethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	11 n.d. <0.2
Dibromomethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Dichlorodifluoromethane	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	3 n.d. <0.2
Ethylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Ethylene Dibromide	2 n.d. <0.2	6 n.d. <0.5	
Hexachlorobutadiene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Isopropylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
m- and p-Xylene Isomers	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Methylene chloride	1 n.d. <0.2 1 n.d. <1.0	6 n.d. <0.5 6 n.d. <1.0	3 n.d. <0.2 7 n.d. <1.0
n-Butylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
n-Propylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Naphthalene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
o-Xylene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
p-Isopropyl toluene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
sec-Butylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Styrene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
tert-Butylbenzene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Tetrachloroethene	2 n.d. <0.2	6 n.d. <0.5 6 n.d. <0.2	10 n.d. <0.2
Toluene	2 n.d. <0.2	2 6 n.d. <0.5 5 n.d. <0.2	10 n.d. <0.2
Total trihalomethanes	2 n.d. <0.2		0
Total xylene isomers	2 n.d. <0.2	1 n.d. <0.5	
trans-1,2-Dichloroethylene	2 n.d. <0.2	6 n.d. <0.5 5 n.d. <0.2	10 n.d. <0.2

...continued

6. Surveillance Water Monitoring

Table 6-10. Analyses of water from supply wells, Site 300, 1992 (*continued*).

Parameter	Well ^a		
	Well 01	Well 18	Well 20
trans-1,3-Dichloropropene	2 n.d. <0.2	6 n.d. <0.5 5 n.d. <0.2	10 n.d. <0.2
Trichloroethene	2 n.d. <0.2	0.9 0.8 1 0.9 1.1 0.8 0.7 1.1 1 0.5	10 n.d. <0.2
Trichlorofluoromethane	1 n.d. <0.2 1 n.d. <1.0	2 n.d. <0.2 6 n.d. <0.5 6 n.d. <0.2	3 n.d. <1.0 7 n.d. <0.2
Vinyl chloride	2 n.d. <0.2	6 n.d. <0.5 5 n.d. <0.2	10 n.d. <0.2
EPA Method 601 (µg/L)			
1,1,1-Trichloroethane	2 n.d. <0.5		1 n.d. <0.5
1,1,2,2-Tetrachloroethane	2 n.d. <0.5		1 n.d. <0.5
1,1,2-Trichloroethane	2 n.d. <0.5		1 n.d. <0.5
1,1-Dichloroethane	2 n.d. <0.5		1 n.d. <0.5
1,1-Dichloroethene	2 n.d. <0.5		1 n.d. <0.5
1,2-Dichlorobenzene	2 n.d. <0.5		1 n.d. <0.5
1,2-Dichloroethane	2 n.d. <0.5		1 n.d. <0.5
1,2-Dichloroethene (total)	2 n.d. <0.5		1 n.d. <0.5
1,2-Dichloropropane	2 n.d. <0.5		1 n.d. <0.5
1,3-Dichlorobenzene	2 n.d. <0.5		1 n.d. <0.5
1,4-Dichlorobenzene	2 n.d. <0.5		1 n.d. <0.5
2-Chloroethylvinylether	2 n.d. <0.5		1 n.d. <0.5
Bromodichloromethane	2 n.d. <0.5		1 n.d. <0.5
Bromoform	2 n.d. <0.5		1 n.d. <0.5
Bromomethane	2 n.d. <0.5		1 n.d. <0.5
Carbon tetrachloride	2 n.d. <0.5		1 n.d. <0.5
Chlorobenzene	2 n.d. <0.5		1 n.d. <0.5
Chloroethane	2 n.d. <0.5		1 n.d. <0.5
Chloroform	2 n.d. <0.5		1 n.d. <0.5
Chloromethane	2 n.d. <0.5		1 n.d. <0.5
cis-1,2-Dichloroethene	2 n.d. <0.5		1 n.d. <0.5
cis-1,3-Dichloropropene	2 n.d. <0.5		1 n.d. <0.5
Dibromochloromethane	2 n.d. <0.5		1 n.d. <0.5
Dichlorodifluoromethane	2 n.d. <0.5		1 n.d. <0.5
Freon-113	2 n.d. <0.5		1 n.d. <0.5
Methylene chloride	2 n.d. <0.5		1 n.d. <0.5

...continued

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Table 6-10. Analyses of water from supply wells, Site 300, 1992 (*concluded*).

Parameter	Well ^a		
	Well 01	Well 18	Well 20
Tetrachloroethene	2 n.d. <0.5		1 n.d. <0.5
trans-1,2-Dichloroethene	2 n.d. <0.5		1 n.d. <0.5
trans-1,3-Dichloropropene	2 n.d. <0.5		1 n.d. <0.5
Trichloroethene	2 n.d. <0.5		1 n.d. <0.5
Trichlorofluoromethane	2 n.d. <0.5		1 n.d. <0.5
Vinyl chloride	2 n.d. <0.5		1 n.d. <0.5
EPA Method 602 (µg/L)			
1,2-Dichlorobenzene			1 n.d. <0.5
1,3-Dichlorobenzene			1 n.d. <0.5
1,4-Dichlorobenzene			1 n.d. <0.5
Benzene			1 n.d. <0.5
Chlorobenzene			1 n.d. <0.5
Ethylbenzene			1 n.d. <0.5
Toluene			1 n.d. <0.5
Total xylene isomers			1 n.d. <0.5
Bacteria and trihalomethanes (µg/L)			
Bromodichloromethane			1 n.d. <0.5
Bromoform			1 n.d. <0.5
Chloroform			1 n.d. <0.5
Dibromochloromethane			1 n.d. <0.5
Total coliform (MPN/100mL)			1 n.d. <2.2
Total trihalomethanes			0
Plate count (CFU/mL)			73
Radioactivity (Bq/L)			
Gross alpha	0.03 ± 0.09	0.03 ± 0.10	-0.04 ± 0.08
	0.08 ± 0.10	0.00 ± 0.15	-0.03 ± 0.09
	0.06 ± 0.09	0.00 ± 0.26	-0.06 ± 0.10
	0.12 ± 0.10	0.04 ± 0.19	-0.05 ± 0.12
Gross beta	0.12 ± 0.06	0.22 ± 0.07	0.21 ± 0.07
	0.11 ± 0.08	0.15 ± 0.08	0.22 ± 0.09
	0.11 ± 0.07	0.00 ± 0.26	0.29 ± 0.09
	0.16 ± 0.05	0.26 ± 0.07	0.20 ± 0.05
Tritium	200 ± 11	0.14 ± 0.04	0.15 ± 0.12
	231 ± 13	0.13 ± 0.11	0.10 ± 0.03
	195 ± 10	0.12 ± 0.12	0.09 ± 0.03
	235 ± 13	0.66 ± 0.66	0.13 ± 0.12
			0.07 ± 0.07

Notes: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

The abbreviation "n.d." stands for nondetection.

^a See Fig. 6-5 for sampling locations.

Table 6-11. Central Drainage Basin management results (in mg/L), 1992.

Analyte	May 4	Jul. 31	Nov. 16	Dec. 18	Objective	Action level
Ammonia nitrogen (N)	0.03	0.05	0.17	0.086	<0.025	>0.1
Boron	— ^a	<0.2	— ^a	— ^a	<0.5	>0.7
Chemical oxygen demand	<10	25	28	20	<20	>20 ^b
Chlorophyll a	— ^a	0.0024	0.0028	0.0017	<10	>10
Fecal coliform (MPN/100mL)	— ^a	130	— ^a	50	<200	>400
Nitrate plus nitrite (N)	<0.1	<0.1	1.5	1.9	<0.2	>0.2
Oil and grease	— ^a	5	— ^a	<5.	<15	>15
Total alkalinity (CaCO ₃)	40	80	160	130	>75	<50
Total coliform (MPN/100mL)	— ^a	500	— ^a	700	<2000	>5000
Total dissolved solids	97	110	240	200	<400	>350
Total phosphorus (as PO ₄)	0.23	0.17	0.06	— ^a	<0.02	>0.02
Total VOCs (μg/L)	— ^c	— ^c	— ^c	— ^c	<5	>5

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a Sample not tested for this constituent.

^b Action level for BOD.

^c All analytes were found below the detection limits listed for EPA Method 601 in 40 CFR Part 136.

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Table 6-12. Central Drainage Basin discharge results (in µg/L), 1992.

Analyte	Dec. 9	Dec. 16	Dec. 30	Discharge limit ^a
1,2-Dibromo-3-chloropropane	<0.5	<0.5	<0.5	0.02
1,2-Dibromoethane	<0.2	<0.2	<0.2	0.02
Antimony (mg/L)	<0.2	<0.2	<0.2	1.46
Aquatic bioassay, survival (%)	90			90% survival
Arsenic (mg/L)	0.0027	<0.002	<0.002	0.02
Benzene	<0.2	<0.2	<0.2	0.70
Beryllium (mg/L)	<0.0002	<0.0002	<0.0002	0.0007
Boron (mg/L)	0.35	0.38	0.24	7.00
Cadmium (mg/L)	<0.0005	<0.0005	<0.0005	0.005
Chromium (mg/L)	0.006	<0.005	<0.005	0.05
Copper (mg/L)	<0.05	<0.05	<0.05	0.02
Iron (mg/L)	<0.1	<0.1	0.65	3.00
Lead (mg/L)	<0.002	<0.002	<0.002	0.0056
Manganese	<0.05	<0.05	<0.05	0.50
Mercury (mg/L)	<0.0002	<0.0002	<0.0002	0.001
Nickel (mg/L)	0.0072	<0.005	<0.005	0.0071
pH	8.4	8.1	8	>6.5 and <8.5
Selenium (mg/L)	<0.002	<0.002	<0.002	0.10
Silver (mg/L)	<0.0005	<0.0005	<0.0005	0.0023
Tetrachloroethene	<0.2	<0.2	<0.2	4
Thallium	<0.3	<0.4	<0.4	0.13
Vinyl chloride	<0.2	<0.2	<0.2	2
Zinc (mg/L)	<0.05	<0.05	<0.05	0.058
Total VOCs	— ^b	— ^b	— ^b	5
Total petroleum hydrocarbons	— ^c	— ^c	— ^c	50
PAHs	— ^d	— ^d	— ^d	15
Base/neutral acid and pesticides	— ^e	— ^e	— ^e	5

Note: Results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a Discharge limits established in NPDES permit CA0029829.

^b All analytes were found below the detection limits listed for EPA Method 601 in 40 CFR Part 136.

^c All analytes were found below the detection limits listed for EPA Method 8015 in EPA SW 846.

^d All analytes were found below the detection limits listed for EPA Method 610 in 40 CFR Part 136.

^e All analytes were found below the detection limits listed for EPA Method 625 in 40 CFR Part 136.

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Introduction

Ground water protection activities at LLNL are performed as part of the investigation, study, monitoring, and remediation of contamination caused by past practices and as a safeguard against new contamination. The existing ground water monitoring network at the Livermore site was installed to assess ground water quality and investigate contamination in response to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

In addition to these ground water remediation activities, DOE Order 5400.1 establishes requirements for environmental protection programs at DOE operations to assure compliance with local, state, and federal laws and regulations. Section 9, Chapter IV, of the DOE Order addresses environmental monitoring programs and sets forth requirements for a ground water protection plan that builds upon monitoring programs implemented for compliance with the Resource Conservation and Recovery Act of 1976 (RCRA). Development of the monitoring portion of this protection plan for the Livermore site continued during 1992.

LLNL conducts ground water monitoring at Site 300 under two programs. One program is designed to meet regulatory commitments established for specific site investigations under CERCLA, such as the investigation of trichloroethene (TCE), tritium, and high-explosives (HE) compounds in ground water at Site 300. Details of this program are described in the *LLNL Site 300 Environmental Investigations Quarterly Reports* (Carlsen 1991a, b) and in the *Draft Remedial Investigation of the Building 833 Area, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten et al. 1991), *Investigation of Holocene Faulting Near Decommissioned Landfill Pit 6, Lawrence Livermore National Laboratory Site 300* (Carpenter et al. 1991), and *Draft Feasibility Study for Landfill Pit 6, Lawrence Livermore National Laboratory Site 300* (Taffet et al. 1991); the program is summarized in this chapter.

The second program consists of compliance ground water monitoring at landfill and wastewater surface impoundment units, as required by the California Regional Water Quality Control Board (RWQCB), Central Valley

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Region; California Department of Toxic Substances Control (DTSC); and the U.S. Environmental Protection Agency (EPA). Details of this program are described in the LLNL Site 300 Ground Water Monitoring Program quarterly reports (Fischer et al. 1992a-d).

Livermore Site

Ground Water Remediation

In the 1940s, before it became a research laboratory, the U.S. Navy used the Livermore site as a flight training base and aircraft rework facility. An asphalt-paved landing mat was located near the center of the site, with peripheral taxiways and a concrete parking apron. The Navy used some unpaved areas within the landing mat for aircraft maintenance and for storage and disposal of fuels, solvents, and other related materials. After the Livermore Naval Air Station was closed in the late 1940s, short-term users of the site included the California Research and Development Corporation and Pratt and Whitney.

During the operation of the naval station, volatile organic compounds (VOCs) were used routinely in aircraft and engine assembly, repair, and overhaul operations, and in paint stripping. Much of this activity was performed in the southeast portion of the site and in the unpaved areas adjacent to the landing mat. In 1954, LLNL (known then as the University of California Radiation Laboratory) stored organic solvents and stored and treated hazardous waste on a portion of the East Taxi Strip. From 1956 to the present, LLNL has engaged in research and other activities that involve the storage, use, and disposal of VOCs, fuel hydrocarbons, and other hazardous materials. Since the late 1970s, LLNL has taken many steps to eliminate discharges of hazardous materials to the environment.

LLNL began a ground water investigation in December 1983, after detecting tetrachloroethene (PCE) and TCE in on-site monitoring wells and in several nearby off-site domestic and agricultural wells. During preliminary ground water investigations from 1980 to 1983 made under the requirements of the RWQCB, LLNL completed, logged, sampled, and hydraulically tested over a dozen monitoring wells. (By 1992 over 300 monitoring wells had been installed.) Data from this sampling have been interpreted in conjunction with results of record searches to determine the extent and possible sources of ground water contamination. The sources of much of the VOCs in the ground water are believed to be related directly to the solvent use and disposal practices employed by the U.S. Navy during its occupation of the site. There is also evidence that localized spills, leaking tanks, and impoundments contributed VOCs, fuel hydrocarbons (FHCs), chromium, and tritium to ground water and unsaturated sediments in the post-Navy era (Ziagos 1992).

Since being placed on the National Priorities List, LLNL has structured its Ground Water Project to conform with specific EPA CERCLA guidance and the negotiated Federal Facility Agreement (U.S. Department of Energy 1988). The environmental restoration effort encompasses numerous activities to be performed over several years to investigate, evaluate, and eventually remediate potentially hazardous compounds that may have affected soil, sediment, and ground water quality. The Ground Water Project also encompasses air and surface water as these environmental media relate to the investigation and remediation efforts. Because the impact of past releases to the air and surface water have been relatively minor, most of the emphasis is placed on investigating the soil, sediment, and ground water.

The remedial activities include investigation of the hydrogeology of the site, including known and suspected sources of contamination; installation of piezometers and monitoring and extraction wells; soil, sediment, and ground water sampling; evaluation and closure of potential conduit wells; aquifer testing; and development of computer models and a conceptual site model to aid ground water studies and to design remediation strategies. In addition, LLNL continues to search historical records to identify potential sources of contamination; assess potential risks to public health resulting from the identified contaminants in soil, sediment, and ground water; provide project information to the public and coordinate community involvement in the remedial process; evaluate numerous studies designed to aid site remediation; prepare reports documenting the investigation, evaluation, and remediation; and implement the appropriate technologies to accomplish environmentally responsive cleanup of the site.

Several documents related to the environmental restoration effort have been submitted to the regulatory agencies. The Work Plan (Webster-Scholten and Hall 1988) outlines the above activities and other related tasks associated with the formal Remedial Investigation (RI; Thorpe et al. 1990) and Feasibility Study (FS; Isherwood et al. 1991) reports, and resultant remedial action. The RI report provides significant detail regarding the environmental investigation of potential sources of contamination. A Community Relations Plan (CRP; Anderson and Post 1988) was submitted and, as provided in this plan, personnel in the LLNL Livermore-site Ground Water Project hold community meetings, publish an informational pamphlet, and have formed a Community Work Group to keep the public informed and provide a pathway for public input to the remedial action process. The Quality Assurance Project Plan (QAPP; Rice 1988) outlines methods and processes to ensure that the project data are precise, accurate, complete, representative, and can be compared, and that project data are maintained at an acceptable level.

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The FS report presents alternatives for remediating contaminants present in ground water and unsaturated sediments on the Livermore site, and the Proposed Remedial Action Plan (PRAP; Dresen et al. 1991) selects the alternatives that best meet all appropriate requirements. The PRAP was presented for public comment in the last quarter of 1991, and the Record of Decision and Responsiveness Summary (Ziagos 1992), which documents LLNL's responses to public comments regarding the PRAP, has been submitted to the regulatory agencies and DOE.

During 1992, LLNL completed numerous environmental restoration tasks at the Livermore site; the most important efforts include:

- LLNL investigated potential sources of ground water contamination in the East Taxi Strip-Trailer 5475 area, Building 292 area, northeast boundary area, and MW-501 area.
- The Infiltration Experiment Site in the northwest part of the site and the Gasoline Spill Area in the southern part of the site were investigated as part of the Vadose Zone Investigation Program. This program was initiated to better understand potential impacts to ground water by contaminants in the unsaturated zone.
- At the Gasoline Spill Area, steam injection wells, electrical heating wells, and associated monitoring wells were installed for the Dynamic Underground Stripping Demonstration Project (DUSDP), which uses steam and electrical heating to remove free-phase fuel hydrocarbons. The DUSDP began in November 1992 and will continue into 1993.
- Treatment Facilities A and B (TFA, TFB) continued operation during 1992 to remove VOCs from extracted ground water.

CERCLA documents submitted to the regulatory agencies include:

- Record of Decision (Ziagos 1992), issued on August 5, 1992,
- Remedial Design Report 1 (Boegel et al. 1993), issued on October 9, 1992, and
- Draft Remedial Action Implementation Plan (Dresen et al. 1992), issued on November 6, 1992.

In addition, work began on a Community Relations Plan (Anderson and Post 1988); DOE/LLNL met four times with the Community Work Group and produced and distributed issues of the Ground Water Update, an informational bulletin for interested parties.

Other accomplishments include (1) further development of the computer code NUFT to simulate the vadose zone contaminant transport; (2) measuring physical, chemical, and hydraulic properties on vadose zone sediment samples;

- (3) conducting five constant discharge pumping tests in extraction wells and piezometers in the Gasoline Spill Area and in the vicinity of TFA and TFB; and
- (4) drilling, sampling, and conducting hydraulic tests on monitoring wells.

As part of the RI, LLNL continues to drill additional wells, sample ground water, sediment, and soil, and perform hydraulic tests. These activities enable LLNL to refine its understanding of the hydrogeologic system, determine how and when contaminants are transported, and determine the extent of VOCs present. To facilitate the preparation of the FS, LLNL executed pilot studies for extraction and treatment of ground water in the off-site area, as well as ground water and soil vapor in the Gasoline Spill Area (**Figure 7-1**). Using the acquired data, LLNL is developing both analytic and numeric models to assist in the design of optimal remediation strategies and to satisfy other CERCLA requirements.

Following is a more detailed discussion, updated based on 1992 investigations, on the presence of contaminants in unsaturated sediment and ground water at the Livermore site.

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VOCs in Unsaturated Sediment. Present data indicate that total VOC concentrations exceeding one part per million (ppm) in unsaturated sediment, high enough to possibly contaminate ground water, occur in five areas: the east traffic circle, the vicinity of Building 518, Eastgate Drive, the vicinity of Building 514, and the East Taxi Strip in the southeastern portion of LLNL (Isherwood et al. 1991). Sediment samples from other potential source areas contained total VOC concentrations ranging from less than 5 parts per billion (ppb) to less than 500 ppb, with most containing less than 100 ppb, below levels that might contaminate ground water.

VOCs in Ground Water. Eight chlorinated solvents—PCE, TCE, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethane (1,1-DCA), carbon tetrachloride, and chloroform—have been detected in ground water in the Livermore-site area in concentrations exceeding federal or State Action Levels or maximum contaminant levels (MCLs). TCE is the most abundant VOC and occurs primarily in the eastern portion of Livermore site in concentrations exceeding 1 ppm near the historic sources. PCE occurs mainly in the southwest part of Livermore site and in the adjacent off-site area to the west. PCE also is present in the eastern portion of Livermore site, at concentrations lower than that of TCE. Although generally at levels below their respective MCLs, the presence of Freon-11, Freon-113, and 1,1,1-trichloroethane (1,1,1-TCA) is being considered in the design of the treatment system for the areas in which those contaminants occur.

Fuel Hydrocarbons (FHCs). Significant concentrations of FHCs occur only in the Gasoline Spill Area (Figure 7-1), where about 64,000 liters of leaded gasoline leaked prior to 1979 and have contaminated both the unsaturated sediments and ground water.

Radiological Parameters. Tritium is the only radiological substance present in ground water in concentrations that exceed an MCL. In the southeast part of the Livermore site, MW-206 (Figure 7-2) currently contains tritium above the MCL of 740 Bq/L (20,000 pCi/L). At the time of the RI (Thorpe et al. 1990), 11 other LLNL monitoring wells reportedly contained tritium activities above 37 Bq/L (1,000 pCi/L). The most recent sampling data indicate that 10 of these original 11 wells still have tritium activities greater than 37 Bq/L (1,000 pCi/L). By using analytical methods having lower detection limits in subsequent investigations, tritium was detected at activities from 7 to 560 Bq/L (200 to 15,100 pCi/L) in 32 other monitoring wells (Macdonald et al. 1993).

Ground Water Protection

Ground water protection monitoring at and near the Livermore site is required by DOE Order 5400.1, which establishes environmental protection

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program requirements to assure that DOE operations comply with local, state, and federal environmental protection laws and regulations; federal Executive Orders; and internal DOE policies. Section 9, Chapter IV, of DOE Order 5400.1 also addresses requirements for a Ground Water Protection plan, which must be a part of the Environmental Protection Implementation Plan. The Ground Water Protection Plan augments existing monitoring programs implemented to comply with RCRA (40 CFR 264 and 265) and other programs developed to monitor pollutant sources. The DOE Order also states that documentation for compliance with the Safe Drinking Water Act, RCRA, and CERCLA may be used in whole or in part to satisfy this requirement.

The goal of the Ground Water Protection Plan is to provide LLNL the opportunity to detect and mitigate, before ground water has been impacted, any releases or spills that occur as a result of current operations. For this reason, and because ground water travels at such a slow rate at the Livermore site, ground water monitoring is not the most appropriate mechanism for detecting the potential of LLNL operations to affect it. The protection of ground water at the Livermore site relies most heavily on monitoring other environmental media. The timely detection of potential contaminants from current operations requires that sediment, soil, and storm water runoff be monitored for indications of a release or spill.

The Ground Water Protection Plan is under development for the Livermore site. Developing this plan is a four-step process: (1) identify geologic areas susceptible to ground water contamination, (2) identify existing sources of contaminants, (3) assess existing monitoring programs, and (4) develop and implement any new monitoring that is needed.

In addition to our existing efforts in soil and storm water monitoring, the major effort in strengthening the Ground Water Protection Plan during 1992 involved identifying and controlling sources of contaminants. The potential sources of contaminants to the ground water beneath LLNL include underground storage tanks (both for wastewater retention and hazardous product storage); the sanitary sewer system; discharges of wastewater to storm sewers or ground; hazardous, radioactive, and other waste and chemicals temporarily stored in buildings on site. During 1992, four existing and new programs produced results that are being incorporated into the overall Ground Water Protection Plan.

Underground Storage Tanks. To comply with local, state and federal tank and clean water regulations and ordinances, LLNL implements a tank testing and permitting process; provides guidance for the proper construction and operation of tank systems; and oversees and implements closure of old or out-of-use tank systems. LLNL is presently implementing the Tank Upgrade Project to bring all LLNL tank systems into compliance with current environmental regulations

promulgated to prevent the accidental release of hazardous substances to the environment.

The primary objective of the Tank Upgrade Project is to remove, modify, reclassify, or replace all hazardous waste and product tanks to meet all current state and federal regulations. The present scope of work includes 214 tank systems—roughly 100 for upgrading, including replacement (22 aboveground and 28 below-ground waste retention tank systems, and 13 aboveground and 37 below-ground petroleum product tank systems), and 24 for closure only. In addition, there are approximately 90 tanks and/or transformers designated as requiring corrective actions to meet Spill Prevention Control and Countermeasures (SPCC) regulations.

Spill Prevention Control and Countermeasures Plans. These plans were distributed to LLNL operators, supervisors, and managers having responsibility for oil-containing tanks, containers, and equipment. The SPCC Plans provide guidance and procedures to prevent and mitigate spills of oil to navigable waters from equipment and tanks. An SPCC training plan was developed during the 1992 calendar year and classes were given to recipients of the SPCC Plans in February and March of 1993.

Building Drain Investigation/Sanitary Sewer Rehabilitation. Two key efforts to directly reduce potential contamination of ground water during 1992 were the Sanitary Sewer Rehabilitation Project and the Building Drain Line Investigation. The Sanitary Sewer Rehabilitation Project is a 3-year effort to rehabilitate the aged and somewhat deteriorated sanitary sewer system and correct past construction deficiencies. Staff used closed-circuit television to identify and locate problems. Directly replacing old pipe or installing sewer pipe inversion linings eliminates any significant potential for infiltration of storm water or exfiltration of wastewater.

On the basis of current environmental regulations, LLNL must certify that a building's wastewater discharge lines are properly connected to the appropriate retention tank system, sewer, or storm lines. The Building Drain Line Investigation documented all building and trailer drain lines at both the Livermore site and Site 300. Each building drain line was dye-tested or otherwise verified to confirm the discharge destination. The investigation resulted in the identification of required repair actions to bring the sanitary and storm sewer systems into compliance with regulatory requirements.

Storm Water Pollution Prevention Plans. LLNL initiated a major effort during 1992 to control potential contamination of ground water from pollutants in storm water runoff. This effort complied with the California RWQCB General Storm Water Permit for Industrial Discharges and for Construction activities. The Industrial Discharges Permit prohibits discharges of unpermitted nonstorm water to the storm drainage system. As part of this effort, LLNL inventoried and

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described all potential sources of pollutants to storm water, as well as existing storm water management practices, including pollution prevention personnel, preventive maintenance, good housekeeping practices, spill prevention and response, sediment and erosion prevention, employee training, and inspection practices. The Construction Permit seeks to reduce, through "best management practices," the discharge of sediment in storm water from construction sites, and eliminate, to the extent feasible, any discharges that are not uncontaminated storm water. These efforts are described in storm water pollution prevention plans (SWPPPs). During 1992, SWPPPs were prepared for three construction projects, a building (B132) at the Livermore site, a road improvement project at Site 300, and the closure of two hazardous waste disposal pits, also at Site 300.

This ongoing effort is a major step in establishing a Ground Water Protection Plan because it eliminates all nonpermitted discharges, identifies potential sources of storm water pollutants, and documents LLNL storm water pollution prevention practices. Infiltration from the storm sewer system provides the most probable pathway to ground water.

Further efforts to strengthen LLNL's Ground Water Protection Plan will continue in 1993.

Site 300

Ground Water Remediation

Ground water at Site 300 moves via pores and fractures. The regional ground water table lies within sandstone and conglomerate beds, and ground water generally follows the dip of the bedrock under the influence of head differences. Three known perched ground water bodies exist locally beneath the site. Site 300 drinking and process water is supplied by a separate deep confined aquifer.

Areas of investigation at Site 300 include the HE Process Area, the General Services Area, the East and West Firing Areas, the Building 834 Complex, and the Pit 6 Area (**Figure 7-3**). Early activities associated with the investigation and remediation of these areas included researching the site hydrogeology; installing monitoring wells, extraction wells, and piezometers; testing aquifers; surveying soil vapor to identify areas that could be sources of contamination; sampling saturated and unsaturated sediment from boreholes and wells; developing closure and post-closure plans for solid-waste landfills and the HE Burn Pit facility; identifying and investigating former water supply wells; evaluating, sealing, and abandoning specific inactive water supply wells; investigating and closing underground tanks that may have leaked; sampling ground and surface waters; developing computer models and a conceptual site hydrogeologic model to aid ground water studies; evaluating how contaminants are transported and what eventually happens to them; continuing to search historical records to

identify potential sources of contamination; and submitting reports to regulatory agencies to document these activities.

More recent activities performed for this project include (1) preparing a *Draft Site-Wide Remedial Investigation Report (SWRI)* (Webster-Scholten 1993) which compiles all ground water and soil investigation information for the entire site; (2) assessing potential public health risks and ecological risks resulting from contamination of soil, sediment, and ground water; (3) involving the public in the ground water remediation process and supplying public information materials; (4) capping two landfills; and (5) performing extraction and cleanup of contaminated ground water.

Ground water investigations began in 1981 under the regulatory authority of the Central Valley RWQCB. In August 1990, Site 300 was placed on EPA's

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National Priorities List under CERCLA. In June 1992, the DOE and LLNL negotiated a Federal Facility Agreement, pursuant to CERCLA, which describes the ground water and soil investigations to be conducted and specifies their due dates.

The compounds addressed in the investigations at Site 300 include primarily TCE, tritium, and two HE compounds [cyclotetra-methyltetramine (HMX) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)]. To date, no other major environmental contaminants have been identified for these areas.

During 1992, a number of environmental restoration tasks were accomplished at Site 300. These tasks, some of which have been under way for several years, include:

- Closure of landfill Pits 1 and 7 with approval by the EPA, RWQCB, and DTSC.
- Conducting ground water "pump and treat" operations at the central and eastern General Services Area as CERCLA removal actions.
- Preparing the SWRI (Webster-Scholten 1993).

The following sections, updated based on 1992 activities, summarize the investigation activities at Site 300 since the early 1980s. Summary results are presented in the accompanying figures detailing the isoconcentrations of the contaminant for each investigation.

TCE Investigation. In 1982, LLNL began initial assessment of the environmental effects of TCE released in several areas of the site. By 1987, ten locations within the site were found to have TCE present in soil, sediment, and ground water. TCE investigations have continued, emphasizing the southeast part of the site (**Figure 7-3**), the Building 834 Complex, the HE Process Area, the General Services Area, and the Pit 6 Area. Recent monitoring has also revealed trace amounts of TCE in ground water near the Pit 7 Complex (in the West Firing Area) and at Pit 8 (in the East Firing Area). RI reports have been written for each area (Taffet et al. 1989b, Taffet et al. 1992). Feasibility studies have been written or begun for each area.

HE Compounds Investigation. Discharges of rinse water from buildings within the HE Process Area historically have been disposed of in unlined lagoons adjacent to the processing buildings. Use of these lagoons was terminated in 1985; the lagoons were closed and capped with impermeable clay in 1989. Sporadic, but generally low, concentrations of HE compounds, metals, and VOCs were identified in the vadose zone beneath some of the lagoons, but these contaminants have not dispersed to the underlying ground water (Webster-Scholten 1993). During field investigations of ground water, low concentrations of TCE and HE compounds were discovered in two perched water-bearing zones within

the HE Process Area. The full extent of the contamination has been determined, and remedial alternatives are being studied.

Tritium Investigation. Debris from HE tests historically has been disposed of in landfills at the northern portion of Site 300. In 1981, the Hazardous Waste Assessment study of the hydrology, geology, and ground water chemistry associated with Site 300 landfills was initiated. As part of this project, monitoring wells were installed at the landfills, and a program of periodic ground water monitoring was initiated. In 1984, tritium activities in water from four of the wells rose above the California MCL for drinking water. A tritium investigation was initiated, and two areas that have tritium in ground water have been delineated: (1) the Pit 7 Complex and (2) Building 850, Doall Road, and Elk Ravine in the West and East Firing areas.

Landfill Closures. Until November 8, 1988, LLNL operated two Class II solid-waste landfills (Pits 1 and 7) at Site 300, which received firing-table debris from explosives testing. The landfills are subject to RCRA regulation and were operated under RCRA interim status. In March 1988, partly because the landfills were nearly full, LLNL decided not to pursue its RCRA Part B permit application for land disposal. Disposal of wastes at Pits 1 and 7 was discontinued in November 1988. LLNL submitted a closure and post-closure plan for the landfills to the regulatory agencies, which was approved early in 1991. LLNL completed most of the capping and closure efforts at these pits in 1992. Closure is expected in 1993.

Ground Water Protection Monitoring

Monitoring of Pit 1, Pit 6, Pit 7, and the B-817 HE Process Area surface impoundments is reported quarterly as set forth in the Department of Health Services (DHS) Interim Status Document (ISD) CA 2890090002 (California DHS 1981), which currently is administered by the California EPA's Department of Toxic Substances Control (DTSC); and Waste Discharge Requirements (WDR) Order Nos. 80-184 (1980) and 85-188 (1985), administered by the Central Valley RWQCB. Wells in the Pit 2 and Pit 8 areas are also monitored for a variety of metals, minerals, organic compounds, and radionuclides.

The compliance sampling program encompasses 38 wells that monitor the ground water beneath the inactive landfills. The wells are located in four geographic areas of Site 300:

- Portions of the East Firing Area (17 wells and 6 Barcad samplers). Included in the area are the Building 801 and 802 firing tables and inactive landfill Pits 1, 2, 8, and 9.
- Portions of the West Firing Area (10 wells). This area includes the Building 850 and 851 firing tables and the Pit 7 Complex.

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- Another inactive landfill Pit 6 (six wells), located south along the Site 300 boundary bordering Corral Hollow Road.
- The Building 817 HE Process Area, which has a network of four wells and one piezometer to monitor the HE wastewater surface impoundments.

Detection limits and analytical parameters for the ground water compliance monitoring wells (see **Figure 6-1** in Chapter 6 on Surveillance Water Monitoring for monitoring locations) are presented in **Tables 7-1** and **7-2**.

On April 15, 1992, in accordance with California Code of Regulations (CCR) Title 23 requirements for a revised monitoring plan, LLNL submitted a Draft Report of Waste Discharge (ROWD) covering Pit 1, Pit 7, and the B817 HE Process Area surface impoundments (Hoppe et al. 1992). However, ground water monitoring performed in 1992 was not substantially changed from 1991, pending implementation and approval of new Waste Discharge Requirements issued by the State Water Resources Control Board (SWRCB).

As requested by the Central Valley RWQCB, the ROWD was submitted as a draft to allow for preliminary review and comments. The final report for Pits 1 and 7 was to be submitted upon signing the Federal Facility Agreement (effective as of June 29, 1992). The final report for the HE Process Area surface impoundments was to be submitted by June 30, 1992. LLNL did not receive a request for preliminary changes and, therefore, the draft ROWD was submitted as LLNL's proposed revision to the existing compliance ground water plan for those areas (draft updated to final status on July 5, 1992). These changes will be implemented upon approval by the Central Valley RWQCB and modification of existing WDR Order Nos. 80-184 and 85-188.

During the 1992 third quarter monitoring period, closure activities at Site 300 included capping of landfill Pits 1 and 7. Pit 1 upgradient wells K1-01C and K1-07, along with the newly added Pit 7 downgradient well NC7-48, were inaccessible during the capping of these landfills for about a month, preventing collecting three samples from the Pit 1 wells and four samples from well NC7-48. These locations were restored and sampling resumed during the fourth quarter.

Radiological Results. Details of the quarterly sampling and monitoring results can be found in the LLNL Site 300 Ground Water Monitoring Program quarterly reports (Fischer et al. 1992a-d). **Tables C-1** through **C-8** in Appendix C contain supporting monitoring data.

Well NC2-07: This well is the most downgradient monitoring point for Pits 1, 2, 7, 8, and 9 and is sampled for radiological compounds, gross alpha, gross beta, and tritium. The highest observed gross alpha and gross beta activities did not exceed 35% and 15%, respectively, of the MCL. Tritium activities in NC2-07 did not exceed 5% of the drinking water MCL during 1992 (**Table C-1**).

Pit 1: Gross alpha, gross beta, and tritium activities in Pit 1 wells were well below corresponding drinking water MCLs. The highest average gross alpha and gross beta values for Pit 1 wells (**Figure 7-4, Table C-2**) did not exceed 33% and 10% of the EPA and DTSC MCLs, respectively (U.S. Environmental Protection Agency 1977, 22 CCR 64443). The highest gross alpha and gross beta activities [0.224 and 0.238 Bq/L, respectively (1.38 and 6.43 pCi/L)] were both observed in Pit 1 well K1-01C. These values were 40% and 13% of the MCL. The highest average tritium activities for Pit 1 wells did not exceed 10% of the EPA and DTSC MCL.

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Pit 2: Gross alpha, gross beta, and tritium activities in Pit 2 monitor wells were higher than those observed at Pit 1 but, with one exception, below applicable MCLs (Table C-3). The exception was the one sample collected from well K2-04S, which resulted in an unusually high gross alpha activity of 0.67 Bq/L (18.1 pCi/L), which is above the MCL of 0.56 Bq/L, compared to other Pit 2 wells; however, the other three quarterly samples collected from this location averaged only 21% of the MCL. Other gross alpha and gross beta results from Pit 2 wells were all an average of 10% to 30% of the MCLs.

Pit 6: Average gross alpha and gross beta activities for Pit 6 wells did not exceed 20% of the MCLs. Tritium activities averaged less than 1% of the MCL (Table C-4).

Pit 7 Complex: We observed elevated levels of ^{234}U and ^{238}U in the third quarter samples from well K7-06. Results for other quarters were more in line with historic activities. Levels of all radionuclides except ^{226}Ra were somewhat elevated in well NC7-26 compared to results reported in the *Environmental Report for 1991* (Gallegos et al. 1992a; see Table C-5). Gross alpha and total uranium activities continue to occur above MCLs in well NC7-25. During the second quarter of 1992, well NC7-48 was added to the Pit 7 Complex compliance ground water monitoring network. NC7-48 is located immediately downgradient of Pit 7 and upgradient of landfill Pit 3. Thus, it is the only monitoring well that samples ground water that could be affected only by Pit 7. Gross alpha activity at well NC7-48 was as high as 0.57 Bq/L (15.4 pCi/L), slightly above the MCL, but averaged only 55% of the MCL. Radium-226 and total uranium activities were also elevated above the respective MCLs in the two samples collected in 1992. Too few data have been collected from well NC7-48 to permit statistical analysis or trending.

Tritium activities continued to be observed above the MCL (740 Bq/L) in samples from three routine monitoring wells: K7-01 [1438 to 1882 Bq/L (3.88×10^4 to 5.08×10^4 pCi/L)], K7-03 [1435 to 6424 Bq/L (3.88×10^4 to 17.36×10^4 pCi/L)], and NC7-25 [8531 to 11,689 Bq/L (2.3×10^5 pCi/L to 31.6×10^5 pCi/L)]. Tritium activities in the other five Pit 7 wells all averaged less than 20% of the MCL (Figure 7-5).

Pit 8: Gross alpha and gross beta values from well K8-01 were less than 25% of the MCL. Tritium activities were low, averaging less than 1% of the MCL (Table C-6). Uranium activities at K8-01 were less than 35% of the MCL; ^{226}Ra was not detected.

HE Rinse Water Surface Impoundments: Water samples are only analyzed for tritium in the Building 817 area. During 1992, average tritium activities from the B817 area wells did not exceed 0.5% of the MCL (Table C-7).

Pit 9: The highest gross alpha value [0.028 Bq/L (0.76 pCi/L) at well K9-02] from Pit 9 wells was less than 5% of the MCL. The average gross beta values

were below 20% of the MCL. Tritium activities at Pit 9 wells averaged 5% or less of the MCL (Table C-8).

Nonradiological Results. Nonradiological results are summarized according to the geographical areas of Site 300. Tables C-1 through C-8 in Appendix C contain monitoring data for all four geographical areas.

NC2-07: Analyses at this location do not include metals. No volatile organic compounds were detected in well NC2-07 by EPA Method 601 (Table C-1).

Pit 1: Several metals were observed in 1992 samples at background concentrations. None exceeded 25% of the respective MCL (Table C-2; Fischer et al.

Figure 7-5. Tritium activities (Bq/L) in ground water in the Pit 7 Complex, Building 850/Doall Ravine, and EFA subareas, EFA/WFA study area, 4th Quarter 1991.

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1992a-d). Single nickel activities at well K1-0-1C (0.046 mg/L, less than one-half the MCL) and well K1-08 (0.2 mg/L, twice the MCL) were not confirmed by subsequent sampling and analysis and we now believe that they resulted from analytical laboratory error.

Well K1-02B (downgradient of Pit 1) continues to show a significantly higher specific conductance than the average of samples from wells K1-01C and K1-07, which are upgradient Pit 1 wells (Fischer et al. 1992a-d). A study of correlations was performed during the second quarter (Fischer et al. 1992b) between specific conductance and calcium, chloride, sodium, sulfate, and total dissolved solids (TDS). The results of this study indicate that spatial variation in the Pit 1 wells' specific conductance values can be largely attributed to variation in calcium, chloride, and sulfate. Additionally, as the temporal variation of specific conductance is common to all eight Pit 1 Area wells (upgradient and downgradient), the variation is not likely caused by leakage of contaminants from Pit 1.

Low concentrations of Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) continue to be observed in wells K1-05, K1-08, and K1-09. The highest concentration observed during 1992, which was 115 µg/L in K1-09, is less than 10% of the recommended State Action Level (SAL) but is more than the highest concentration (35 µg/L) observed in 1991 in the same well.

Pit 2: Metal analyses at well K2-01C, K2-04D, and K2-04S are limited to beryllium and lead. One of four quarterly samples from well K2-01C contained lead at 0.011 mg/L, still below the MCL (0.05 mg/L). This concentration, much higher than historical lead values at this well, was not confirmed by subsequent sampling and analysis (**Table C-3**) and may be the result of analytical laboratory error. Dichloro-difluoromethane (Freon-12) was the only VOC detected in the Pit 2 area wells (one time detection of 0.6 µg/L at well K2-01C; detection level of 0.5 µg/L).

Although chloroform (0.9 µg/L; detection level of 0.5 µg/L) was detected in well K8-01, this common laboratory contaminant was detected only once. Trichloroethene (TCE) was detected at concentrations as high as 6 µg/L (MCL of 5 µg/L, **Table C-6**) but was otherwise below the MCL. Additional characterization of the ground water in this vicinity is being conducted as part of the Site 300 TCE investigations (Webster-Scholten 1993).

Pit 6: Arsenic, iron, and selenium were observed in Pit 6 wells at concentrations consistent with those of natural constituents of the area ground water (Buddemier et al. 1987, Carlsen et al. 1987).

Pit 7 Complex: Samples from Pit 7 Complex wells were analyzed for four metals: barium, beryllium, lead, and vanadium. In 1992, all four metals were observed at background concentrations (**Table C-5**).

TCE continued to be observed in wells K7-01 and K7-03 at concentrations near or exceeding the MCL. Also 1,1-dichloroethene was detected in samples

from wells K7-01 and K7-03. The Pit 7 Complex ground water investigation of TCE is discussed in the LLNL SWRI (Webster-Scholten 1993). There were first-time and one-time detections of 1,1,1-TCA and chloroform in well NC7-26 (1.2 µg/L and 0.6 µg/L, respectively; detection limit of 0.5 µg/L); and a one-time detection of 0.9 µg/L of trichlorofluoromethane (Freon-11; detection limit of 0.5 µg/L) in NC7-48. Subsequent samples did not confirm these three observations; thus, they may be the result of analytical laboratory error. No other VOCs were detected in any other Pit 7 ground water protection monitoring well samples (Table C-4).

Pit 8: Chromium was the most commonly detected metal from well K8-01. The average concentrations (0.024mg/L) were one-half the MCL (0.05 mg/L). Nitrate plus nitrite (as nitrate) was detected at an average concentration of 9 mg/L, just below the MCL of 10 mg/L. Similarly, higher values of nitrate plus nitrite (as nitrogen) were detected, at an average concentration of 40 mg/L, below the MCL of 45 mg/L. The nitrate levels likely occur naturally in the ground water near Pit 8, as these results are consistent with historical values for this location (Table C-6). As in Pit 2, these observations are considered consistent with natural constituents of the area ground water (Buddemeier et al. 1987, Carlsen et al. 1987).

HE Surface Impoundments: Elevated levels of nitrate, selenium, and arsenic, all exceeding the corresponding drinking water MCL, have been consistently detected in the wells of this area since the wells were installed in 1985. These observations are considered to be natural constituents of the area ground water (Carlsen et al. 1987). There were also observations, at or near the detection limit, of chromium, iron, vanadium, zinc, and lead (Table C-7).

During 1992, TCE continued to be observed in ground water samples collected from three of the four wells downgradient of the B817 surface impoundments. For the fourth downgradient well (W-817-02), TCE had been detected in a fourth quarter 1991 ground water sample. However, TCE was not detected in any of the four ground water samples collected in 1992. The TCE breakdown product cis-1,2-dichloroethene was again observed throughout 1992 in well W-817-03A (Table C-7). Ongoing investigation of VOCs in the HE Process Area is being conducted by LLNL, and progress of this investigation has been described in the SWRI (Webster-Scholten 1993).

Except in samples collected in April 1992, RDX continued to be detected in concentrations from <30 µg/L to 116 µg/L (Table C-6) in ground water samples collected from well W-817-01. Although HMX was reported in the second quarter 1991 in W-817-04, no HE compounds were detected in any ground water samples collected in 1992. HE compounds in the HE Process Area are being investigated as described in the SWRI (Webster-Scholten 1993).

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HE compounds in the B817 HE Process Area ground water are being investigated and will be discussed in Chapter 13 of the SWRI, to be submitted at a later date.

Pit 9: Concentrations of metals in the Pit 9 wells were within historical values, and no VOCs were detected (Table C-8).

Environmental Impact

Livermore Site

The primary environmental impact to ground water at the Livermore site is from contamination by nonradiological constituents of unsaturated sediments and ground water and is a result of past practices.

Nonradiological Impacts. Significant VOC concentrations (exceeding 1 ppm) in unsaturated sediment occur in five areas: the east traffic circle, the vicinity of Building 518, Eastgate Drive, the vicinity of Building 514, and the former East Taxi Strip in the southeastern portion of LLNL. At only two of these locations, the East Taxi Strip and Building 518, are VOC concentrations high enough to possibly affect ground water (Isherwood et al. 1991).

VOCs occur in large, diffuse, ground water plumes 9 to 30 meters thick, which underlie about 85% of the Livermore site (Figure 7-1). VOCs are seldom found below a depth of 60 meters, and the calculated volume of VOCs in ground water is less than 760 liters. VOCs have migrated off site in two areas, one about 750 meters west of Vasco Road under private property, and the second about 250 meters south of southeastern LLNL under DOE property at Sandia National Laboratories, California (SNL/CA). Investigations have determined that the ground water plume near Vasco Road appears to be migrating from the southwest corner of the site to the west-northwest, at a maximum rate of about 20 meters per year (Figure 7-1). Three California Water Service municipal supply wells are situated within 3 kilometers of this plume. Moving at the rate of 20 meters per year, this plume would reach these wells in about 150 years if, in fact, the wells are in the direct flow path, which is questionable. Chemical and hydraulic data strongly indicate that a TCE plume identified northwest of LLNL originates on private property (Figure 7-1). That plume currently is under investigation by the RWQCB and property owners in that area. For more detailed information, see Iovenitti et al. (1991).

Detailed geologic and chemical mapping of the Gasoline Spill Area shows that the highest concentrations of fuel hydrocarbons (FHCs) in the unsaturated sediments (above 10 ppm) are mainly restricted to the immediate spill point, within a radius of approximately 15 meters, and decrease rapidly away from the spill center. The FHCs appear to have moved vertically downward through the vadose zone, spreading laterally immediately upon entering the water table.

Petroleum hydrocarbons (as gasoline concentrations exceeding 10 ppm in ground water) form a north-south trending, oval-shaped plume, which extends approximately 30 meters away from the spill center along its long axis. Benzene concentrations above the 0.001-ppm MCL level are restricted to an area within 90 meters of the leak point. FHCs in ground water are not present below about 50 meters. The only other FHC reported in concentrations exceeding an MCL is ethylene dibromide, which recent analyses suggest is present in five monitoring wells in the immediate vicinity of the gasoline spill point.

Remediation. Treatment Facility A (TFA) treated more than 71 million liters of ground water during 1992, removing and destroying approximately 10 kilograms (6.3 liters) of VOCs. About 200 million liters of ground water have been treated since TFA began operating. Treatment Facility B (TFB) treated about 9.4 million liters of water in 1992, removing and destroying approximately 1.5 kilograms (0.9 liter) of VOCs from ground water. More than 15 million liters have been treated since TFB began operating.

Construction activities for Treatment Facility F (TFF), the treatment system for the steam injection/ground water and vapor extraction experiments, occurred at the Gasoline Spill Area throughout 1992. TFF will support the DOE-sponsored Dynamic Underground Stripping Project as well as sediment and ground water remediation. Remediation operations at TFF during 1992 were limited to four 10-hour soil vapor extraction tests conducted between August and December. Vapor extraction occurred for a total of about 40 hours at a combined vapor extraction rate of about 50 standard cubic feet per minute (scfm). Total fuel hydrocarbon concentrations measured in extracted air ranged from about 4000 to 6000 parts per million by volume (ppmv), resulting in a new fuel hydrocarbon removal in 1992 of about 76 liters of gasoline.

Radiological Impacts. The most significant site of radiological contamination involves tritium in ground water beneath the former East Taxi Strip area. The migration of tritium from this area has been evaluated, and the tritium is expected to decay to levels below the MCL (or to background) long before affecting any drinking water supplies. Therefore, impact to human health is expected to be minimal.

Tritium has not been detected above 37 Bq/L (1000 pCi/L) in off-site wells. The natural half-life for tritium (12.3 years) and the slow movement of ground water ensure that the observed tritium will have decayed to well below the MCL long before migrating off site (Isherwood et al. 1991).

Site 300

The primary environmental impacts to Site 300 ground water arise from contamination from past practices that has reached the ground water in perched aquifers beneath disposal sites, rinse water lagoons, and buildings; and the low

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concentration of TCE in ground water extending off site south and northeast of Site 300 along Corral Hollow Creek.

Nonradiological Impacts. TCE is present in soil, sediment, or ground water at eleven locations at Site 300. The most significant areas of contamination include the Building 834 Complex, the HE Process Area, the General Services Area, Pit 6 Area, Pit 7 Complex, and the Building 865 Advanced Testing Accelerator upgradient of Pit 1. Following is an assessment of several areas that evidenced changes in the ground water concentration during 1992.

General Services Area: The General Services Area is located in the southeastern corner of Site 300. Since 1982 LLNL has conducted an intensive investigation in the General Services Area and off-site areas to locate VOC release points and to define the vertical and horizontal distribution of VOCs, primarily TCE and PCE, in the sediment and ground water. Total VOC concentrations in excess of 1 ppb extended about 1 kilometer off site from the eastern General Services Area along Corral Hollow Creek in 1991, but has since been partially remediated. From startup of the system in July 1991 through December 1992, approximately 33 million liters of TCE-containing ground water were treated.

Building 865 Area: Trending analysis conducted on the Freon-113 observations from Pit 1 wells indicated that concentrations are increasing rapidly (**Figure 7-6**) but are still well below the MCL. Pit 1 has no record of Freon-113 disposal and is not believed to be its source. Although these wells are upgradient (K1-05) and cross gradient (K1-08 and K1-09) from the Pit 1 landfill, they are all located downgradient from Building 865, the Advanced Test Accelerator, which will be investigated by LLNL. The SWRI (Webster-Scholten 1993) indicates that Freon-113 has been detected in ground water from several wells downgradient of Building 865.

Pit 6: TCE concentrations in well EP6-09 have increased, with some fluctuation, since 1987. As shown in **Figure 7-7**, this pattern continued in 1992. Our experience suggests that as the main body of the TCE plume reaches this well, the concentration will level off. Tetrachloroethene (PCE) was detected for the first time in compliance well EP6-08 (0.92 µg/L; MCL is 5 µg/L), although it has been detected before in Pit 6 wells that are not part of the Pit 6 monitoring network. The compound 1,2-dichloroethane (1,2-DCA) was detected at 0.6 µg/L in well EP6-09 (**Table C-4**). No other VOCs were detected in the Pit 6 area. Ongoing investigation of VOCs in the ground water at Pit 6 are discussed in the SWRI (Webster-Scholten 1993).

Pit 7: As reported in Fischer et al. (1992b), TCE concentrations (average 11.0 µg/L range 10 to 12 µg/L, n = 4) in K7-01, which already exceed the MCL, have been increasing at a rate of greater than 10% per year.

HE Process Area: Trend analysis of TCE levels in HE surface impoundment wells indicate that TCE concentrations are decreasing in W-817-03A at about 10% per year ($F_{(1,21)} = 7.15$, $p < 0.01$, $r^2 = 0.25$) (Figure 7-8).

Building 834 Complex: Remediation has begun at the Building 834 Complex, where about 300 kilograms of TCE have been removed from the unsaturated sediment and ground water by extraction and treatment.

Radiological Impacts. Two areas exhibit significant impact to ground water from tritium contamination. These are the Pit 7 Complex and the area of Building 850, Doall Road, and Elk Ravine. Computer modeling indicates that by the time the tritiated water from sites of known ground water contamination reaches the Site 300 boundary, the tritium will have decayed to near or at background activities. LLNL has submitted draft RI/FS reports of the tritium investigation to the regulatory agencies.

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Details of the Remedial Investigation for the East and West Firing Areas Study Area are discussed in the SWRI (Webster-Scholten 1993). The SWRI indicates that at the Building 850 firing tables, tritium was released to the subsurface by percolation of rainfall runoff and dust control water. Tritium from the Building 850 area has recently migrated to the area of Pit 1. Tritium was released to ground water from Pits 3 and 5 in the Pit 7 Complex, due to heavy rains in 1982–83 and the resulting rising water table.

The highest tritium activity [84.4 Bq/L (2279 pCi/L)] observed in a Pit 1 well (K1-02B) increased from the value observed in 1991 [51.4 Bq/L (1388 pCi/L)]. This increase results from the arrival of the leading edge of the ground water tritium plume emanating from Building 850 (Figure 7-4).

Figure 7-7. Trichloroethane in well EP6-09, 1992.

We performed a trend analysis of tritium activities in well K1-02B (Figure 7-9). The estimated model fit to the data is statistically significant ($p = 0.0001$). These estimates indicate that tritium activity levels at well K1-02B are increasing by about 40% per year, or doubling about every 23 months. We anticipate that this trend will level off when the main body of the plume arrives at K1-02B.

Pit 2: The Building 850 tritium plume also appears to be impacting ground water at Pit 2. Average tritium values for Pit 2 wells increased from those observed during 1991 as a result of the Building 850 tritium plume, but did not exceed 70% of the EPA and DTSC MCLs.

Pit 7: We do not believe that the elevated uranium levels seen in Pit 7 wells are the result of contamination. Naturally occurring uranium nominally contains 99.2830% by weight ^{238}U , 0.7110% ^{235}U , and 0.0054% ^{234}U . Studies show that the percentage weight of ^{235}U in natural uranium varies by as much as 0.1%,

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depending on the source (Weast et al. 1982). Adding the 0.1% variation, we expect a range of 0.611 to 0.811% ^{235}U in natural uranium, and consider a value less than 0.611% indicative of depleted uranium. Our analysis of uranium ^{235}U ratio of 0.814%, very close to the upper range expected from natural uranium, and well above that of depleted uranium.

Summary

The primary environmental impacts from Livermore site and Site 300 ground water arise from contaminants released by past practices affecting ground water aquifers beneath disposal sites, rinse water lagoons, and buildings. Although concentrations of contaminants at some localized areas are high, modeling has shown that this contamination is unlikely to migrate to any extent that would significantly affect human health at any on-site or off-site location.

Figure 7-9. Tritium in well K1-02B, 1989 – 1992.

At the Livermore site, areas of contamination are well known, and either active remediation is under way, or modeling has shown that concentrations will drop to near background by the time plumes leave the site boundary.

The one area of off-site contamination at Site 300 is the low concentration of TCE in a ground water plume extending off site along Corral Hollow Creek. Remediation efforts are under way to mitigate any potential impacts of this plume in the eastern General Services Area and off-site concentrations have significantly decreased. Detections of TCE in off-site ground water production wells are discussed in Chapter 6 on Surveillance Water Monitoring.

In summary, during 1992 there were no significant impacts to the environment or public health arising from ground water contamination at the Livermore site or Site 300, nor any indication of recent releases affecting ground water.

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Table 7-1. Water quality parameters and detection limits for monitoring wells, Site 300, 1992.

Parameter	Pits ^a	Detection limit ^b (mg/L)
Physical and chemical		
Aluminum	8	0.2
Ammonia nitrogen (as N)	1, 2, 6, 8, 9	0.02
Antimony	HE	0.2
Arsenic	1, 6, 8, 9, HE	0.002
Barium	1, 6, 7, 8, 9, HE	0.05
Beryllium	1, 2, 6, 7, 8, 9, HE	0.0005
Bicarbonate alkalinity (as CaCO ₃)	1, 6, 8, 9, HE	— ^c
Cadmium	1, 6, 8, 9, HE	0.0005
Calcium	1, 9, HE	0.5
Carbonate alkalinity (as CaCO ₃)	1, 6, 8, 9, HE	— ^c
Chloride	1, 6, 8, 9, HE	1
Chromium	1, 6, 8, 9, HE	0.005
Cobalt	HE	0.05
Conductivity (μmhos/cm)	1, 6, 8, 9, HE	— ^c
Copper	1, 9, HE	0.05
Filterable residue (TDS)	1, 6, 8, 9, HE	10
Fluoride	1, 6, 8, 9	0.1
Hydroxide alkalinity (as CaCO ₃)	1, 6, 8, 9, HE	— ^c
Iron	1, 6, HE	0.1
Lead	1, 2, 6, 7, 8, 9, HE	0.002
Magnesium	1, 9, HE	0.5
Manganese	1, 6, 9, HE	0.05
Mercury	1, 6, 8, 9, HE	0.0002
Molybdenum	HE	0.1
Nickel	1, 6, 9, HE	0.005
Nitrate (as NO ₃)	1, 2, 6, 8, 9, HE	0.4
Nitrate (as N)	1, 2, 6, 8, 9, HE	0.1
Nitrite (as N)	1, 2, 6, 8, 9, HE	0.01
Nitrite (as NO ₂)	1, 2, 6, 8, 9, HE	0.03
Nonfilterable residue (TSS)	1, 6, 9	1
pH (units)	1, 6, 8, 9, HE	— ^c
Potassium	1, 9, HE	1
Selenium	1, 6, 8, 9, HE	0.002
Silver	1, 6, 8, 9, HE	0.0005
Sodium	1, 6, 8, 9, HE	5
Sulfate	1, 6, 8, 9, HE	1
Thallium	HE	0.2
Total alkalinity (as CaCO ₃)	1, 6, 8, 9, HE	— ^c
Total Kjeldahl nitrogen	1, 2, 6, 8, 9	0.5
Vanadium	1, 6, 7, 9, HE	0.05
Zinc	1, 9, HE	0.05

...continued

Table 7-1. Water quality parameters and detection limits for monitoring wells, Site 300, 1992 (*concluded*).

Parameter	Pits ^a	Detection limit ^b
Purgeable halocarbons (EPA Method 601)		(µg/L)
All analytes	1, 2, 6, 7, 8, HE	0.5
Title 22 Organics		
2,4,5-TP (Silvex)	1, 6, 9	1
2,4-D	1, 6, 9	5
Endrin	1, 6, 9	0.05
Lindane	1, 6, 9	0.03
Methoxychlor	1, 6, 9	0.2
Toxaphene	1, 6, 9	0.5
Purgeable priority pollutants (EPA Method 624)		
Acetone	7, 8, 9	5
Acrolein	7, 8, 9	5
Acrylonitrile	7, 8, 9	5
Methyl ethyl ketone	7, 8, 9	5
All other analytes	7, 8, 9	0.5
High explosives		
HMX	1, 6, 8, 9, HE	20
RDX	1, 6, 8, 9, HE	30
TNT	1, 6, 8, 9, HE	30
Other organics		(mg/L)
Low-level phenolics	1, 6, 8, 9	0.005
TOC	1, 6, 8, 9, HE	0.5
TOX	1, 6, 8, 9, HE	0.02
Radiological parameters		(Bq/L)
Gross alpha	1, 2, 6, 7, 8, 9	0.064
Gross beta	1, 2, 6, 7, 8, 9	0.058
Tritium	1, 2, 6, 7, 8, 9, HE	0.062
Uranium-238	1, 6, 7, 8, 9	0.0006
Uranium-235	1, 6, 7, 8, 9	0.0005
Uranium-233, -234	1, 6, 7, 8, 9	0.0004
Radium-226	1, 6, 7, 8, 9	0.004

^a HE = High Explosives Process-Water Surface Impoundment wells.

^b Detection limits may vary from sample to sample depending on such items as matrix interference, instrument sensitivity, or requested method. The limits shown are the lowest detection limits reported.

^c Not applicable.

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Table 7-2. Parameters sampled in Pits 1 and 2 Barcad samplers, Site 300, 1992.

Parameter	Barcad sampler			
	K1-01A	K1-01B	K1-02A	K2-01A
Physical and chemical (mg/L)				
Arsenic	0.0050	0.0100	0.0120	< 0.0020
Barium	3 n.d. at < 0.0500	0.0600 0.0500	4 n.d. at < 0.0500	4 n.d. at < 0.0500
Beryllium	3 n.d. at < 0.0005	1 n.d. at < 0.0500 3 n.d. at < 0.0005	3 n.d. at < 0.0005 1 n.d. at < 0.0002	3 n.d. at < 0.0005 1 n.d. at < 0.0002
Cadmium	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Chromium	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Iron	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Lead	0.0020 2 n.d. at < 0.0020	0.0970 2 n.d. at < 0.0020	4 n.d. at < 0.0020	4 n.d. at < 0.0020
Manganese	< 0.0500	< 0.0500	< 0.0500	< 0.0500
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Nickel	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Selenium	< 0.0020	< 0.0020	< 0.0020	< 0.0020
Silver	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Vanadium	< 0.0500	< 0.0500	< 0.0500	< 0.0500
Radiological (Bq/L)				
Gross alpha	0.036 ± 0.095	0.025 ± 0.081	0.0 ± 0.076	0.091 ± 0.104
	-0.006 ± 0.101	0.003 ± 0.079	-0.031 ± 0.096	0.013 ± 0.057
	-0.009 ± 0.087	0.001 ± 0.082	0.002 ± 0.079	0.1 ± 0.1
Gross beta	0.206 ± 0.071	0.055 ± 0.062	0.023 ± 0.089	0.061 ± 0.108
	0.158 ± 0.085	0.094 ± 0.07	0.102 ± 0.062	0.167 ± 0.068
	0.0676 ± 0.077	0.077 ± 0.072	0.15 ± 0.07	0.089 ± 0.064
Tritium	0.133 ± 0.079		0.14 ± 0.05	0.207 ± 0.074
				0.153 ± 0.068
	-0.46 ± 3.42	-1.32 ± 3.38	-0.77 ± 3.41	-0.22 ± 3.43
Uranium-234	-1.47 ± 3.35	-0.40 ± 3.37	0.74 ± 3.35	2.01 ± 3.50
	-2.07 ± 2.35	0.15 ± 2.46	0.01 ± 2.43	0.64 ± 2.39
			3.81 ± 4.48	2.29 ± 3.89
Uranium-235	0.023 ± 0.004	0 ± 0.002	0.011 ± 0.003	0.005 ± 0.002
	0.021 ± 0.005	0.002 ± 0.002	0.006 ± 0.003	0.003 ± 0.002
	0.041 ± 0.008	0.026 ± 0.005	0.017 ± 0.004	0.033 ± 0.007
Uranium-238			0.014 ± 0.004	0.013 ± 0.003
	0.0002 ± 0.0009	0 ± 0.001	0.0002 ± 0.0005	0 ± 0.0007
	0.001 ± 0.001	0 ± 0.001	0.001 ± 0.001	0 ± 0.001
Radium-226	0.0004 ± 0.0008	0.0003 ± 0.0006	0 ± 0.0006	0.001 ± 0.002
			0 ± 0.001	0.001 ± 0.001
	0.01 ± 0.003	0 ± 0.001	0.006 ± 0.002	0.006 ± 0.002
	0.011 ± 0.003	0.001 ± 0.001	0.003 ± 0.002	0.001 ± 0.001
	0.008 ± 0.003	0.001 ± 0.001	0.006 ± 0.003	0.016 ± 0.005
			0.007 ± 0.003	0.007 ± 0.002
	0.010 ± 0.019	-0.011 ± 0.018	0 ± 0.016	0.01 ± 0.02
	0.0035 ± 0.02	-0.009 ± 0.024	-0.006 ± 0.026	0.018 ± 0.015
	0 ± 0.037	0.021 ± 0.024	0.014 ± 0.014	0.002 ± 0.022
			0.0017 ± 0.017	0.008 ± 0.014

...continued

Table 7-2. Parameters sampled in Pits 1 and 2 Barcad samplers, Site 300, 1992 (*concluded*).

Parameter	Barcad sampler		
	K2-01B	K2-02A	K2-02B
Physical and chemical (mg/L)			
Arsenic	0.0220	0.0500	< 0.0020
Barium	4 n.d. at < 0.0500	4 n.d. at < 0.0500	4 n.d. at < 0.0500
Beryllium	3 n.d. at < 0.0005	3 n.d. at < 0.0005	3 n.d. at < 0.0005
	1 n.d. at < 0.0002	1 n.d. at < 0.0002	1 n.d. at < 0.0002
Cadmium	< 0.0005	< 0.0005	< 0.0005
Chromium	< 0.0050	< 0.0050	< 0.0050
Iron	< 0.1000	< 0.1000	< 0.1000
Lead	4 n.d. at < 0.0020	4 n.d. at < 0.0020	4 n.d. at < 0.0020
Manganese	< 0.0500	< 0.0500	< 0.0500
Mercury	< 0.0002	< 0.0002	< 0.0002
Nickel	< 0.1000	< 0.1000	< 0.1000
Selenium	< 0.0020	< 0.0020	< 0.0020
Silver	< 0.0005	< 0.0005	< 0.0005
Vanadium	< 0.0500	< 0.0500	< 0.0500
Radiological (Bq/L)			
Gross alpha	0.102 ± 0.093	0.225 ± 0.122	-0.036 ± 0.084
	0.018 ± 0.089	0.110 ± 0.098	0.009 ± 0.101
	0.027 ± 0.102	0.138 ± 0.103	-0.04 ± 0.09
	0.073 ± 0.087	0.066 ± 0.107	0.017 ± 0.084
Gross beta	0.159 ± 0.069	0.202 ± 0.073	0.110 ± 0.066
	0.096 ± 0.076	0.059 ± 0.077	0.136 ± 0.069
	0.087 ± 0.114	0.178 ± 0.075	0.111 ± 0.067
	0.150 ± 0.049	0.121 ± 0.057	0.143 ± 0.048
Tritium	3.06 ± 3.57	-3.03 ± 3.30	0.17 ± 3.45
	9.27 ± 3.79	0.14 ± 3.37	0.76 ± 3.42
	2.77 ± 2.58	-0.14 ± 2.45	-0.64 ± 2.38
	10.62 ± 4.70	2.04 ± 4.03	4.92 ± 4.11
Uranium-234	0.107 ± 0.009	0.138 ± 0.014	0 ± 0.001
	0.080 ± 0.012	0.144 ± 0.017	0.001 ± 0.002
	0.110 ± 0.014	0.154 ± 0.017	0.014 ± 0.005
	0.090 ± 0.009	0.145 ± 0.012	0.006 ± 0.002
Uranium-235	0.003 ± 0.001	0.003 ± 0.002	-0.0007 ± 0.0004
	0.002 ± 0.002	0.004 ± 0.003	-0.0004 ± 0.0008
	0.002 ± 0.002	0.002 ± 0.002	0.002 ± 0.002
	0.002 ± 0.001	0.003 ± 0.002	0 ± 0.001
Uranium-238	0.072 ± 0.007	0.031 ± 0.006	-0.0002 ± 0.0004
	0.057 ± 0.009	0.036 ± 0.007	0.0003 ± 0.0007
	0.052 ± 0.009	0.035 ± 0.007	0.001 ± 0.001
	0.057 ± 0.007	0.035 ± 0.005	0.0001 ± 0.0005
Radium-226	-0.005 ± 0.019	0.007 ± 0.017	-0.002 ± 0.008
	-0.007 ± 0.014	0.024 ± 0.019	-0.012 ± 0.019
	0.022 ± 0.016	0.002 ± 0.012	-0.008 ± 0.018
	-0.005 ± 0.017	0.010 ± 0.012	0.003 ± 0.02

Note: The abbreviation "n.d." stands for nondetection.

Gretchen M. Gallegos

Introduction

Soil, defined as weathered materials near the surface of the earth, suitable for the growth of plants, is an integrating medium that can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. The U.S. Department of Energy guidance, on which much of LLNL environmental monitoring is based (U.S. Department of Energy 1991), states that "periodic sampling and analysis of indicator materials, such as soil...should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment. ... Soil sampling and analysis should be used to evaluate the long-term accumulation trends and to estimate environmental radionuclide inventories." The guidance specifies that nuclides in use at the facility, as well as naturally occurring nuclides, should be monitored. In particular, the guidance states that "it is desirable to assess, document, and periodically reassess the distribution and fate of radionuclides in the environment, especially plutonium in soil samples." Particulate radionuclides are of major interest in the LLNL soil monitoring program because airborne particulate releases are the most likely potential pathway for LLNL-induced soil contamination.

Sediments are defined as finely divided solid materials that have settled out of a liquid stream or standing water. In a geologic sense, the top 1000 meters or more at LLNL is sediment. To evaluate current conditions, LLNL samples stream sediments in currently active drainages. Sedimentary materials also can accumulate contaminants. According to U.S. Department of Energy (1991), "the sampling of sedimentary material from streams or ponds can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment. The accumulation of radioactive materials in sediment can lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source... ." U.S. Department of Energy (1991) also states that sampling and analysis of sediments is a more sensitive indicator of waterborne radionuclides than direct water sampling because in sedimentary material there is the potential for the accumulation of contaminants over a period of time. Sediments also have the potential to concentrate nonradioactive constituents, such as metals and organic compounds, that are present in storm water runoff. Stream sediment sampling, followed by radiological and chemical analyses, helps LLNL determine if

8. Soil and Sediment Monitoring

significant buildups of radioactive or nonradioactive pollutants have occurred in nearby arroyos and other drainage areas.

Since 1971, surface soil sampling in the vicinity of LLNL and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. Similarly, sediment samples have been collected from selected arroyos and other drainage areas at and around LLNL since 1988; these locations largely coincide with selected storm water sampling locations. Analyses have been conducted on both radioactive and nonradioactive constituents of sediment samples every year since the inception of sediment monitoring.

Because high-explosive tests at Site 300 occasionally involve the use of depleted uranium (^{238}U), one purpose of the annual soil sampling is to determine if these tests perturb the natural uranium content of the soil. The inclusion of the other naturally occurring nuclides (^{40}K , ^{226}Ra , ^{228}Ra , ^{232}Th , and ^{235}U) and the long-lived fission product ^{137}Cs provides background information and baseline data on global fallout. In 1991, LLNL began analyzing surface soil samples for beryllium, a potentially toxic metal used at both the Livermore site and Site 300.

Location maps for soil and sediment sampling conducted during 1992 are provided in **Figures 8-1** through **8-3**. LLNL established soil sampling locations in all possible directions around the Livermore site, included areas selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations), and included areas with known contaminants, such as plutonium at the Livermore Water Reclamation Plant (LWRP). In general, Site 300 soil sampling locations were established around firing tables and other areas of potential soil contamination. Stream sediment sampling locations were chosen to coincide with major LLNL storm water drainages. All soil and sediment sampling locations have permanent location markers for reference and are suitable for emergency response applications, depending on the nature of the emergency incident. Other locations can be selected and sampled using existing written procedures published with the *Environmental Monitoring Plan* (Gallegos et al. 1992b). It is unlikely that LLNL operations could have any large-scale impacts on soil and sediment that would not be detected by the current monitoring networks.

The soil and sediment monitoring networks are subject to continuing evaluation and reassessment. Changes and additions to the soil and sediment monitoring networks since 1988 are evidence of an LLNL goal to monitor more adequately the soils and sediments that potentially could be affected by LLNL operations. Soil and sediment monitoring at LLNL has increased to meet increasing regulatory requirements and self-imposed monitoring and assessment goals.

Methods

Soils

Prior to 1988, soil samples were collected at sites selected at random from Livermore Valley locations previously sampled for a 1971–1972 study. That earlier study was conducted to determine background concentrations of radionuclides in area soils. In 1988, Livermore Valley surveillance soil sampling locations were chosen to coincide with air sampling locations or to give coverage to areas with contaminants from past incidents or of other special concern. In 1991, five additional soil sampling locations associated with air sampling locations were established. The 1992 soil samples were collected from the same locations as those in 1991. During 1992, soil samples were collected from the same fourteen Site 300 sampling locations as in 1990 and 1991. The use of constant sampling locations from year to year allows more meaningful trending of data.

Choices of soil sampling locations were based on the following criteria: (1) proximity to LLNL and the potential for being affected by LLNL operations, (2) background locations with geologically similar substrates as those near LLNL, but unlikely to be affected by LLNL operations, and (3) areas of known or suspected LLNL-induced contamination. Additionally, soil sampling locations frequently were located near air monitoring locations, for comparative purposes; pollution released to the air is the most likely potential source for surface soil contaminants. Frequently tilled or disturbed areas, or locations near buildings or other obstructions, were avoided. Sampling locations were also chosen to avoid areas with unusual wind or precipitation influences. Other considerations included access during inclement weather and personnel safety in vehicle operation, vehicle parking, or sample collection.

Sampling locations at areas with known or suspected contaminants were monitored to delimit the extent of the contaminants and to track the contaminants from year to year.

Figure 8-1. Soil sampling locations, Livermore Valley, 1992.

8. Soil and Sediment Monitoring

For example, six soil sampling locations were located near LWRP to monitor soils that contain elevated plutonium levels originating from a 1967 accidental release to the sewer.

Soil sampling is conducted according to written, standardized procedures contained in Gallegos et al. (1992b). Samples are collected from undisturbed areas in the proximity of the permanent sampling location marker. These areas generally are level, free of rocks, and are unsheltered by trees or buildings. The sampling technician chooses a one-meter square from which to collect the sample, and records how far away and in what direction from the permanent marker the sample is collected. Each sample is a composite consisting of five subsamples collected individually, with a core sampler, at the four corners and the center of the square.

Figure 8-2. Site 300 soil sampling locations, 1992.

Surface vegetation is cleared away from the sampling area. Before handling any samples, sample collectors put on clean, disposable, vinyl gloves so the sample does not become contaminated. A stainless steel core sampler (8.25-cm diameter), designed at LLNL, is driven into the ground to a depth of 5 cm for each subsample, and the five subsamples are composited in a plastic bag. All subsamples are collected from the top 5 cm of soil because surface deposition from the air is the primary pathway for potential contamination. An aliquot (approximately 10 g) of soil is removed, placed in a plastic vial, and submitted for beryllium analysis. The remainder of the sample is double-bagged to avoid sample contamination, a sample identification tag is attached to the outside bag, and the sample is submitted for analyses.

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Quality assurance (QA) samples are submitted with each batch of soil samples. At locations chosen for duplicate samples, two identical samples are collected. Adjacent cores are collected from the corners and center of the sampling square. Separate composites of five cores each are made, and the two samples are identified with unique sample identifier codes. Similarly, duplicate 10-g aliquots for beryllium analyses are produced. The sampling locations of QA samples are not identified on the sample bags, the sample identification tags, or vial labels, so the analytical laboratory does not know where the QA samples originated. However, this information is recorded on Field Tracking Forms.

New gloves are worn at each sampling location. After all subsamples are collected from a location, the core sampler is decontaminated by washing it thoroughly with deionized water and a low-phosphate detergent. After decontamination, the core sampler is kept in a plastic bag to avoid subsequent contamination.

Samples are delivered on the day of collection to LLNL's Radiation Analytical Sciences laboratory for analyses. Soil samples are dried, ground, sieved, and blended. The plutonium content of a sample aliquot is determined by alpha spectroscopy, following four hours of acid leaching in a mixture of concentrated HNO₃ and HCl and separation and purification by ion exchange/electroplating. Other sample aliquots (300 g) are analyzed for more than 150 radionuclides by gamma spectroscopy, using a Ge (Li) detector (Garrison et al. 1985). The 10-g subsamples for beryllium analyses are sent to a contract analytical laboratory and are analyzed by graphite-furnace atomic absorption spectroscopy. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

The samples collected for the special sediment study were collected using these soil sampling techniques.

Stream Sediments

Annual stream sediment surveillance samples from drainages at and around the Livermore site are collected after the cessation of spring runoff and are analyzed for a variety of constituents. The concentrations of radionuclides (including tritium and plutonium), heavy metals, volatile and semivolatile organic compounds, pesticides, and polychlorinated biphenyls (PCBs) are determined.

The number and location of sediment sampling locations have been reevaluated and increased since sediment sampling began in 1988. Sediment was sampled from ten major LLNL drainages, including four locations first sampled during 1991 (4THA, at Fourth and A Streets; B438, adjacent to Building 438; GRNE, at the northeast influent to Arroyo Las Positas just off Greenville Road; and WPDC, in the west-perimeter drainage channel). Location CDB2, a location near the middle of the Central Drainage Basin, was not sampled because construction activities placing clay and rock in the drainage basin were under way in 1992. The sediment sampling locations coincided with storm water runoff sampling locations so it would be possible to compare the sampling results from these two related media.

A culvert, bridge, or other permanent marker serves as a reference point for each sampling location. Three samples are collected at randomly selected distances from the

permanent marker of each sampling location. The sample collection technicians record how far away and in what direction from the permanent marker the samples are actually collected.

As described below, an individual sediment sample is collected as two subsamples, from varying depths, in two steps. The first subsample is collected with a hand auger and is submitted for radiological analyses. A split-spoon sampler is used to collect the second subsample from the bottom of the same hole. That subsample is analyzed for metals and organic compounds.

Before handling a sample, the technicians put on clean, disposable, vinyl gloves so the sample does not become contaminated. Using a hand auger, the technician removes sediment to a depth of 0.30 m. The auger is used again to collect an additional 0.15 m of sediment from the hole, and this subsample is placed in a glass container. A sample identification label is attached to the sample container, which is placed on ice in an ice chest and delivered to the Radiation Analytical Sciences laboratory. The lab analyzes the sample for tritium and other radiological constituents.

To prepare for the collection of the second subsample, all loose sediment is cleared from the sample hole. Using a slide hammer, the technician drives the split-spoon sampler an additional 0.15 m into the ground, extracts it, and disassembles it, revealing the internal sampling tube containing the intact, untouched sediment sample. The sample tube is sealed with Teflon and protective plastic caps, a sample identification label is attached, and the sample tube is placed on ice in an ice chest. This subsample is analyzed for metals and organic compounds by a contract analytical laboratory.

QA samples are submitted with each batch of sediment samples. In reality, the three samples taken at each sediment sampling location are duplicate samples. However, blind duplicates are also collected. A fourth sample is taken from each of three designated sampling locations, and is submitted blind, as a QA sample, to the analytical laboratories. The sampling locations of QA samples are not identified on the sample containers or Chain-of-Custody Record Forms. However, the locations are recorded on Field Tracking Forms.

New gloves are worn when each sample is collected. Before collecting additional samples, either at the same location or at another location, the auger, split-spoon sampler, and other sampling equipment are thoroughly decontaminated by washing them with deionized water and a low-phosphate detergent.

Subsamples that are collected with the auger and placed in glass sample containers are delivered on the same day to the Radiation Analytical Sciences laboratory for analysis. Using freeze-drying techniques, water is recovered from the samples, and the tritium content of the water is determined by liquid-scintillation counting. The plutonium content of a sample aliquot is determined by alpha spectroscopy, following the sample preparation procedures outlined above for soil samples. Other sample aliquots are analyzed for more than 150 radionuclides using gamma spectroscopy as described above for soil samples. Subsamples, collected with the split-spoon sampler and contained in the sample tubes, are submitted to a contract laboratory for analysis. The sediment samples are analyzed for metals by inductively coupled plasma (ICP) emission spectroscopy, following extraction in water, for comparison to regulatory limits (22 CCR 66261.24).

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Standard EPA methods (8010 for halogenated volatile organic compounds, Method 8020 for aromatic volatile organic compounds, and Method 8080 for pesticides and PCBs) are used to analyze the samples for organic compounds. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

The radioanalytical methods employed in the soil and sediment monitoring programs by the Radiation Analytical Sciences laboratory are state-of-the-art; the methods enable detection of concentrations at levels more sensitive than regulatory limits. Nonradiological analyses are performed by State of California certified analytical laboratories using state-of-the-art technology.

Results

Livermore Site

Table 8-1 presents data on the concentrations of ^{239}Pu , ^{40}K , ^{60}Co , ^{137}Cs , ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U , ^{238}U , and ^{241}Am in surface soils from the Livermore Valley sampling locations. These were the only positively detected radionuclides from the over 150 that were included in the sample analysis.

The concentrations and distributions of all observed radionuclides in soil for 1992 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations; the ratio of ^{235}U to ^{238}U reflects the natural ratio of 0.7%. The source of the low but positively detected level of ^{60}Co at WRP6 (at the Livermore Water Reclamation Plant, hereafter LWRP) could not be determined; this isotope is widely used in a variety of medical, technical, and research applications.

Plutonium-239 was detected at a higher level than background, $3.2 \times 10^{-3} \text{ Bq/g}$ ($8.5 \times 10^{-8} \mu\text{Ci/g}$) at location ZON7. Although last year's sample from this location was within background, since 1973 soil samples in this area have generally shown ^{239}Pu values that are higher than background. The slightly higher values have been attributed to the operation of solar evaporators located on the Livermore site in the early 1970s nearly due west of the sampling locations (Silver et al. 1974).

Elevated levels of ^{239}Pu , resulting from an estimated 32-mCi plutonium release to the sewer in 1967 and first observed in soils near LWRP during the early 1970s, again were detected in locations WRP1 to WRP6. The highest value of $110 \times 10^{-3} \text{ Bq/g}$ ($3.0 \times 10^{-6} \mu\text{Ci/g}$) measured at LWRP during 1992 represents 22% of the proposed EPA surface soil screening level of 7400 Bq/m^2 ($0.2 \mu\text{Ci/m}^2$), or 0.5 Bq/g ($13 \times 10^{-6} \mu\text{Ci/g}$), assuming average Livermore Valley soil densities of 1.5 g/cm^3 and a potential resuspension depth of 1.0 cm (42 Federal Register 230, 1977; U.S. Environmental Protection Agency 1977, 1978). The proposed EPA screening level for surface soil contamination was derived using very conservative assumptions and mathematical models that considered both the inhalation and ingestion pathways. According to the proposed EPA

guidance, areas that do not exceed the screening level are generally said to be in compliance and need no further investigation for possible remediation (42 Federal Register 230, 1977; U.S. Environmental Protection Agency 1977, 1978). Historical plots of average ^{239}Pu concentrations in soil in the Livermore Valley, at Site 300 and at LWRP are shown in Figure 8-4. Livermore Valley and Site 300 concentrations have remained relatively constant over the past ten years and are indicative of worldwide fallout. The apparent increase in ^{239}Pu at LWRP is a result of a high value in 1992. The ^{239}Pu is likely to be present in discrete particles, so the presence or absence of the particles will dominate the measured ^{239}Pu in any given sample. The high value found in 1992 caused the mean to be high, while a low value in 1989 caused the mean to be low. Further statistical analysis showed that all LWRP ^{239}Pu soils data are lognormally distributed, and there is no general increase or decrease in ^{239}Pu values with time. Moreover, all measured concentrations, regardless of location and year, have been a small fraction of the proposed EPA screening level, which is also shown in Figure 8-4 for comparison.

At WRP5, in the same area that exhibited elevated ^{239}Pu levels, and at WRP2, ^{241}Am was detected at a low level; it probably is caused by the natural decay of the trace concentrations of ^{241}Pu that are typically present with ^{239}Pu .

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Table 8-1 also shows data on the concentrations of beryllium in surface soils from Livermore Valley sampling locations. Beryllium levels in soil samples from the Livermore Valley were comparable to the normal range of background concentrations (Wilber 1980).

Table 8-2 presents data on radionuclides detected in the sediment samples. Again, only positively detected levels are shown. The levels of ^{239}Pu were generally at background concentrations, reflective of worldwide fallout; the slightly higher values at ALPE, ALPW, and CDB may be attributed to historic activities at LLNL. Most other radionuclides were detected at levels similar to those reported from 1988 through 1991: ^{137}Cs , a fission product, was found at worldwide background concentrations; and ^{40}K , ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U , and ^{238}U —naturally occurring radionuclides—were detected at background concentrations. Tritium concentrations were below those reported from 1988 through 1991. The location CDB showed the highest tritium and ^{239}Pu values. This location is a drainage point over which one-third of Livermore-site surface area discharge flows; therefore it is expected that materials collected at this point could be higher than at other locations.

Table 8-3 presents data on metals that were detected in the sediment samples. There are no specific regulatory limits for metals in sediments, except for purposes of disposal; however, comparison of these values to disposal limits found in 22 CCR § 66261.24 provides a means to distinguish analytes of concern. No concentrations above levels normally encountered in sediments were detected. As in 1991, most mean (or median) metal concentrations were less than 1%, and all were less than 10% of the standards set in 22 CCR § 66261.24.

Table 8-4 presents data on positively detected organic compounds in the sediment samples. Current techniques for detecting these compounds are very sensitive; therefore, traces of a variety of compounds (many of which were undetectable before 1989) were observed in some samples. Only a few positively detected analytes were found in most samples, and many of these were concentrations at, or marginally above, the analytical detection limits. A few samples contained organic compound concentrations slightly greater than background concentrations (for example, BHC, beta isomer, one time only, at ASW; dieldrin, two times at 4THA and one time at ASW; total xylene isomers, one time only, at ASS2). Toluene was detected at all locations except GRNE; however, the mean toluene concentration in 1992 was <0.014 , while in 1991 it was <0.023 . These concentrations are not of regulatory or health concern, but will be monitored during sediment sampling scheduled for 1993.

Most of the detected organic compounds in sediments are typical of fuel constituents and are expected in locations, such as the arroyos where samples are taken, that concentrate storm water runoff from roads, parking lots, and fields on site. Others are typical laboratory solvents. As for metals, there are no specific

regulatory standards for organic compounds in sediments, so again regulatory levels for disposal are used for comparison (Marshack 1986; 22 CCR § 66261.24, § 66268.43). For those positively detected organic compounds that have published regulatory limits for disposal, all mean concentrations in sediments were less than 5%, and most were less than 0.1% of those limits.

Site 300

Table 8-5 presents data on the concentrations of ^{239}Pu , ^{40}K , ^{137}Cs , ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U , and ^{238}U in soil from the Site 300 sampling locations; only positively detected radionuclides are shown. The concentrations and distributions of all observed radionuclides in Site 300 soil for 1992 remain similar to the levels measured from 1988 through 1991, lie within the ranges reported in all years since monitoring began, and generally reflect worldwide fallout and naturally occurring concentrations; the ratio of ^{235}U to ^{238}U reflects the natural ratio of 0.7%.

Historical trends of ^{238}U concentrations from both the Livermore Valley and Site 300 are shown in **Figure 8-5**. Mean values have remained relatively constant for both places; however, Site 300 mean values are slightly greater than those from the Livermore Valley because of naturally occurring uranium in Site 300 soil. Maximum values at Site 300 represent perturbations to the natural levels caused by the use of depleted uranium in high-explosive tests. Since 1988, these levels have been reduced by the cleanup activities around firing tables and landfills.

As in 1991, but in contrast to previous years, no 1992 soil samples, including those from regions near the firing tables and disposal areas, exhibited markedly greater-than-background concentrations of ^{238}U . The highest value of 12 $\mu\text{g/g}$ (about 3 times greater than average background) was significantly lower than values reported prior to 1991 (**Figure 8-5**). In 1989, a maximum value of 98.2 $\mu\text{g/g}$ was detected in the vicinity of an inactive firing table (soil sampling location 812N), and in 1990 a maximum value of 62.2 $\mu\text{g/g}$ was detected in the vicinity of an on-site landfill (soil sampling location DSW). In 1991 and 1992, the soil samples from these locations contained ^{238}U at background concentrations.

Table 8-5 also presents data on concentrations of beryllium in soil from Site 300 sampling locations in 1992. Beryllium content of soil samples from Site 300 were comparable to the normal range of background concentrations (Wilber 1980). However, Site 300 beryllium concentrations were approximately twice that from the Livermore Valley. Whether this difference is attributable to natural variability in background beryllium levels or because beryllium has been used at Site 300 in high-explosive tests is unknown. However, Shinn et al. (1989) stated that "the maximum deposition of beryllium (from high-explosive tests) contributed a very small amount of beryllium to the soil compared to the natural

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background. The maximum observed deposition would amount to less than 3% of the natural background... ."

Environmental Impact

Livermore Site

Routine soil and sediment sample analyses indicate that the impact of LLNL operations on these media in 1992 has not changed from previous years and remains insignificant. The apparent increase in ^{239}Pu at the LWRP is a result of a high value in 1992 and low value in 1989 affecting the mean; further statistical analysis of all LWRP data shows no significant increase or decrease of ^{239}Pu over time. Most analytes of interest or concern were detected at background concentrations, in trace amounts, or could not be measured above detection limits. Even where certain analytes are detected, concentrations are far below regulatory standards. Sampling of soils and sediments will continue on an annual basis.

Site 300

With the exception of a single sample exhibiting slightly elevated ^{238}U (below those reported for previous years), the concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are representative of background or naturally occurring levels. In the past, ^{238}U -contaminated gravel from the firing tables was removed to on-site landfills. These landfills at Site 300 have been inactive since 1988. The 1992 analyses did not detect significantly higher concentrations of ^{238}U in soil in areas adjacent to firing bunkers and near the landfills, in contrast to previous years (Gudiksen et al. 1973, Holland et al. 1987, Holland and Brekke 1988, Sims et al. 1991). The level of ^{238}U has been reduced to near background levels, probably because of the bunker cleanup operations that removed contaminated gravel to the landfills.

Special Projects: Shallow Sediment Sampling

Sediment samples have been taken at LLNL for the past five years. Samples for analysis of radionuclides are collected at 0.30–0.45 m deep, and samples for analysis of metals are taken from 0.45–0.60 m deep. This year, we also sampled sediments at 0.05 m (the depth at which soils are sampled), to ascertain if there are any differences in metal or radionuclide concentrations for shallow or deeper samples. The results for the shallow samples are reported in **Tables 8-6 and 8-7**; the results for the routine deeper samples are shown in **Tables 8-2 and 8-3**. Most of the analytes show similar concentrations at both depths. Beryllium-7 was only detected in shallow samples. Because ^7Be is generated from cosmic rays and has a short half-life (53.4 days), there is little chance for it to migrate to deeper levels before decaying. Thorium-232 was found at lower concentrations at the shallower depth; this may be due to weathering in this rather dense, naturally occurring radionuclide. Of the metals, only zinc and copper had higher concentrations at shallower depths. Both of these could be attributed to the operation of motor vehicles. Copper is found in brake pads and diesel fuel, and zinc is present in tires; both are regarded as sources of storm water pollution (Mangarella 1992). The sediments samples are taken in storm water drainage channels, and motor vehicles would provide constant addition of such pollutants.

8. Soil and Sediment Monitoring

Table 8-1. Positively detected radionuclides and beryllium in soil sampled at depths from 0 to 50 mm, Livermore Valley, 1992.

Location ^a	²⁴¹ Am	⁶⁰ Co	²³⁹ Pu	²³² Th	²³⁵ U	²³⁸ U
	(10 ⁻³ Bq/dry g)			(μg/dry g)		
ALTA	<1.92	<0.11	0.18 ± 0.02	8.8 ± 0.3	0.024 ± 0.005	<2.5
CAFE	<0.93	<0.07	0.70 ± 0.04	5.5 ± 0.2	0.017 ± 0.004	2.5 ± 2.1
COW	<0.89	<0.11	0.09 ± 0.01	7.2 ± 0.2	0.020 ± 0.005	<2.5
ERCH	<2.18	<0.07	0.25 ± 0.04	5.4 ± 0.2	0.022 ± 0.005	2.2 ± 1.1
FCC	<0.59	<0.07	0.09 ± 0.01	5.9 ± 0.1	0.017 ± 0.005	2.4 ± 1.6
HOSP	<1.59	<0.07	0.14 ± 0.02	4.7 ± 0.1	0.014 ± 0.005	1.9 ± 1.2
MESQ	<0.85	<0.11	0.03 ± 0.01	7.3 ± 0.2	0.020 ± 0.005	<1.1
MET	<0.52	<0.07	0.05 ± 0.01	6.9 ± 0.2	0.021 ± 0.004	<1.5
NEP	<0.96	<0.07	0.09 ± 0.01	6.1 ± 0.2	0.017 ± 0.005	2.4 ± 1.9
PATT	<0.41	<0.11	0.02 ± 0.005	8.9 ± 0.3	0.032 ± 0.009	2.9 ± 2.6
RRCH	<0.48	<0.07	0.28 ± 0.02	6.4 ± 0.2	0.019 ± 0.005	<1.2
SALV	<0.37	<0.07	0.20 ± 0.02	7.1 ± 0.3	0.023 ± 0.005	2.3 ± 2.0
TANK	<1.63	<0.11	0.006 ± 0.003	6.0 ± 0.1	0.017 ± 0.004	<1.8
VIS	<1.96	<0.07	0.60 ± 0.04	7.1 ± 0.1	0.023 ± 0.005	2.5 ± 2.3
ZON7	<1.00	<0.22	3.2 ± 0.18	6.6 ± 0.2	0.020 ± 0.005	4.4 ± 2.9
WRP1	<1.63 ^b	<0.07	3.9 ± 0.18 ^b	6.1 ± 0.1	0.017 ± 0.004	2.2 ± 1.7
WRP2	1.92 ± 0.92 ^b	<0.07	2.8 ± 0.12 ^b	8.0 ± 0.2	0.021 ± 0.005	2.7 ± 2.4
WRP3	<0.89 ^b	<0.11	3.20 ± 0.15 ^b	7.5 ± 0.2	0.024 ± 0.006	<2.3
WRP4	<1.81 ^b	<0.07	0.84 ± 0.05 ^b	6.6 ± 0.1	0.018 ± 0.005	2.7 ± 2.4
WRP5	31.45 ± 4.09 ^b	1.26 ± 0.20	110 ± 6.0 ^b	6.2 ± 0.2	0.025 ± 0.006	3.3 ± 2.0
WRP6	<1.74 ^b	<0.07	0.34 ± 0.05 ^b	5.5 ± 0.2	0.160 ± 0.050	1.9 ± 1.7
Mean	<1.00 ^c	<0.07 ^c	0.40 ^d 20 ^e	6.7	0.027	<2.3
Std dev	— ^f	— ^f	0.80 ^d (44 ^e)	1.1	0.031	— ^f
	(10 ⁻³ pCi/dry g)					
Mean	<27 ^c	<1.9 ^c	11 ^d (540 ^e)			
Std dev	— ^f	— ^f	22 ^d (1200 ^e)			

...continued

Table 8-1. Positively detected radionuclides and beryllium in soil sampled at depths from 0 to 50 mm, Livermore Valley, 1992 (*concluded*).

Location ^a	⁴⁰ K	²²⁶ Ra	²²⁸ Ra	¹³⁷ Cs	Be
	(Bq/dry g)			(10 ⁻³ Bq/dry g)	(mg/kg)
ALTA	0.60 ± 0.02	0.025 ± 0.0005	0.031 ± 0.0013	8.0 ± 0.32	0.91
CAFE	0.47 ± 0.02	0.019 ± 0.0006	0.019 ± 0.0010	3.4 ± 0.24	0.35
COW	0.54 ± 0.02	0.024 ± 0.0005	0.025 ± 0.0010	3.4 ± 0.34	0.48
ERCH	0.34 ± 0.01	0.019 ± 0.0004	0.021 ± 0.0006	11 ± 0.33	0.33
FCC	0.40 ± 0.01	0.022 ± 0.0004	0.021 ± 0.0008	3.6 ± 0.33	0.50
HOSP	0.35 ± 0.01	0.017 ± 0.0005	0.017 ± 0.0009	6.6 ± 0.26	0.40
MESQ	0.50 ± 0.01	0.024 ± 0.0005	0.027 ± 0.0011	0.81 ± 0.32	0.66
MET	0.54 ± 0.02	0.021 ± 0.0006	0.024 ± 0.0007	2.2 ± 0.24	0.46
NEP	0.49 ± 0.02	0.021 ± 0.0006	0.021 ± 0.0011	3.4 ± 0.24	0.47
PATT	0.52 ± 0.02	0.045 ± 0.0014	0.032 ± 0.0016	1.0 ± 0.30	0.66
RRCH	0.41 ± 0.02	0.022 ± 0.0007	0.022 ± 0.0011	9.7 ± 0.39	0.63
SALV	0.41 ± 0.01	0.027 ± 0.0005	0.027 ± 0.0008	0.81 ± 0.21	0.52
TANK	0.37 ± 0.01	0.018 ± 0.0004	0.021 ± 0.0009	0.22 ± 0.19	0.49
VIS	0.44 ± 0.01	0.025 ± 0.0005	0.025 ± 0.0008	5.5 ± 0.33	0.49
ZON7	0.57 ± 0.02	0.022 ± 0.0007	0.024 ± 0.0010	10 ± 0.31	0.57
WRP1	0.41 ± 0.01	0.019 ± 0.0004	0.021 ± 0.0006	1.3 ± 0.21	0.48
WRP2	0.47 ± 0.01	0.026 ± 0.0005	0.027 ± 0.0011	2.2 ± 0.28	0.42
WRP3	0.45 ± 0.01	0.024 ± 0.0005	0.026 ± 0.0010	2.6 ± 0.33	0.52
WRP4	0.41 ± 0.01	0.022 ± 0.0004	0.024 ± 0.0010	2.2 ± 0.28	0.47
WRP5	0.40 ± 0.01	0.022 ± 0.0004	0.021 ± 0.0011	11 ± 0.33	0.93
WRP6	0.35 ± 0.01	0.017 ± 0.0005	0.019 ± 0.0008	1.2 ± 0.17	0.33
Mean	0.45	0.023	0.024	4.3	0.53
Std dev	0.08	0.006	0.004	3.6	0.16
	(pCi/dry g)			(10 ⁻³ pCi/dry g)	
Mean	12.2	0.62	0.65	116	
Std dev	2.2	0.16	0.11	97	

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 8-1 for sampling locations.

^b Samples from areas of known contamination.

^c Median value; see Quality Assurance chapter.

^d Summary statistics for samples from uncontaminated areas.

^e Summary statistics for samples from areas of known contamination.

^f No measure of dispersion calculated; see Quality Assurance chapter.

8. Soil and Sediment Monitoring

Table 8-2. Positively detected radionuclides in arroyo sediments near the Livermore site, 1992.

Location ^a	¹³⁷ Cs	²³⁹ Pu	⁴⁰ K	²²⁶ Ra	²²⁸ Ra
	(10 ⁻³ Bq/dry g)		(Bq/dry g)		
4THA	5.4 ± 0.40	0.16 ± 0.028	0.42 ± 0.01	0.021 ± 0.0004	0.022 ± 0.0009
	1.3 ± 0.23	0.054 ± 0.013	0.50 ± 0.02	0.026 ± 0.0008	0.029 ± 0.0012
	8.9 ± 0.36	0.21 ± 0.034	0.46 ± 0.01	0.023 ± 0.0007	0.024 ± 0.0012
ALPE	<0.11	<0.001	0.43 ± 0.01	0.027 ± 0.0005	0.029 ± 0.0009
	<0.11	0.0065 ± 0.003	0.49 ± 0.01	0.028 ± 0.0006	0.029 ± 0.0009
	<0.11	<0.0022	0.50 ± 0.01	0.028 ± 0.0006	0.030 ± 0.0009
ALPN	<0.11	0.0027 ± 0.002	0.59 ± 0.01	0.023 ± 0.0005	0.026 ± 0.0010
	<0.07	0.0076 ± 0.003	0.56 ± 0.02	0.021 ± 0.0004	0.024 ± 0.0007
	<0.11	0.0024 ± 0.002	0.53 ± 0.02	0.019 ± 0.0006	0.024 ± 0.0012
ALPW	1.2 ± 0.33	0.27 ± 0.017	0.55 ± 0.02	0.021 ± 0.0006	0.027 ± 0.0014
	2.0 ± 0.28	1.02 ± 0.055	0.45 ± 0.01	0.019 ± 0.0004	0.020 ± 0.0008
	1.4 ± 0.39	0.19 ± 0.019	0.46 ± 0.01	0.019 ± 0.0006	0.021 ± 0.0015
ASS2	0.67 ± 0.23	0.025 ± 0.006	0.42 ± 0.01	0.017 ± 0.0005	0.017 ± 0.0009
	0.63 ± 0.18	0.027 ± 0.006	0.49 ± 0.02	0.018 ± 0.0007	0.018 ± 0.0011
	0.67 ± 0.20	0.014 ± 0.003	0.49 ± 0.01	0.019 ± 0.0004	0.019 ± 0.0008
ASW	0.63 ± 0.27	0.015 ± 0.003	0.41 ± 0.01	0.020 ± 0.0006	0.021 ± 0.0011
	2.4 ± 0.26	0.084 ± 0.008	0.45 ± 0.01	0.015 ± 0.0005	0.016 ± 0.0010
	0.56 ± 0.21	0.012 ± 0.003	0.47 ± 0.02	0.024 ± 0.0005	0.022 ± 0.0009
B438	<0.07	0.0059 ± 0.002	0.54 ± 0.02	0.023 ± 0.0005	0.028 ± 0.0008
	<0.11	0.0037 ± 0.002	0.48 ± 0.01	0.023 ± 0.0005	0.025 ± 0.0008
	0.19 ± 0.14	0.086 ± 0.007	0.49 ± 0.01	0.024 ± 0.0005	0.025 ± 0.0007
CDB	0.37 ± 0.23	0.68 ± 0.032	0.50 ± 0.02	0.029 ± 0.0006	0.030 ± 0.0009
	<0.19	0.56 ± 0.029	0.48 ± 0.02	0.024 ± 0.0010	0.027 ± 0.0014
	0.44 ± 0.20	0.99 ± 0.044	0.46 ± 0.01	0.027 ± 0.0005	0.028 ± 0.0011
GRNE	<0.07	0.0012 ± 0.001	0.62 ± 0.02	0.027 ± 0.0005	0.026 ± 0.0010
	<0.11	0.00073 ± 0.0006	0.56 ± 0.02	0.025 ± 0.0005	0.027 ± 0.0011
	<0.11	<0.00041 ± 0.0005	0.59 ± 0.01	0.027 ± 0.0005	0.029 ± 0.0009
WPDC	<0.07	<0.00032 ± 0.0004	0.59 ± 0.02	0.033 ± 0.0007	0.035 ± 0.0011
	<0.11	0.0011 ± 0.001	0.59 ± 0.02	0.029 ± 0.0006	0.035 ± 0.0010
	<0.11	<0.00005	0.56 ± 0.02	0.027 ± 0.0005	0.034 ± 0.0010
Mean	<0.19 ^b	<0.15	0.50	0.024	0.026
Std dev	— ^c	>0.28	0.059	0.0042	0.0050
	(10 ⁻³ pCi/dry g)		(pCi/dryg)		
Mean	<5.1 ^b	<4.1	14	0.65	0.70
Std dev	— ^c	>7.6	1.6	0.11	0.14

...continued

8. Soil and Sediment Monitoring

Table 8-2. Positively detected radionuclides in arroyo sediments near the Livermore site, 1992 (*concluded*).

Location ^a	³ H	²³² Th	²³⁵ U	²³⁸ U
	(Bq/L) ^d	(μg/dry g)		
4THA	16 ± 1.5	6.7 ± 0.2	0.018 ± 0.0050	<2.4
	19 ± 1.6	8.5 ± 0.3	0.023 ± 0.0058	<1.4
	18 ± 1.6	6.8 ± 0.3	0.017 ± 0.0056	<1.3
ALPE	14 ± 1.4	8.3 ± 0.2	0.023 ± 0.0049	<2.2
	16 ± 1.5	8.7 ± 0.2	0.018 ± 0.0046	<1.3
	16 ± 2.0	8.6 ± 0.2	0.017 ± 0.0035	<2.0
ALPN	7.8 ± 1.2	7.4 ± 0.3	0.012 ± 0.0038	<1.9
	5.0 ± 1.5	7.0 ± 0.1	0.018 ± 0.0046	<1.5
	5.7 ± 1.1	6.8 ± 0.2	0.016 ± 0.0053	<2.4
ALPW	14 ± 1.4	8.2 ± 0.3	0.024 ± 0.0071	3.9 ± 3.3
	13 ± 1.4	5.7 ± 0.1	0.018 ± 0.0043	3.1 ± 2.7
	7.2 ± 1.2	6.4 ± 0.3	0.013 ± 0.0087	<1.0
ASS2	5.2 ± 1.5	5.0 ± 0.2	0.016 ± 0.0045	3.3 ± 1.8
	6.8 ± 1.1	5.6 ± 0.2	0.015 ± 0.0054	<1.9
	4.7 ± 1.1	5.7 ± 0.2	0.017 ± 0.0048	2.6 ± 2.3
ASW	2.7 ± 1.0	6.1 ± 0.2	0.017 ± 0.0060	<2.4
	3.2 ± 1.0	4.7 ± 0.1	0.014 ± 0.0042	2.7 ± 2.7
	2.6 ± 1.0	6.7 ± 0.2	0.016 ± 0.0046	<1.9
B438	27 ± 1.9	7.3 ± 0.3	0.027 ± 0.0065	2.3 ± 1.4
	19 ± 1.7	7.3 ± 0.1	0.018 ± 0.0048	<2.1
	7.9 ± 1.2	6.5 ± 0.3	0.024 ± 0.0058	1.7 ± 1.2
CDB	96 ± 4.6	8.5 ± 0.3	0.022 ± 0.0052	<1.1
	78 ± 3.9	7.7 ± 0.3	0.020 ± 0.0087	4.6 ± 3.4
	85 ± 4.2	8.1 ± 0.2	0.019 ± 0.0046	4.0 ± 2.2
GRNE	4.7 ± 1.0	7.5 ± 0.2	0.015 ± 0.0052	2.0 ± 1.7
	6.4 ± 1.5	8.1 ± 0.2	0.018 ± 0.0057	2.9 ± 2.6
	4.3 ± 1.5	8.4 ± 0.2	0.022 ± 0.0054	<2.1
WPDC	7.4 ± 1.2	9.3 ± 0.4	0.028 ± 0.0067	3.1 ± 1.4
	7.8 ± 1.2	9.4 ± 0.4	0.031 ± 0.0075	2.8 ± 1.5
	6.8 ± 1.2	9.3 ± 0.3	0.029 ± 0.0047	2.9 ± 2.5
Mean	18	7.3	0.020	<2.3 ^b
Std dev	24	1.3	0.0048	— ^c
	(pCi/L)			
Mean	490			
Std dev	650			

Note: Radionuclide results are reported $\pm 2\sigma$; see Quality Assurance chapter.

^a See Fig. 8-3 for sampling locations.

^b Median value; see Quality Assurance chapter.

^c No measure of dispersion calculated; see Quality Assurance chapter.

^d Activity in recovered water.

8. Soil and Sediment Monitoring

Table 8-3. Positively detected metals^a (in mg/L) in arroyo sediments near the Livermore site, 1992.

Location ^b	As	Ba	Cd	Total Cr	Co	Cu	Pb	Hg	Ni	V	Zn
4THA	0.03	9.6	<0.05	0.05	0.48	0.17	0.3	<0.002	0.7	0.24	8.1
	0.06	9.5	<0.05	0.10	0.51	0.22	0.4	<0.002	0.8	0.24	4.4
	0.04	11	<0.05	0.08	0.58	0.24	0.5	<0.002	1.0	0.28	6.2
ALPE	0.03	11	<0.05	0.08	0.77	0.08	<0.2	<0.002	1.4	0.65	0.31
	<0.02	9.9	<0.05	0.07	0.55	0.11	<0.2	<0.002	0.9	0.49	0.43
	<0.02	9.3	<0.05	0.08	0.63	0.07	<0.2	<0.002	1.0	0.56	0.35
ALPN	<0.02	9.9	<0.05	<0.05	0.47	<0.05	<0.2	<0.002	0.5	0.43	0.08
	<0.02	12	<0.05	<0.05	0.49	0.06	<0.2	<0.002	0.6	0.34	0.08
	0.02	11	<0.05	<0.05	0.47	<0.05	<0.2	<0.002	0.7	0.46	0.07
ALPW	0.08	7.7	<0.05	0.19	0.43	0.18	0.3	<0.002	0.4	0.72	1.1
	0.23	5.4	<0.05	0.17	0.53	0.61	<0.2	0.002	0.4	0.36	4.8
	0.05	6.4	<0.05	0.11	0.37	1.0	<0.2	<0.002	0.3	0.32	2.0
ASS2	0.02	6.8	0.24	0.08	0.22	0.11	3.4	<0.002	0.4	0.21	0.48
	0.03	6.7	<0.05	0.06	0.23	0.10	<0.2	<0.002	0.4	0.23	0.66
	0.03	7.2	<0.05	<0.05	0.17	0.12	<0.2	<0.002	0.4	0.18	0.43
ASW	0.03	5.7	<0.05	0.11	0.23	0.24	0.4	<0.002	0.4	0.21	0.82
	0.04	5.5	<0.05	0.10	0.18	0.33	0.8	<0.002	0.3	0.20	1.1
	0.06	7.5	<0.05	0.09	0.23	0.41	0.4	<0.002	0.4	0.24	1.4
B438	<0.02	8.1	<0.05	<0.05	0.46	0.08	<0.2	<0.002	0.5	0.20	0.10
	<0.02	7.3	<0.05	<0.05	0.36	0.06	<0.2	<0.002	0.2	0.18	0.10
	<0.02	6.9	<0.05	<0.05	0.36	0.14	<0.2	<0.002	0.4	0.20	1.1
CDB	<0.02	8.9	<0.05	<0.05	0.45	0.09	<0.2	<0.002	0.7	0.24	0.14
	<0.02	10	<0.05	<0.05	0.51	0.11	<0.2	<0.002	0.7	0.30	0.57
	<0.02	7.9	<0.05	<0.05	0.36	0.06	<0.2	<0.002	0.6	0.21	0.09
GRNE	<0.02	10	<0.05	<0.05	0.51	0.11	<0.2	<0.002	0.4	0.38	0.06
	0.03	13	<0.05	0.05	0.52	0.10	<0.2	<0.002	0.6	0.66	0.16
	0.05	8.3	0.06	0.22	0.52	0.18	<0.2	<0.002	0.5	0.60	0.32
WPDC	0.02	11	<0.05	0.07	0.47	0.13	<0.2	<0.002	0.6	0.36	0.08
	<0.02	13	<0.05	<0.05	0.55	0.13	<0.2	<0.002	0.5	0.43	0.08
	<0.02	13	<0.05	0.05	0.53	0.15	<0.2	<0.002	0.6	0.36	0.06
Mean	0.02 ^c	9.0	<0.05 ^c	0.06 ^c	0.44	<0.18	<0.2 ^c	<0.002 ^c	0.6	0.35	1.2
Std dev	— ^d	2.3	— ^d	— ^d	0.14	>0.19	— ^d	— ^d	0.3	0.16	2.0

^a Other metals for which analysis was performed include beryllium, molybdenum, antimony, selenium, thallium, and silver. However, all values for those analyses were below detection limits.

^b See Fig. 8-3 for sampling locations.

^c Median value; see Quality Assurance chapter.

^d No measure of dispersion calculated; see Quality Assurance chapter.

8. Soil and Sediment Monitoring

Table 8-4. Positively detected organic compounds (in mg/kg) in arroyo sediments at the Livermore site, 1992.

Location ^a	BHC alpha isomer	BHC beta isomer	Carbon tetra- chloride	Chloro- form	Dichloro- difluoro- methane	Dieldrin	Endo- sulfan I	Endrin	Endrin aldehyde
4THA	0.003	<0.002	<0.0002	<0.0002	<0.0002	<0.004	<0.002	<0.004	<0.006
	0.002	<0.002	<0.0002	<0.0002	<0.0002	<0.004	<0.002	<0.004	<0.006
	0.002	<0.002	<0.0002	0.0016	<0.0002	0.008	<0.002	<0.004	<0.006
ALPE	<0.002	<0.002	<0.0002	<0.0002	<0.0002	<0.004	<0.002	<0.004	<0.006
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
ALPN	<0.001	<0.001	<0.0002	0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
ALPW	<0.001	<0.001	<0.0002	<0.0002	0.0002	<0.002	0.002	0.003	<0.003
	<0.001	<0.001	<0.0002	<0.0002	0.0002	<0.002	<0.001	<0.002	<0.003
	<0.002	<0.002	<0.0002	0.0013	<0.0002	<0.004	<0.002	<0.004	<0.006
ASS2	<0.001	<0.001	0.0002	0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	0.0002	0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
ASW	<0.001	0.002	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	0.0007	<0.0002	0.004	<0.001	0.005	0.003
	<0.001	<0.001	<0.0002	<0.0002	0.0003	<0.002	<0.001	<0.002	<0.003
B438	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
CDB	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
GRNE	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
WPDC	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
Median	<0.001	<0.001	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.002	<0.003
Std dev	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b	— ^b

...continued

8. Soil and Sediment Monitoring

Table 8-4. Positively detected organic compounds (in mg/kg) in arroyo sediments at the Livermore site, 1992 (*concluded*).

Location ^a	Freon-113	Methylene chloride	p,p'-DDE ^c	Tetra-chloro-ethene	Toluene	Total xylene isomers	1,1,1-TCA ^d	Trichloro-ethene	Trichloro-fluoro-methane
4THA	<0.0002	<0.0002	<0.004	<0.0002	0.005	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.004	<0.0002	0.010	<0.002	<0.0002	<0.0002	<0.0002
	0.0009	0.0004	0.007	0.0002	0.027	<0.002	0.0004	<0.0002	0.0076
ALPE	<0.0002	<0.0002	<0.004	<0.0002	0.004	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.010	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.014	<0.002	0.0002	<0.0002	<0.0002
ALPN	<0.0002	<0.0002	<0.002	<0.0002	0.015	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.008	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.003	<0.002	<0.0002	<0.0002	<0.0002
ALPW	<0.0002	0.0002	<0.002	<0.0002	0.090	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.027	<0.002	0.0002	0.0003	<0.0002
	<0.0002	<0.0002	<0.004	<0.0002	0.028	<0.002	<0.0002	<0.0002	<0.0002
ASS2	<0.0002	0.0066	<0.002	<0.0002	0.004	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	0.0064	0.003	<0.0002	0.011	<0.002	<0.0002	<0.0002	0.0004
	<0.0002	0.0020	<0.002	<0.0002	0.004	0.004	<0.0002	<0.0002	<0.0002
ASW	<0.0002	<0.0002	0.004	<0.0002	0.012	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	0.0002	<0.002	0.0034	0.033	<0.002	0.0022	0.0006	<0.0002
	<0.0002	<0.0002	0.003	<0.0002	0.006	<0.002	<0.0002	<0.0002	<0.0002
B438	<0.0002	<0.0002	<0.002	<0.0002	<0.002	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.004	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.004	<0.002	<0.0002	<0.0002	<0.0002
CDB	<0.0002	0.0002	<0.002	0.0002	0.043	<0.002	0.0003	0.0011	<0.0002
	0.0004	<0.0002	<0.002	0.0032	0.012	<0.002	<0.0002	0.0006	0.0003
	<0.0002	<0.0002	<0.002	<0.0002	0.008	<0.002	<0.0002	0.0003	<0.0002
GRNE	<0.0002	<0.0002	<0.002	<0.0002	<0.002	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	<0.002	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	<0.002	<0.002	<0.0002	<0.0002	<0.0002
WPDC	<0.0002	<0.0002	<0.002	<0.0002	0.004	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.012	<0.002	<0.0002	<0.0002	<0.0002
	<0.0002	<0.0002	<0.002	<0.0002	0.002	<0.002	<0.0002	<0.0002	<0.0002
Median	<0.0002	<0.0002	<0.002	<0.0002	<0.014 ^e	<0.002	<0.0002	<0.0002	<0.0002
Std dev	— ^b	— ^b	— ^b	— ^b	>0.018	— ^b	— ^b	— ^b	— ^b

^a See Fig 8-3 for sampling locations.

^b No measure of dispersion calculated; see Quality Assurance chapter.

^c p,p'-DDE; p,p'-dichlorodiphenyldichloroethylene; or 2,2-bis(4-chlorophenyl)-1,1-dichloroethylene.

^d 1,1,1-Trichloroethane.

^e Mean value; see Quality Assurance chapter.

8. Soil and Sediment Monitoring

Table 8-5. Positively detected radionuclides and beryllium in soil sampled at depths from 0 to 50 mm, Site 300, 1992.

Location ^a	¹³⁷ Cs	²³⁹ Pu	⁴⁰ K	²²⁶ Ra	²²⁸ Ra
	(10 ⁻³ Bq/dry g)			(Bq/dry g)	
801E	3.4 ± 0.3	0.070 ± 0.008	0.53 ± 0.02	0.038 ± 0.0008	0.034 ± 0.001
801N	4.7 ± 0.2	0.12 ± 0.011	0.39 ± 0.01	0.032 ± 0.0006	0.029 ± 0.001
801W	1.6 ± 0.3	0.073 ± 0.008	0.54 ± 0.02	0.044 ± 0.0009	0.044 ± 0.001
812N	0.3 ± 0.2	0.011 ± 0.003	0.33 ± 0.01	0.014 ± 0.0004	0.014 ± 0.001
834W	0.5 ± 0.2	0.016 ± 0.004	0.50 ± 0.02	0.038 ± 0.0008	0.041 ± 0.002
851N	3.8 ± 0.3	0.10 ± 0.012	0.49 ± 0.02	0.043 ± 0.0009	0.050 ± 0.002
856N	3.0 ± 0.2	0.078 ± 0.010	0.39 ± 0.01	0.025 ± 0.0005	0.033 ± 0.001
858S	3.2 ± 0.3	0.080 ± 0.011	0.43 ± 0.01	0.030 ± 0.0006	0.033 ± 0.001
DSW	8.9 ± 0.4	0.22 ± 0.018	0.47 ± 0.01	0.032 ± 0.0006	0.030 ± 0.001
EOBS	<0.1 ^b	0.066 ± 0.010	0.51 ± 0.01	0.024 ± 0.0005	0.035 ± 0.001
EVAP	4.5 ± 0.3	0.060 ± 0.007	0.39 ± 0.02	0.030 ± 0.0006	0.032 ± 0.001
GOLF	2.8 ± 0.3	0.0085 ± 0.003	0.49 ± 0.01	0.028 ± 0.0006	0.028 ± 0.001
NPS	3.7 ± 0.3	0.092 ± 0.009	0.63 ± 0.02	0.028 ± 0.0006	0.030 ± 0.001
WOBS	9.5 ± 0.4	0.25 ± 0.022	0.42 ± 0.01	0.023 ± 0.0005	0.026 ± 0.001
Mean	<3.6	0.089	0.47	0.031	0.033
Std dev	>2.8	0.070	0.078	0.0082	0.0085
	(10 ⁻³ pCi/dry g)			(pCi/dry g)	
Mean	>97	2.4	13	0.84	0.89
Std dev	<76	1.9	2.1	0.22	0.23

...continued

8. Soil and Sediment Monitoring

Table 8-5. Positively detected radionuclides and beryllium in soil sampled at depths from 0 to 50 mm, Site 300, 1992 (*concluded*).

Location ^a	²³² Th	²³⁵ U	²³⁸ U	Be
	(μg/dry g)			(mg/kg)
801E	10 ± 0.3	0.030 ± 0.0090	6.7 ± 3.8	1.28
801N	7.5 ± 0.4	0.024 ± 0.0077	2.7 ± 1.3	2.50
801W	13 ± 0.3	0.027 ± 0.0079	5.1 ± 4.1	1.61
812N	4.0 ± 0.1	0.035 ± 0.0045	12 ± 2.0	0.34
834W	12 ± 0.4	0.020 ± 0.0071	3.0 ± 2.2	1.00
851N	14 ± 0.3	0.030 ± 0.0069	6.4 ± 3.5	1.07
856N	8.6 ± 0.3	0.029 ± 0.0068	2.7 ± 2.0	1.09
858S	9.2 ± 0.3	0.026 ± 0.0073	4.7 ± 2.4	1.11
DSW	8.7 ± 0.2	0.033 ± 0.0049	5.1 ± 2.5	0.63
EOBS	10 ± 0.2	0.019 ± 0.0047	<3.1	0.73
EVAP	9.1 ± 0.3	0.030 ± 0.0054	4.8 ± 2.0	0.54
GOLF	7.7 ± 0.2	0.020 ± 0.0044	2.4 ± 2.1	0.77
NPS	8.3 ± 0.2	0.025 ± 0.0046	2.4 ± 2.3	0.48
WOBS	7.8 ± 0.2	0.017 ± 0.0049	<3.0	0.51
Mean	9.3	0.026	<4.6	0.98
Std dev	2.5	0.0055	>2.6	0.56

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 8-2 for sampling locations.

^b A duplicate sample taken at this location yielded the same result.

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Table 8-6. Positively detected radionuclides in arroyo sediments (0 to 50 mm) near the Livermore site, 1992.

Location ^a	⁷ Be	¹³⁷ Cs	²³⁹ Pu	⁴⁰ K	²²⁶ Ra	²²⁸ Ra
	(10 ⁻³ Bq/dry g)			(Bq/dry g)		
4THA	<2.3	4.0 ± 0.28	0.23 ± 0.015	0.48 ± 0.01	0.024 ± 0.0005	0.024 ± 0.0010
ALPE	<2.6	0.74 ± 0.24	0.038 ± 0.005	0.34 ± 0.01	0.016 ± 0.0003	0.015 ± 0.0007
ALPN	5.7 ± 4.6	<0.074	0.0059 ± 0.002	0.54 ± 0.02	0.013 ± 0.0004	0.013 ± 0.0007
ALPW	<2.4	0.89 ± 0.24	0.041 ± 0.006	0.54 ± 0.02	0.025 ± 0.0005	0.026 ± 0.0010
ASS2	10 ± 6.4	1.0 ± 0.23	0.025 ± 0.004	0.53 ± 0.01	0.020 ± 0.0004	0.020 ± 0.0008
ASW	4.5 ± 2.9	0.41 ± 0.10	0.018 ± 0.004	0.31 ± 0.01	0.011 ± 0.0003	0.011 ± 0.0006
B438	<7.8	<0.52	0.37 ± 0.022	0.47 ± 0.01	0.020 ± 0.0006	0.023 ± 0.0009
CDB	4.1 ± 3.6	0.74 ± 0.16	1.5 ± 0.062	0.52 ± 0.02	0.026 ± 0.0005	0.026 ± 0.0011
GRNE	<2.3	1.0 ± 0.19	0.029 ± 0.004	0.47 ± 0.01	0.021 ± 0.0006	0.022 ± 0.0011
WPDC	<2.5	<0.11	0.0019 ± 0.001	0.51 ± 0.02	0.029 ± 0.0006	0.032 ± 0.0010
Mean	<3.4 ^b	0.74 ^b	0.23	0.47	0.021	0.021
Std dev	— ^c	— ^c	0.46	0.082	0.0058	0.0065
Mean	<92 ^b	20 ^b	6.2	13	0.57	0.57
Std dev	— ^c	— ^c	12	2.2	0.16	0.18

Location ^a	²³² Th	²³⁵ U	²³⁸ U
	(μg/dry g)		
4THA	6.8 ± 0.2	0.020 ± 0.0040	3.03 ± 3.00
ALPE	4.4 ± 0.1	0.011 ± 0.0038	<1.2
ALPN	3.6 ± 0.1	0.012 ± 0.0034	<1.6
ALPW	7.3 ± 0.3	0.021 ± 0.0053	2.8 ± 2.3
ASS2	5.9 ± 0.1	0.018 ± 0.0040	<2.0
ASW	2.8 ± 0.2	0.015 ± 0.0051	0.7 ± 0.6
B438	6.6 ± 0.2	0.018 ± 0.0053	<1.5
CDB	6.9 ± 0.3	0.027 ± 0.0064	3.5 ± 2.2
GRNE	5.9 ± 0.2	0.020 ± 0.0049	<1.6
WPDC	8.9 ± 0.3	0.028 ± 0.0050	3.8 ± 2.9
Mean	5.9	0.019	<1.8 ^b
Std dev	1.8	0.006	— ^c

Note: Radionuclide results are reported ±2σ; see Quality Assurance chapter.

^a See Fig. 8-3 for sampling locations.

^b Median value; see Quality Assurance chapter.

^c No measure of dispersion calculated; see Quality Assurance chapter.

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Table 8-7. Positively detected metals^a (in mg/L) in arroyo sediments (0 to 50 mm depth) near the Livermore site, 1992.

Location ^b	As	Ba	Cd	Total Cr	Co	Cu	Pb	Ni	V	Zn
4THA	0.095	7.5	0.12	0.26	0.55	2.5	4.1	0.62	0.26	26
ALPE	<0.02	8.3	<0.05	0.17	0.30	0.22	1.2	0.43	0.15	9.1
ALPN	<0.02	4.6	<0.05	<0.05	0.34	0.078	<0.2	0.41	0.17	1.8
ALPW	0.056	10	<0.05	0.12	0.61	0.24	<0.2	0.71	0.44	1.1
ASS2	<0.02	7.6	<0.05	<0.05	0.37	0.18	<0.2	0.4	0.22	2.4
ASW	<0.02	4.9	<0.05	<0.05	0.25	0.15	<0.2	0.31	0.13	3.7
B438	<0.02	9.2	<0.05	0.064	0.54	0.34	<0.2	0.79	0.22	6.9
CDB	0.031	10	<0.05	<0.05	0.58	0.37	<0.2	0.68	0.38	3.1
GRNE	0.045	11	<0.05	<0.05	0.42	0.44	2.2	0.54	0.42	9.7
WPDC	<0.02	14	<0.05	0.05	0.70	0.15	<0.2	0.96	0.39	0.25
Mean	<0.02 ^c	8.7	<0.05 ^c	<0.05 ^c	0.47	0.47	<0.2 ^c	0.6	0.28	6.4
Std dev	— ^d	2.8	— ^d	— ^d	0.15	0.72	— ^d	0.2	0.12	7.6

^a Other metals for which analysis was performed include beryllium, molybdenum, antimony, selenium, thallium, and silver. However, all values for those analyses were below detection limits.

^b See Fig. 8-3 for sampling locations.

^c Median value; see Quality Assurance chapter.

^d No measure of dispersion calculated; see Quality Assurance chapter.

Introduction

Because vegetation can be a biological end point for pollutants originally released to the soil, to the air, or through liquid effluents, the sampling and analysis of native vegetation can provide information about the presence and movement of radionuclides in the environment. Contaminated vegetation can contribute radiation dose to humans through direct ingestion or indirectly through the products from animals that have consumed it.

DOE guidance states that "periodic sampling and analysis of indicator materials, such as soil or vegetation, should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment." Terrestrial foods are specifically mentioned in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) as appropriate for surveillance sampling and analysis, even if the potential annual effective dose equivalent from ingestion is below 0.01 mSv (1.0 mrem). The DOE guidance also calls for pathway analyses, and particularly mentions the need for analyses of milk and other representative samples of pathway-significant agricultural products grown in the proximity of the LLNL site (within 16 kilometers).

Since 1972, vegetation and foodstuff sampling in the vicinity of LLNL and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity, to evaluate any increase in radioactivity that might have resulted from LLNL operations, and to calculate potential human doses resulting from direct and indirect ingestion of these items. During 1992, LLNL collected and analyzed samples of vegetation, milk, honey, and wine. Using the monitoring data and dose models presented in Appendix B, LLNL calculated potential human doses from all of these substances except honey. Dose assessments were not made for honey because there is very limited information regarding its consumption.

Tritium is the nuclide of major interest in the LLNL vegetation and foodstuff monitoring program because LLNL has historically released tritium to the air both accidentally and in the course of routine operations. Tritium has the propensity to move into the environment as tritiated water, and as such can be assimilated easily into vegetation and foodstuff. In this manner, it can contribute to human radiation dose burdens if it is ingested directly or indirectly.

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All LLNL environmental surveillance monitoring networks are subject to constant evaluation. Changes and additions to the vegetation and foodstuff monitoring networks since 1988, including those instituted during 1992, are evidence of the LLNL goal to more adequately monitor all media potentially affected by LLNL operations. Vegetation and foodstuff monitoring has increased to meet increasing regulatory requirements and self-imposed monitoring and assessment goals. Moreover, the radioanalytical methods used in the LLNL vegetation and foodstuff monitoring program are state-of-the-art and, in fact, detect radionuclides at levels far more sensitive than any required by regulatory limits.

Because of the importance of food to human life, the potential effects of LLNL operations on local foodstuffs and agricultural products are often the subject of public and regulatory concern. This concern justifies the current level of monitoring and the use of sophisticated analytical techniques. It is unlikely that any realistic significant impacts to vegetation and local foodstuff could be produced by LLNL operations and not be detected by the current monitoring networks.

Methods

Vegetation

LLNL surveillance vegetation samples, usually annual grasses, were collected quarterly from fixed locations in the Livermore Valley, the San Joaquin Valley, the San Ramon Valley, and Site 300 and then analyzed for tritium. Sampling locations in 1992 were the same as those sampled during 1991; location maps are provided in **Figures 9-1** and **9-2**. These locations were originally selected so samples would represent vegetation that (1) had proximity to LLNL and the potential for being affected by LLNL operations, (2) was from background locations where vegetation was similar to that which grows near LLNL, but unlikely to be affected by LLNL operations, and (3) was from areas of known or suspected LLNL-induced contamination.

All vegetation sampling was conducted according to written and approved standardized procedures (Gallegos et al. 1992b). For all vegetation sample collections, frequently tilled or disturbed areas and locations near buildings or other obstructions were avoided. The selected areas were unshaded and exhibited native vegetation for much of the year. Areas with unusual wind or precipitation/irrigation influences also were avoided. Practical considerations also tempered the location selections. These included access during inclement weather, personnel safety in vehicle operation, vehicle parking, or sample collection requirements.

The routine vegetation sampling locations are in areas designated with permanent location markers. Consistent use of the same general sampling locations allows for more meaningful trending of data and closer monitoring of areas of concern. Such is the case regarding Site 300 vegetation sampling activities; vegetation from areas where tritium is known to be present in the subsurface soil are examined closely each year.

9. Vegetation and Foodstuff Monitoring

In 1992, vegetation samples usually consisted of the green leaves and green stems of annual grasses. Other herbaceous vegetation or even perennial vegetation was sampled if grasses were not available. Approximately 0.5 to 1 kilogram of vegetation was collected for analysis. Two subsamples of vegetation comprised a single sample. The laboratory analyzed one subsample and archived the other in a freezer in case the sample had to be reanalyzed due to loss of sample or a questionable analytical result.

Before handling any sample, technicians put on clean, disposable vinyl gloves so the sample would not be contaminated. Shears (decontaminated between samples) were used to trim the vegetation near the base of the plants. Any obviously dead leaves or stems were removed, and any root material was trimmed and discarded. Samples were double-bagged in plastic to avoid sample contamination, placed on dry ice in an ice chest, and kept frozen (to minimize water loss to the bag's surface) until analysis.

Figure 9-1. Livermore Valley vegetation sampling locations, 1992.

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Samples were identified with a tag on which a sample identification code, which includes the location designator, was written. This code was recorded on a Field Tracking Form, along with the distance and direction of the actual sampling location from the permanent sampling location marker. Other pertinent information about the sample, such as the species (if known) or generalized plant group (e.g., annual grass, herb, perennial shrub, tree) was also recorded. Standard chain-of-custody procedures were followed.

Samples were delivered on the day of collection to LLNL's Radiation Analytical Sciences laboratory, and were kept frozen prior to processing. Water from the vegetation was collected using freeze-drying techniques (lyophilization), and the tritium content of the water was determined by liquid-scintillation counting.

Approximately 10% of the sites were sampled in duplicate to comply with quality assurance protocols (Holland 1987). Duplicate collections consisted of four subsamples of vegetation collected from a sampling location using identical methodology. Two of the

subsamples served as the official sample, while the other two subsamples were considered to be duplicates. Duplicate samples were preserved, stored, processed, and analyzed with methods identical to those employed for all other samples.

Milk

Milk is widely consumed by all age groups, and therefore the U.S. Department of Energy (1991) considers it important as one of the foods most frequently contributing radiation dose to people when dairy animals are pastured near a nuclear site. DOE guidance on milk sampling states that the number of sampling locations depends on how many milk production facilities there are, but should include at a minimum one background location and one potentially affected location. Milk sampling locations around LLNL are limited by the fact that there is only one cow milk facility near LLNL. As a result, LLNL obtained goat milk samples from producers in the Livermore Valley (potentially affected locations, all within 5 kilometers of LLNL) and from the Central Valley of California (to represent background locations for comparative purposes). Milk samples generally were collected where the goats were being raised (Figure 9-3). However, one set of samples was purchased from a grocery store, and another was purchased at a goat-milk plant in the Central Valley. A cow milk sample became available during mid-1992 and was collected and analyzed for comparative purposes.

Milk samples were collected monthly except during the months of December and January, when the goat's milk production was limited or absent. Milk production was variable, so samples were obtained as available. All of the milk samples were obtained in pre-cooled, one-gallon sample containers provided by LLNL and were kept refrigerated until analysis.

The samples generally were delivered on the day of collection to LLNL's Radiation Analytical Sciences laboratory. If not delivered on the same day, samples were kept secure and refrigerated until they could be delivered. Chain-of-custody procedures were followed throughout the delivery and analytical process.

The laboratory analyzed the samples for tritium and gamma-emitting isotopes (to determine background milk doses from fallout and naturally occurring radionuclides). A one-liter aliquot of each milk sample was preserved with formalin at the laboratory and was analyzed, in a Marinelli beaker with a Ge(Li) spectrometer, for gamma-emitting isotopes. The remainder of each sample was freeze-dried (lyophilization) and the resultant water was analyzed for tritium by liquid-scintillation counting. At least one milk location was sampled in duplicate each month to comply with quality assurance protocols (Holland 1987).

Honey

Honey is another local agricultural product that potentially can be affected by LLNL operations. Bees collecting pollen and nectar from contaminated vegetation may pass the contamination along to their honey. Human ingestion of contaminated honey can be a pathway contributing to total radiation dose. As was the case for milk, the honey sampling network design was limited by the number of the honey producers in the sampling

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area. During 1992, LLNL obtained three honey samples with a variety of flower sources from beekeepers in the Livermore Valley and three samples from background locations.

Honey samples were collected during September and October. We contacted the sample providers in advance to ensure that the honey collected was from 1992 and was from the desired general location. Each sample consisted of one to three pounds of honey. The honey was transferred to standard sample containers that were labeled for identification. Information provided by the honey producers was recorded along with other information about the samples, such as where the honey was actually produced, where the bees gathered pollen, and what flower species were involved.

Chain-of-custody procedures were followed when delivering samples to LLNL's Radiation Analytical Sciences laboratory and throughout the analytical process. Honey samples were analyzed for tritium by combusting the samples in a Parr bomb and performing liquid-scintillation counting of the water that was produced during combustion.

Figure 9-3. Goat and cow milk sampling locations, 1992.

Honey-sample submittals complied with quality assurance protocols (Holland 1987).

Wine

Wine is the most important agricultural product in the Livermore Valley, representing an approximately \$30-million annual industry. Data since monitoring began have indicated that although tritium concentrations in all wines are low, Livermore Valley wines contain statistically more tritium than do their California counterparts.

Wine samples of three types were collected and analyzed for tritium concentrations: wine produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California outside the Livermore Valley, and wines produced from grapes grown in Europe (France, Germany, and Italy). The latter two groups were divided into eight and thirteen wine-producing regions, respectively, and were used as comparative samples.

The wine samples were purchased from local retailers in a variety of vintages and thus reflect the body of wines available to the general public during 1992. The resulting analytical data can be used to estimate the potential tritium dose received by consumers during the year of purchase. The 1992 sampling data cannot, however, be used to indicate how the year's operations at LLNL affected wines produced in 1992. Some time—in some cases, several years—will have elapsed between the harvest of the grapes and the release of the vintage. However, wine sample data can be decay-corrected to its original tritium concentrations (given the number of months that have elapsed between wine production and LLNL analysis) to determine trends and to help determine the impact of LLNL operations during a particular vintage year.

Wine samples were purchased in 750-milliliter to 1-liter bottles. One wine from four of the eight non-Livermore, California wine growing regions and one wine from six of the thirteen European wine growing regions was purchased and submitted for tritium analyses. The selection of samples from all the wines available within a geographic area was random. Any estate wine from a designated area was considered representative of that area. The most recent vintages available were collected, with an equal mix of red and white wines. Approximately 10% of the total complement of wines were sampled in duplicate to comply with quality assurance protocols (Holland 1987). Because of the importance of the wine sampling network, LLNL sampled and analyzed as many of the available Livermore Valley wines as possible. Twelve Livermore Valley estate wines not previously sampled were purchased and analyzed.

The wine samples were submitted for analysis unopened, to avoid airborne tritium contamination. Chain-of-custody procedures were followed when delivering samples and throughout the analytical process. Wines were analyzed for tritium using ^3He mass spectrometry in the LLNL Nuclear Chemistry Noble Gas Mass Spectrometry Laboratory (Surano et al. 1991). We used this highly sensitive method for our wine analysis so that we could determine differences in the tritium content of the samples. Had less sensitive methods been used, such as those employed by commercial analytical laboratories, the tritium content of all samples would be near or below detection limits and no differences would be apparent.

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Results

Livermore

Vegetation. Table 9-1 shows 1992 tritium data for vegetation collected in the Livermore-site vegetation monitoring program. In general, vegetation tritium concentrations were lower than found in previous years.

An analysis of variance (ANOVA) indicated that location VIS had statistically greater vegetation tritium concentrations than all other locations except AQUE and MESQ. AQUE and MESQ, in turn, had greater tritium concentrations than all other locations except RAIL and MET. All other locations exhibited tritium concentrations in vegetation that were not statistically different.

Three logical groups of vegetation locations can be examined. The first group, "Near," consists of locations at or within 1 kilometer of the Livermore-site perimeter (AQUE, RAIL, MESQ, MET, and VIS). The "Intermediate" group consists of locations in the Livermore Valley, removed from the site (1 to 5 kilometers from the Livermore-site perimeter), but close enough and often downwind so that they are still potentially under the influence of tritium releases at the site. The Intermediate locations are I580, TSW, ZON7, and PATT. The third group, "Background," represents locations unlikely to be affected by LLNL operations. Three of these locations (MOD, DAN, CAL) are far removed from the Livermore site; all are more than 25 kilometers away. The other two (FCC, PARK) are in the Livermore Valley, but are sufficiently removed from the Livermore site (greater than 5 kilometers) and are generally upwind so they are unlikely to be affected by LLNL operations. A statistical evaluation using ANOVA performed on these groups of data indicated that the Near group had significantly higher plant water tritium concentrations [mean of 25 Bq/L (666 pCi/L)] than either the Intermediate or the Background groups [means of 9 Bq/L (243 pCi/L) and 3 Bq/L (81 pCi/L), respectively]. The differences between the Intermediate and Background groups were not significant at the 95% confidence level. The plant water tritium concentrations in vegetation from the Near and Intermediate groups were about half those reported for 1991; Background group concentrations remained essentially unchanged from 1991.

Wine. The results from the 1992 wine tritium analyses are shown in Table 9-2. The sample numbers shown in the table were assigned randomly to wine samples from each region and are not related to sample numbers used in previous years. Tritium concentrations were within the range of those reported in previous years, and they remained low in wines from all areas.

The data for the 1992 sampling year were analyzed using ANOVA. The statistical analysis showed that the mean tritium concentration of the Livermore wines sampled was statistically greater than that of the California (other than Livermore) wines sampled. However, the mean tritium concentration of the

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Livermore wines sampled was not significantly different from that of the European wines sampled. The statistical analyses also indicated that there was no significant difference between the means of European and California wines sampled. Multiple comparison tests indicated that the mean levels of the 1992 sampling year data from California and Europe were not statistically different from those reported for the 1990 and 1991 sampling years. For Livermore wines, the 1992 values were statistically lower than those reported in 1991, but were not statistically different from those reported for 1990. Figure 9-4, which shows the results of the wine analyses by sampling year since monitoring began, also shows that 1992 tritium concentrations are among the lowest for all Livermore wines since monitoring began.

Regression analyses and ANOVA of the wine data (when decay-corrected) grouped by vintage year showed tritium concentrations have statistically decreased for all areas since monitoring began, and since 1980.

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Last year we reported that Livermore wines, examined by vintage year, had statistically greater tritium concentrations since 1980 than European wines. This is particularly apparent since 1986 (Figure 9-5). The 1991 vintage tritium concentrations from these two areas are similar. However, even with these similar 1991 vintage data used in the statistical comparisons, the tritium concentration of vintage Livermore wines since 1980 remains statistically greater than that of either European or other California wines. Vintage wines from both Livermore and Europe continue to exhibit statistically higher tritium concentrations than vintage wines from other California areas during the same period, indicating three distinct data sets still exist.

Honey. Table 9-3 shows tritium data for honey collected from producers in the Livermore Valley and from other producers in California during 1992.

Although the mean tritium concentration of Livermore Valley honey is greater than that of honey from other areas of California, the difference is not statistically significant, as determined by ANOVA. The single high value of note

Figure 9-5. Mean tritium in retail wines, 1980 – 1991, decay-corrected and plotted by vintage year (error bars are ± 1 standard error).

from the Livermore Valley [at 28 Bq/L (749 pCi/L), from hives kept in Livermore] was corroborated by a replicated analysis. Similar values from both Livermore and other areas of California have been reported in past years, and the large variance of tritium values in honey is not unusual (Griggs et al. 1984, Brekke et al. 1989, Sims et al. 1990). Tritium concentrations in honey are not necessarily indicative of the specific locations where the hives are kept; however, they can generally be indicative of regional tritium sources. This is because bees can have extensive ranges and their hives are often transported from place to place to fulfill pollination needs.

ANOVA also indicated that the tritium concentrations in Livermore Valley honey have not changed significantly during the past five years. The statistical analyses also indicated that 1992 California tritium values in honey were not significantly different from those reported from 1988 through 1991. **Figure 9-6** shows the mean values for Livermore Valley honey collected from 1979 through 1992, and other California honey collected from 1980 through 1992. The graph shows that the tritium content of honey fluctuates significantly from year to year, and although the mean Livermore Valley concentration is usually somewhat higher than that of other California honey, the differences are rarely

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statistically significant. Large variances in both Livermore Valley and California tritium concentrations in honey are often seen in the sample data, as evidenced by the large standard-error bars for many of the points.

Goat Milk. The activities of tritium, ^{40}K (potassium-40, a naturally occurring radionuclide), and ^{137}Cs (cesium-137, a fallout product) in goat-milk samples collected during 1992 are shown in Tables 9-4 through 9-6. No other radionuclides were present at detectable levels; ^{137}Cs and ^{40}K were detected at background levels.

ANOVA showed that tritium values for Livermore Valley goat milk as a whole are not significantly different (at 95% confidence) from the background concentrations. Furthermore, there were no significant differences among any of the Livermore Valley sampling locations. The cow-milk samples contained nearly the same amount of tritium as all the goat-milk samples. Dose calculations in Table 9-4 are based on a goat-milk intake of 310 L/y, tritium dose factors provided by DOE (U.S. Department of Energy 1988), and on models described in Appendix B. Because ^{40}K is not an effluent at LLNL and because values from all goat-milk samples were similar, individual doses from ^{40}K were not calculated for each sampling location.

Site 300

Vegetation. Table 9-7 shows tritium data for vegetation collected at Site 300 during 1992. With the exception of a single location, most values are at or near detection limits and are similar to those reported from 1988 through 1991. As was the case in 1990 and 1991, vegetation samples from location DSW contained the highest tritium values detected. As determined by multiple comparison ANOVA, location DSW exhibited plant water tritium concentrations that were significantly greater than the other locations. Tritium concentrations in vegetation from another area of potential concern, EVAP, were not significantly elevated during 1992.

Tritium has been observed in the vegetation of the DSW sampling location since 1971; it is in an area presently being investigated under CERCLA for tritium contamination of ground water. This sampling location is adjacent to a landfill that contain debris contaminated with tritium from past experiments, tritium is no longer used in explosives tests. As a result of seasonal rains, tritium has spread from this debris and is present in the local soil and ground water. The landfill area is under continued investigation for soil and ground water tritium, as described in reports published as part of LLNL's Environmental Restoration Program (see, e.g., Lamarre 1989a-c; Taffet et al. 1989a, b; Taffet et al. 1991; Carlsen 1991a, b; Webster-Scholten 1993).

The effective dose equivalents shown in Table 9-7 were derived using dose-conversion factors provided by DOE (U.S. Department of Energy 1988) and a

dose-pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). Appendix B provides a detailed discussion of dose-calculation methods.

Environmental Impact

Livermore Site

LLNL impacts on vegetation in the Livermore Valley in 1992 remain minimal. Tritium levels detected in the Livermore Valley vegetation were generally reduced from those observed in previous years. The reduction is probably the result of reduced tritium emissions from both LLNL and SNL/CA. The effective dose equivalents shown in **Table 9-1** were derived using the dose-conversion factors provided by DOE (U.S. Department of Energy 1988) and the dose-pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). Based on the conservative assumption that an adult's diet includes vegetables with the highest observed mean tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is 0.00012 mSv/y (0.012 mrem/y).

There are no health standards for radionuclides in wine. However, all the wine tritium levels were far below drinking water standards. In fact, even the highest detected Livermore Valley value [8.84 Bq/L (239 pCi/L)] represents only 1.2% of the California drinking-water standard [741 Bq/L (20,000 pCi/L)]. Doses from wine consumption can be calculated according to methods for water ingestion, which are detailed in Appendix B.

The corresponding annual dose of the highest detected Livermore Valley tritium value in wine [8.84 Bq/L (239 pCi/L)], based on the very conservative assumption that wine is consumed in the same quantities as water (730 L/y or 2 L/d), is 0.00011 mSv (0.011 mrem). Using a more realistic wine consumption factor (52 L/y or 1 L/wk of wine from a single area), and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.0000041 mSv (0.00041 mrem), from European wine would be 0.0000033 mSv (0.00033 mrem), and from California wine would be 0.0000008 mSv (0.00008 mrem). Compared with an annual background dose of approximately 3 mSv (300 mrem), which includes radon, and a 0.1-mSv (10-mrem) dose from a typical chest x ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Therefore, although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

The tritium concentrations in goat milk produced in the Livermore Valley were statistically the same as those of goat milk from other areas of California. Associated doses, like those for wine, were negligible. Regardless of sampling location, the annual ^{40}K dose received from goat-milk consumption has been

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Table 9-1. Tritium in vegetation (in Bq/L of moisture content), 1992 (*concluded*).

	Sampling location ^a			
	DAN	PARK	CAL	VIS
First quarter	2.01 ± 0.83	11.29 ± 1.17	2.28 ± 0.85	12.73 ± 1.20
Second quarter	2.62 ± 1.19	<1.65	1.44 ± 1.15	17.72 ± 2.16
Third quarter	2.94 ± 1.64	1.94 ± 1.59	4.07 ± 1.69	58.83 ± 3.24
Fourth quarter	<2.17	<2.10	<2.18	56.98 ± 3.76
Mean	<2.43	<2.02 ^c	<2.49	36.57
Std dev	>0.42	— ^d	>1.12	24.74
Dose (mSv/y) ^b	<1.2 × 10 ⁻⁵	<9.8 × 10 ⁻⁶	<1.2 × 10 ⁻⁵	1.8 × 10 ⁻⁴
	(pCi/L)			
Mean	<66	<55 ^c	<67	988
Std dev	>11	— ^d	>30	669
Dose (mrem/y) ^b	<1.2 × 10 ⁻³	<9.8 × 10 ⁻⁴	<1.2 × 10 ⁻³	1.8 × 10 ⁻²

Note: Radionuclide results are reported ±2σ, in Bq/L; see Quality Assurance chapter.

^a See Fig. 9-1 for sampling locations.

^b This dose represents the total effective dose equivalent from the forage-cow-milk pathway; see Appendix B.

^c Median value; see Quality Assurance chapter.

^d No measure of dispersion calculated; see Quality Assurance chapter.

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Table 9-2. Tritium in retail wine (in Bq/L), 1992.^a

Sample	Area of production		
	Livermore Valley	California	Europe
1	2.29 ± 0.18	1.44 ± 0.13	2.24 ± 0.14
2	8.60 ± 0.37	0.61 ± 0.12	2.63 ± 0.16
3	3.22 ± 0.23	0.91 ± 0.13	1.84 ± 0.14
4	8.84 ± 0.48	0.68 ± 0.12	3.20 ± 0.17
5	7.96 ± 0.56		10.94 ± 1.11
6	8.43 ± 0.38		1.43 ± 0.12
7	4.21 ± 0.26		
8	3.10 ± 0.26		
9	2.94 ± 0.17		
10	1.07 ± 0.17		
11	2.75 ± 0.19		
12	2.62 ± 0.60		
Mean	4.67	0.91	3.71
Std dev	2.89	0.38	3.60
(pCi/L)			
Mean	126	25	100
Std dev	78	10	97

Note: Radionuclide results are reported $\pm 2\sigma$, in Bq/L; see Quality Assurance chapter.

^a Wines from a variety of vintages were purchased and analyzed in 1992. The concentrations shown are not decay-corrected to vintage year.

Table 9-3. Tritium in honey (in Bq/L in recovered water), 1992.

Sample	Sampling location	
	California	Livermore Valley
1	1.65 ± 0.56	27.71 ± 1.33
2	6.03 ± 0.83	1.10 ± 0.69
3	3.50 ± 0.90	7.73 ± 0.84
Mean	3.73	12.18
Std dev	2.20	13.85
(pCi/L)		
Mean	101	329
Std dev	59	374

Note: Radionuclide results are reported $\pm 2\sigma$, in Bq/L; see Quality Assurance chapter.

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Table 9-4. Tritium in goat's milk (in Bq/L), 1992.

Month	Sampling location ^a			
	WRD (cow) ^b	WRD ^b	MZF ^b	LUP ^b
Feb.	— ^c	— ^d	4.81 ± 1.44	4.96 ± 1.08
Mar.	— ^c	1.61 ± 1.60	<1.58	2.56 ± 1.64
Apr.	— ^c	<1.61	— ^e	<2.31
May	— ^c	1.51 ± 1.21	— ^e	1.92 ± 0.96
June	— ^c	2.78 ± 1.73	— ^e	3.26 ± 1.78
July	— ^c	<1.64	— ^e	2.08 ± 1.69
Aug.	2.07 ± 1.83	2.56 ± 1.85	— ^e	— ^e
Sept.	<1.89	<1.91	— ^e	— ^e
Oct.	<2.01	<2.01	— ^e	— ^e
Nov.	— ^d	<1.62	— ^e	— ^e
Mean	<2.01 ^f	<1.64	<3.20 ^f	<2.85
Std dev	— ^g	— ^g	— ^g	>1.13
Dose (mSv/y) ^k	<1.1 × 10 ⁻⁵	<8.7 × 10 ⁻⁶	<1.7 × 10 ⁻⁵	<1.5 × 10 ⁻⁵
(pCi/L)				
Mean	<54 ^f	<44 ^f	<86 ^f	<77
Std dev	— ^g	— ^g	— ^g	>31
Dose (mrem/y) ^h	<1.1 × 10 ⁻³	<8.7 × 10 ⁻⁴	<1.7 × 10 ⁻³	<1.5 × 10 ⁻³

Month	Sampling location ^a			
	COOL ^b	MOD2 ⁱ	STEVI	TUR ⁱ
Feb.	3.74 ± 1.05	— ^c	— ^c	5.44 ± 1.11
Mar.	<1.54	— ^c	— ^c	2.76 ± 1.64
Apr.	2.26 ± 1.66	<1.59	— ^c	2.42 ± 1.67
May	2.96 ± 0.99	3.60 ± 1.06	— ^c	1.55 ± 1.28
June	<1.65	2.60 ± 1.73	— ^c	<2.41
July	<1.66	<1.65	— ^c	1.76 ± 1.68
Aug.	<1.78	— ^e	3.48 ± 1.88	2.92 ± 1.85
Sept.	<1.88	— ^e	3.35 ± 1.98	<1.89
Oct.	<1.99	— ^e	2.47 ± 2.04	2.92 ± 2.05
Nov.	— ^d	— ^e	1.82 ± 1.63	1.78 ± 1.63
Mean	<1.88 ^h	<2.13 ^h	2.78	<2.59
Std dev	— ^g	— ^g	0.78	>1.12
Dose (mSv/y) ^h	<9.9 × 10 ⁻⁶	<1.1 × 10 ⁻⁵	1.5 × 10 ⁻⁵	<1.4 × 10 ⁻⁵
(pCi/L)				
Mean	<51 ^f	<57 ^f	75	<70
Std dev	— ^g	— ^g	21	>30
Dose (mrem/y) ^h	<9.9 × 10 ⁻⁴	<1.1 × 10 ⁻³	1.5 × 10 ⁻³	<1.4 × 10 ⁻³

...continued

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Table 9-4. Tritium in goat's milk (in Bq/L), 1992 (*concluded*).

Month	Sampling location ^a		
	RIP ^l	WOOD ^l	CART ^l
Feb.	— ^d	— ^c	2.01 ± 0.99
Mar.	3.67 ± 1.68	— ^c	<1.58
Apr.	— ^e	— ^c	2.76 ± 1.69
May	— ^e	— ^c	3.01 ± 1.02
June	— ^e	— ^c	<1.70
July	— ^e	— ^c	2.67 ± 1.70
Aug.	— ^e	— ^c	3.92 ± 1.90
Sept.	— ^e	<1.87	<1.92
Oct.	— ^e	2.26 ± 2.04	2.91 ± 2.06
Nov.	— ^e	<1.60	<1.57
Mean	3.67	<1.87 ^f	<2.34 ^f
Std dev	0.00	— ^g	0.61 ^k
Dose (mSv/y) ^h	1.9 × 10 ⁻⁵	<9.9 × 10 ⁻⁶	<1.2 × 10 ⁻⁵
	(pCi/L)		
Mean	99	<51 ^f	<63 ^f
Std dev	0	— ^g	16 ^k
Dose (mrem/y) ^h	1.9 × 10 ⁻³	<9.9 × 10 ⁻⁴	<1.2 × 10 ⁻³

Note: Radionuclide results are reported ±2σ, in Bq/L; see Quality Assurance chapter.

^a See Fig. 9-3 for sampling locations.

^b Livermore Valley sampling location.

^c Participation in monitoring program began during mid-year.

^d No sample obtained; see Quality Assurance chapter.

^e Provider discontinued participation in monitoring program.

^f Median value; see Quality Assurance chapter.

^g No measure of dispersion calculated; see Quality Assurance chapter.

^h This dose is the effective dose equivalent; see Appendix B.

ⁱ California (non-Livermore Valley) sampling location.

^j Sample purchased in carton from store.

^k Median absolute deviation; see Quality Assurance chapter.

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Table 9-5. Potassium-40 in milk (in Bq/L), 1992.

Month	Sampling location ^a			
	WRD (cow) ^b	WRD ^b	MZF ^b	LUP ^b
Feb.	— ^c	— ^d	53.1 ± 1.1	56.0 ± 1.7
Mar.	— ^c	63.7 ± 1.9	59.5 ± 1.8	75.3 ± 1.5
Apr.	— ^c	62.4 ± 1.9	— ^e	56.4 ± 1.7
May	— ^c	69.0 ± 2.1	— ^e	63.3 ± 1.9
June	— ^c	67.6 ± 2.0	— ^e	60.8 ± 1.2
July	— ^c	68.1 ± 2.0	— ^e	67.4 ± 1.3
Aug.	46.5 ± 0.9	67.2 ± 1.3	— ^e	— ^e
Sept.	57.0 ± 1.7	58.5 ± 1.8	— ^e	— ^e
Oct.	53.4 ± 1.6	55.7 ± 2.2	— ^e	— ^e
Nov.	— ^d	68.4 ± 2.1	— ^e	— ^e
Mean	52.3	64.5	56.3	63.2
Std dev	5.3	4.8	4.5	7.3
(pCi/L)				
Mean	1413	1744	1522	1708
Std dev	144	130	122	197

Month	Sampling location ^a			
	COOL ^b	MOD2 ^f	STEV ^f	TUR ^f
Feb.	52.9 ± 1.6	— ^c	— ^c	63.6 ± 1.9
Mar.	53.1 ± 1.6	— ^c	— ^c	62.6 ± 1.9
Apr.	57.8 ± 1.2	65.6 ± 2.0	— ^c	63.2 ± 1.3
May	58.8 ± 1.8	71.1 ± 2.1	— ^c	65.2 ± 2.0
June	58.1 ± 2.3	66.9 ± 2.0	— ^c	63.6 ± 2.5
July	63.4 ± 1.9	67.6 ± 2.0	— ^c	68.6 ± 1.4
Aug.	63.5 ± 1.9	— ^e	68.1 ± 2.0	68.5 ± 2.1
Sept.	55.5 ± 1.7	— ^e	66.2 ± 2.0	64.4 ± 1.9
Oct.	49.1 ± 1.5	— ^e	59.5 ± 1.8	67.7 ± 2.0
Nov.	— ^d	— ^e	52.8 ± 2.1	63.8 ± 1.9
Mean	56.9	67.8	61.7	65.1
Std dev	4.8	2.3	7.0	2.3
(pCi/L)				
Mean	1538	1832	1666	1760
Std dev	130	63	189	61

...continued

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Table 9-5. Potassium-40 in milk (in Bq/L), 1992 (*concluded*).

Month	Sampling location ^a		
	RIP ^f	WOOD ^f	CART ^g
Feb.	— ^d	— ^c	61.6 ± 1.8
Mar.	67.6 ± 2.0	— ^c	60.4 ± 1.8
Apr.	— ^e	— ^c	61.7 ± 1.9
May	— ^e	— ^c	61.5 ± 1.2
June	— ^e	— ^c	61.3 ± 1.8
July	— ^e	— ^c	67.4 ± 1.3
Aug.	— ^e	— ^c	62.2 ± 1.2
Sept.	— ^e	64.2 ± 1.9	63.1 ± 1.9
Oct.	— ^e	61.4 ± 1.8	66.1 ± 1.3
Nov.	— ^e	62.5 ± 1.9	64.9 ± 1.9
Mean	67.6	62.7	63.0
Std dev	— ^h	1.4	2.3
(pCi/L)			
Mean	1827	1694	1704
Std dev	0	38	63

Note: Radionuclide results are reported $\pm 2\sigma$, in Bq/L; see Quality Assurance chapter.

^a See Fig. 9-3 for sampling locations.

^b Livermore Valley sampling location.

^c Participation in monitoring program began during mid-year.

^d No sample obtained; see Quality Assurance chapter.

^e Provider discontinued participation in monitoring program.

^f California (non-Livermore Valley) sampling location.

^g Sample purchased in carton from store.

^h No standard deviation calculated; see Quality Assurance chapter.

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Table 9-6. Cesium-137 in milk (in Bq/L), 1992.

Month	Sampling location ^a			
	WRD (cow) ^b	WRD ^b	MZF ^b	LUP ^b
Feb.	— ^c	— ^d	0.125 ± 0.048	0.030 ± 0.024
Mar.	— ^c	<0.006	0.189 ± 0.044	0.034 ± 0.029
Apr.	— ^c	<0.006	— ^e	<0.005
May	— ^c	<0.007	— ^e	<0.015
June	— ^c	<0.032	— ^e	<0.005
July	— ^c	<0.014	— ^e	<0.005
Aug.	<0.006	0.044 ± 0.032	— ^e	— ^e
Sept.	<0.014	<0.005	— ^e	— ^e
Oct.	<0.018	<0.012	— ^e	— ^e
Nov.	— ^d	<0.006	— ^e	— ^e
Median	<0.014	<0.007	0.157 ^f	<0.010
Std dev	— ^g	— ^g	0.045	— ^g
(pCi/L)				
Median	<0.38	<0.19	4.25	<0.27
Std dev	— ^g	— ^g	1.22	— ^g

Month	Sampling location ^a			
	COOL ^b	MOD2 ^h	STEV ^h	TUR ^h
Feb.	0.081 ± 0.044	— ^c	— ^c	<0.006
Mar.	0.088 ± 0.048	— ^c	— ^c	<0.006
Apr.	0.048 ± 0.031	<0.007	— ^c	<0.033
May	<0.010	<0.005	— ^c	<0.006
June	<0.005	<0.006	— ^c	<0.005
July	<0.016	<0.006	— ^c	<0.005
Aug.	<0.012	— ^e	<0.007	<0.006
Sept.	<0.005	— ^e	<0.006	0.019 ± 0.017
Oct.	<0.014	— ^e	<0.006	0.035 ± 0.022
Nov.	— ^d	— ^e	<0.005	<0.006
Median	<0.014	<0.006	<0.006	<0.006
Std dev	— ^g	— ^g	— ^g	— ^g
(pCi/L)				
Median	<0.38	<0.16	<0.16	<0.16
Std dev	— ^g	— ^g	— ^g	— ^g

...continued

9. Vegetation and Foodstuff Monitoring

Table 9-6. Cesium-137 in milk (in Bq/L), 1992 (*concluded*).

Month	Sampling location ^a		
	RIP ^h	WOOD ^h	CART ⁱ
Feb.	— ^d	— ^c	<0.031
Mar.	<0.006	— ^c	<0.006
Apr.	— ^e	— ^c	<0.012
May	— ^e	— ^c	<0.005
Jun.	— ^e	— ^c	<0.006
Jul.	— ^e	— ^c	<0.005
Aug.	— ^e	— ^c	<0.005
Sept.	— ^e	<0.006	<0.005
Oct.	— ^e	0.020 ± 0.017	<0.005
Nov.	— ^e	<0.005	<0.033
Median	<0.006	<0.006	<0.006
Std dev	— ^g	— ^g	— ^g
(pCi/L)			
Median	<0.16	<0.16	<0.16
Std dev	— ^g	— ^g	— ^g

Note: Radionuclide results are reported ±2σ, in Bq/L; see Quality Assurance chapter.

^a See Fig. 9-3 for sampling locations.

^b Livermore Valley sampling location.

^c Participation in monitoring program began during mid-year.

^d No sample obtained; see Quality Assurance chapter.

^e Provider discontinued participation in monitoring program.

^f Mean value; see Quality Assurance chapter.

^g No measure of dispersion calculated; see Quality Assurance chapter.

^h California (non-Livermore Valley) sampling location.

ⁱ Sample purchased in carton from store.

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Table 9-7. Tritium in vegetation (in Bq/L of moisture content), Site 300, 1992.

Quarter	Sampling location ^a		
	CARN	GOLF	GEO
First quarter	<1.57	16.91 ± 2.96	16.98 ± 2.11
Second quarter	2.76 ± 1.02	1.91 ± 0.98	2.95 ± 1.39
Third quarter	<1.63	<1.65	<1.62
Fourth quarter	<1.94	<1.87	<1.92
Mean	<1.78 ^b	<1.89 ^b	<2.43 ^b
Std dev	— ^c	— ^c	— ^c
Dose (mSv/y) ^d	$<8.6 \times 10^{-6}$	$<9.1 \times 10^{-6}$	$<1.2 \times 10^{-5}$
(pCi/L)			
Mean	<48 ^b	<51 ^b	<66 ^b
Std dev	— ^c	— ^c	— ^c
Dose (mrem/y) ^d	$<8.6 \times 10^{-4}$	$<9.1 \times 10^{-4}$	$<1.2 \times 10^{-3}$

Quarter	Sampling location ^a		
	DSW	801E	EVAP
First quarter	14.73 ± 2.03	1.66 ± 1.59	3.00 ± 0.88
Second quarter	210.90 ± 8.86	3.81 ± 1.39	4.11 ± 1.72
Third quarter	297.11 ± 6.24	2.92 ± 1.72	4.00 ± 1.76
Fourth quarter	279.72 ± 6.71	<2.49	7.77 ± 2.18
Mean	200.61	<2.72	4.72
Std dev	129.40	>0.90	2.09
Dose (mSv/y) ^d	9.7×10^{-4}	$<1.3 \times 10^{-5}$	2.3×10^{-5}
(pCi/L)			
Mean	5422	<74	128
Std dev	3497	>24	57
Dose (mrem/y) ^d	9.7×10^{-2}	$<1.3 \times 10^{-3}$	2.3×10^{-3}

Note: Radionuclide results are reported $\pm 2\sigma$, in Bq/L; see Quality Assurance chapter.

^a See Fig. 9-2 for sampling locations.

^b Median value; see Quality Assurance chapter.

^c No measure of dispersion calculated; see Quality Assurance chapter.

^d This dose represents the total effective dose equivalent from the forage-cow-milk pathway; see Appendix B.

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Introduction

A wide variety of radioisotopes are used at LLNL, including transuranics, biomedical tracers, tritium, mixed fission products, and other radioisotopes for general research and nuclear weapons research. LLNL conducts direct gamma and neutron radiation monitoring to establish background radiation levels in its vicinity and to determine the environmental radiological impact of its operations in accordance with federal regulations (40 CFR 58.20, 40 CFR 61), DOE Orders 5400.1 and 5400.5, and California Code of Regulations Title 17, Article 1, Section 30250. Because environmental radiological monitoring is used to assess the potential direct radiation dose the public receives as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for its Livermore-site perimeter, the Livermore Valley, and the Site 300 perimeter. LLNL has measured both gamma and neutron radiation at the Livermore-site perimeter since 1973. LLNL implemented an environmental direct radiation monitoring program at Site 300 in 1988.

Gamma radiation is measured using thermoluminescent dosimeters (TLDs); it cannot be collected on filters nor chemically trapped. The TLDs provide a measure of the total amount of gamma radiation at a particular location. Gamma radiation results from natural background sources of geologic/terrestrial or cosmic origin, or from man-made sources, such as fallout from past nuclear weapons testing and any contribution from LLNL operations. Neutron radiation is measured with ^{235}U track-etch detectors (modified neutron rem-meters).

In addition to the routine monitoring, a special gamma radiation study was begun off site near Site 300 in 1991 and was expanded to other areas of the San Francisco Bay Area in 1992. The special study was initiated to determine if the geology at Site 300 or the work conducted at Site 300 were contributing factors in slightly elevated dose levels found at some locations at and near Site 300.

Methods

External doses from gamma radiation are monitored at 16 Livermore-site perimeter locations (**Figure 10-1**), 49 Livermore Valley locations (**Figure 10-2**), 12 Site 300 perimeter locations, and 2 locations in the area surrounding Site 300 (**Figure 10-3**). Off-site TLDs are located in areas surrounding the Livermore site and in nearby residential areas. These are considered background locations and they are used for comparison with perimeter measurements. Six new locations, also shown in **Figure 10-3**, were added in

10. Environmental Radiation Monitoring

1991 in the area near Site 300 as part of the special study described above. In 1992, additional monitoring locations were established in the San Francisco Bay Area to expand this special study (Figure 10-4). The special study is described in detail below.

Direct gamma radiation doses are measured with reusable TLDs mounted in the field on existing structures (such as fence lines) at approximately 1 meter above ground level. Each TLD is heat-sealed in a 8.9 cm × 5.7 cm, 4.5-mm-thick foil pouch for protection against light and moisture. Each quarter, the TLDs are exchanged and read, data are analyzed, and the dose rates are subsequently calculated.

TLDs contain three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Energy is stored when these compounds are exposed to gamma radiation. Impurities in the TLD crystal form low-temperature trapping sites for electrons excited to higher energy states by gamma radiation at normal ambient temperatures. When the TLDs are heated in the analytical laboratory, the electrons return to lower energy states and light (photons) is emitted. The light

Figure 10-1. Gamma and neutron dosimeter locations, Livermore site, 1992.

intensity, measured with a photomultiplier tube, is proportional to the original absorbed dose. After the TLD is read, it is heated again and reread. This second reading should be near zero, indicating that all the stored energy in the traps has been released and measured. This process, called annealing, also verifies that the TLD is again ready for field deployment.

Direct gamma radiation exposures are measured in milliroentgens (mR). The measured exposure is converted to dose by calibrating the dosimeters against sources that deliver a known absorbed dose and then applying a quality factor for a beta/gamma radiation field. The resultant dose equivalents (mSv or mrem) are compared to DOE Order 5400.5 radiation protection standards. The doses at the site boundaries are also compared to background measurements to determine the contribution, if any, from LLNL operations. To ensure accuracy in TLD measurements, some TLDs are irradiated each quarter to specific exposures for calibration purposes. Once each quarter, other

TLDs are irradiated to specific exposures to serve as quality control accuracy checks. Duplicate TLDs are co-located in the field at several locations each quarter to assess TLD measurement precision.

Environmental neutron dose measurements are made using ^{235}U track-etch detectors (modified neutron rem-meters) at eight Livermore-site perimeter locations (Figure 10-1). A detailed description of the detector and spark-count procedure may be found in Fisher (1976). The neutron rem-meters are read each quarter. To ensure accuracy of measurements, quality control checks are conducted on two rem-meters selected at random each quarter.

Results

Livermore Site

Table 10-1 shows the quarterly and annual TLD gamma radiation dose equivalent for the Livermore-site perimeter locations, and Table 10-2 presents data for Livermore Valley off-site locations. The mean 1992 dose equivalent from

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external direct radiation exposure at the Livermore-site perimeter, 0.66 mSv (66 mrem), is the same as background external dose measured in the Livermore Valley (0.66 mSv; 66 mrem). This annual total dose equivalent is typical when compared to that of previous years, i.e., 1987, 0.64 mSv (64 mrem); 1988, 0.63 mSv (63 mrem); 1989, 0.63 mSv (63 mrem); 1990, 0.65 mSv (65 mrem); and 1991, 0.65 mSv (65 mrem).

Table 10-3 presents the data for neutron monitoring at the Livermore-site perimeter. The annual average neutron radiation dose at the Livermore-site perimeter for 1992 was 0.058 mSv (5.8 mrem), similar to values in 1987, 0.050 mSv (5.0 mrem); 1988, 0.042 mSv (4.2 mrem); 1989, 0.053 mSv (5.3 mrem); 1990, 0.046 mSv (4.6 mrem); and 1991, 0.047 mSv (4.7 mrem). The neutron doses measured at the site boundary are consistent with those expected from natural background radiation (NCRP 1976a, b). An absorbed dose rate of 0.047 mSv (4.7 mrem) per year due to cosmic rays was estimated for LLNL from a plot in *Natural Background Radiation in the United States* (NCRP 1976b). This is based

upon an energy deposition rate of 0.043 μ rad/h and a quality factor of 10. The dose rate was also derived from information in NCRP 50 (NCRP 1976a) as 0.087 mSv (8.7 mrem), which is based on an energy deposition rate of 0.1 μ rad/h. These dose rates are consistent with the 1992 monitored neutron dose at the LLNL perimeter.

Site 300

Table 10-4 presents the TLD data for routine monitoring at Site 300 during 1992, expressed as dose equivalent. The perimeter average measured dose in 1992 was 0.77 mSv (77 mrem), ranging from 0.71 to 0.85 mSv (71 to 85 mrem). The off-site measured doses were 0.60 and 0.71 mSv (60 and 71 mrem) at Locations 92 and 93 (in and near Tracy, CA).

Figure 10-3. Gamma dosimeter locations, Site 300, 1992.

Environmental Impact

Livermore Site

Based on past measurements (Lindeken et al. 1973), environmental terrestrial (geologic) radiation doses in the Livermore Valley vary from 0.30 to 0.60 mSv/y (30 to 60 mrem/y). Cosmic radiation, as calculated for the local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966), is about 0.35 mSv/y (35 mrem/y). This combination results in a typical total direct radiation dose level of 0.65 to 0.95 mSv/y (65 to 95 mrem/y). Direct radiation doses measured at the LLNL perimeter in 1992 fall within these predicted values and are statistically equivalent to the off-site doses, which are considered natural background levels. This indicates that there is no contribution from LLNL operations to the direct radiation dose at or beyond the Livermore-site perimeter.

Site 300

The initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the city of Tracy. These off-site locations were chosen to represent background radiation levels. However, the Tracy locations are located on a geological substrate different from that at Site 300. The 1992 average measured dose at the Site 300 perimeter was 0.77 mSv (77 mrem), and the average measured doses near the city of Tracy were 0.60 and 0.71 mSv (60 and 71 mrem), respectively. The doses at the site perimeter fall within the expected range for background locations (Lindeken et al. 1973). The doses measured at the Tracy locations are lower than would be expected for background locations of geologic origin like that at Site 300.

Special Study

Tables 10-5 and 10-6 present results from the special gamma radiation study conducted at and near Site 300 and in the San Francisco Bay Area to determine if the geology of Site 300 (the Neroly rock formation) or the work conducted at Site 300 contribute to slightly higher dose levels measured at some locations. When the direct radiation monitoring program was implemented at the Site 300 perimeter, LLNL observed consistently higher dose levels at some locations. A special study was started in 1991 to monitor gamma radiation at six locations on the Neroly Formation but away from the Site 300 perimeter. Comparisons of data from these locations to those on the Site 300 perimeter were inconclusive. Three locations south of Site 300 exhibited dose levels higher than those from the Site 300 perimeter, and three locations north of Site 300 exhibited doses that were lower. Therefore, the study was expanded during 1992 to investigate variations in background radiation levels of the Neroly Formation. By reviewing geological maps, we identified Neroly Formation rock 40 to 50 kilometers away from

10. Environmental Radiation Monitoring

Figure 10-4. Gamma dosimeter locations, San Francisco Bay Area, 1992.

Site 300. We conducted TLD monitoring at locations in these to Neroly Formation rocks for a one-year period (see Figure 10-5).

An analysis of variance (ANOVA) was performed on the data. The data were grouped as follows: Site 300 perimeter, Site 300 south, Site 300 north, and San Francisco Bay Area. The mean estimate at the Bay Area location is 0.68 ± 0.11 mSv (68 ± 11 mrem), compared to 0.77 ± 0.05 mSv (77 ± 5 mrem) at Site 300 perimeter, 0.72 ± 0.04 mSv (72 ± 4 mrem) at Site 300 north location, and 0.90 ± 0.04 (90 ± 4 mrem) at Site 300 south. The dose levels at the Site 300 perimeter and the Bay Area locations show a significant difference by ANOVA. There is no significant difference between the Bay Area and Site 300 off-site north, and there is no significant difference between Site 300 south and Site 300. However, some Bay Area locations had dose levels equivalent to those at Site 300 perimeter and Site 300 south.

10. Environmental Radiation Monitoring

Variability of gamma measurements in the Neroly Formation rock has been investigated by LLNL (Webster-Scholten 1993) in a study of variable uranium concentrations in ground water. This study concluded "that volcanoclastic Neroly Formation rocks are derived from extrusive rocks formed in what is now the Sierra Nevada region. Clastic material from the erosion of these igneous rocks was transported into the area of Site 300 and lithified to form the Neroly Formation. Uranium distribution in the original magma was variable and consequently resulted in variable uranium content to the subsequent derived formation. Also, volcanic ash containing uranium covered large areas near Site 300. Some of the ash was deposited in the Neroly Formation. However, volcanic ash falls vary in intensity and accumulation, also resulting in variable distribution uranium." Therefore, variability in background radiation levels such as those we have observed is not surprising.

The gamma radiation measurements at Site 300 fall within the range of readings from the suite of locations sampled in this special study. This indicates that the Site 300 gamma readings could result from natural uranium within the Neroly Formation, although a more detailed study of the rock itself would be necessary to verify this finding. LLNL has discontinued the San Francisco Bay Area special study; however, LLNL will continue gamma measurements on the north and south sides of Site 300.

10. Environmental Radiation Monitoring

Table 10-1. TLD environmental radiation measurements (in mSv), Livermore-site perimeter, 1992.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual Total
1	0.18	0.18	0.17	0.19	0.72
2	0.16	0.16	0.15	0.18	0.65
3	0.18	0.18	0.17	0.19	0.72
4	0.18	0.18	0.17	0.23	0.76
5	0.18	0.18	0.17	0.19	0.72
6	0.18	0.17	0.14	0.20	0.69
7	0.17	0.18	0.16	0.19	0.70
10	0.16	0.17	0.16	0.18	0.67
11	0.14	0.13	0.12	0.14	0.53
12	0.15	0.14	0.14	0.17	0.60
13	0.14	0.15	0.14	0.16	0.59
42	0.16	0.16	0.15	0.18	0.65
47	0.16	0.16	0.15	0.18	0.65
50	0.16	0.15	0.14	0.17	0.62
52	0.16	0.15	0.14	0.17	0.62
56	0.16	0.16	0.15	0.17	0.64
Mean	0.16	0.16	0.15	0.18	0.66
Std Dev	0.01	0.02	0.01	0.02	0.06

	[mrem]				
Mean	16	16	15	18	66
Std Dev	1	2	1	2	6

^a See Fig. 10-1 for sampling locations.

10. Environmental Radiation Monitoring

Table 10-2. TLD environmental radiation measurements (in mSv), Livermore Valley, 1992.

Location ^a	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.	Annual Total
14	0.16	0.15	0.15	0.18	0.64
15	0.16	0.15	0.14	0.18	0.63
16	0.17	0.16	0.15	0.18	0.66
17	0.17	0.16	0.15	0.18	0.66
18	0.13	0.12	0.12	0.13	0.50
19	0.17	0.16	0.15	— ^b	0.64 ^c
20	0.16	0.15	0.14	— ^b	0.60 ^c
21	0.16	0.15	0.14	— ^b	0.60 ^c
22	0.18	0.17	0.16	0.19	0.70
23	0.18	0.17	0.16	0.19	0.70
24	0.17	0.17	0.17	— ^b	0.68 ^c
27	0.18	0.18	0.17	0.20	0.73
28	0.18	0.19	0.17	0.21	0.75
29	0.17	0.18	0.17	0.19	0.71
30	0.16	0.17	0.16	0.18	0.67
31	0.16	— ^b	0.15	0.17	0.64 ^c
32	0.16	— ^b	0.15	0.18	0.65 ^c
33	0.17	0.18	— ^b	0.19	0.72 ^c
34	0.18	— ^b	0.17	0.20	0.73 ^c
35	0.17	0.17	0.16	0.19	0.69
36	0.17	0.18	0.18	— ^b	0.66 ^c
37	0.16	0.17	0.15	0.18	0.66
38	0.17	0.19	0.16	0.18	0.70
41	0.16	0.16	— ^b	0.18	0.67 ^c
43	0.17	0.17	0.16	0.19	0.69
44	— ^b	0.18	0.17	— ^b	0.61 ^c
45	0.16	0.15	0.14	0.16	0.61
46	0.16	0.15	0.14	0.17	0.62
51	0.17	— ^b	0.14	0.18	0.65 ^c
55	0.16	0.15	0.14	0.17	0.62
57	0.17	0.18	0.16	0.20	0.71
58	0.17	0.16	0.15	0.18	0.66
59	0.17	0.16	0.16	0.18	0.67

...continued

10. Environmental Radiation Monitoring

Table 10-2. TLD environmental radiation measurements (in mSv), Livermore Valley, 1992 (*concluded*).

Location ^a	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.	Annual Total
60	0.17	0.16	0.16	0.18	0.67
61	0.15	0.14	0.13	0.16	0.58
62	0.15	0.14	0.14	0.16	0.59
63	0.16	0.16	0.16	0.18	0.66
66	0.18	0.16	0.16	0.19	0.69
67	0.15	0.16	0.15	0.17	0.63
68	0.16	0.16	0.15	0.18	0.65
69	0.16	0.15	0.14	0.16	0.61
70	0.17	0.15	0.15	0.18	0.65
71	— ^b	0.15	— ^b	0.19	0.68
72	0.19	0.18	0.17	0.20	0.74
73	— ^b	0.16	0.16	0.18	0.67 ^c
74	0.15	0.15	0.14	0.17	0.61
75	0.14	0.13	0.12	0.15	0.54
76	0.12	0.12	0.13	0.19	0.56
77	— ^b	— ^b	— ^b	0.17	0.68 ^c
Mean	0.16	0.16	0.15	0.18	0.66
Std dev	0.01	0.02	0.01	0.01	0.05
[mrem]					
Mean	16	16	15	18	66
Std dev	1	2	1	1	5

^a See Fig. 10-2 for sampling locations.

^b No data available for these samples; see Quality Assurance chapter.

^c When TLD is missing, annual dose is calculated as four times the mean quarterly dose, as determined from available data.

10. Environmental Radiation Monitoring

Table 10-3. Neutron environmental radiation measurements (in mSv), Livermore-site perimeter, 1992.

Location ^a	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.	Annual Total
1	0.016	0.015	0.013	0.013	0.057
2	0.038	0.014	0.012	0.008	0.072
3	0.015	0.026	0.013	0.010	0.064
4	0.018	0.018	0.007	0.013	0.056
5	0.015	0.017	— ^b	0.011	0.057 ^c
6	0.009	0.009	0.011	0.011	0.040
7	0.009	0.017	0.017	0.014	0.057
8	0.007	0.017	0.029	0.008	0.061
Mean	0.016	0.017	0.015	0.011	0.058
Std dev	0.010	0.005	0.007	0.002	0.009

	[mrem]				
Mean	1.6	1.7	1.5	1.1	5.8
Std dev	1.0	0.5	0.7	0.2	0.9

^a See Fig. 10-1 for sampling locations.

^b No data available for these samples; see Quality Assurance chapter.

^c When neutron dosimeter data are missing, the annual dose is calculated as four times the average quarterly dose, as determined from available data.

10. Environmental Radiation Monitoring

Table 10-4. TLD environmental radiation measurements (in mSv), Site 300 perimeter and off-site locations, 1992.

Location ^a	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.	Annual Total
Site perimeter					
78	0.17	0.18	— ^b	0.18	0.71 ^c
81	0.20	0.21	0.20	0.24	0.85
82	0.18	0.18	0.18	— ^b	0.72 ^c
83	0.19	0.20	— ^b	— ^b	0.78 ^c
84	0.18	0.19	0.18	— ^b	0.73 ^c
85	0.18	0.19	— ^b	— ^b	0.74 ^c
86	0.18	0.20	0.17	— ^b	0.73 ^c
87	0.20	0.24	0.21	— ^b	0.87 ^c
88	0.18	0.20	0.17	0.21	0.76
89	0.19	0.19	0.19	0.23	0.80
90	0.18	0.19	0.18	0.22	0.77
91	0.18	0.19	0.17	0.21	0.75
Mean	0.18	0.20	0.18	0.22	0.77
Std dev	0.01	0.02	0.01	0.02	0.05
[mrem]					
Mean	18	20	18	22	77
Std dev	1	2	1	2	5
Off site					
92	0.18	0.18	0.16	0.19	0.71
93	0.15	0.15	0.14	0.16	0.60
Mean	0.17	0.17	0.15	0.18	0.66
Std dev	0.02	0.02	0.01	0.02	0.08
[mrem]					
Mean	17	17	15	18	66
Std dev	2	2	1	2	8

^a See Fig. 10-3 for sampling locations.

^b No data available for these samples; see Quality Assurance chapter.

^c When TLD data are missing, the annual dose is calculated as four times the average quarterly dose, as determined from available data.

10. Environmental Radiation Monitoring

Table 10-5. TLD environmental radiation measurements (in mSv), special study, Site 300 vicinity, 1992.

Location ^a	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.	Annual Total
94	0.22	— ^b	0.24	0.28	0.99 ^c
95	0.20	0.22	0.21	0.23	0.86
96	0.20	0.21	0.21	0.25	0.87
97	— ^b	— ^b	0.17	— ^b	0.68 ^c
98	— ^b	0.18	0.17	0.21	0.75 ^c
99	0.18	0.18	0.17	0.20	0.73
Mean	0.20	0.20	0.20	0.23	0.81
Std dev	0.02	0.02	0.03	0.03	0.11

	[mrem]				
Mean	20	20	20	23	81
Std dev	2	2	3	3	11

^a See Fig. 10-3 for sampling locations.

^b No data available for these samples; see Quality Assurance chapter.

^c When TLD data are missing, the annual dose is calculated as four times the average quarterly dose, as determined from available data.

10. Environmental Radiation Monitoring

Table 10-6. TLD environmental radiation measurements (in mSv), special study, San Francisco Bay Area, 1992–1993.

Location ^a	Apr.–Jun. 1992	July–Sept. 1992	Oct.–Dec. 1992	Jan.–Mar. 1993	Annual Total
C-100-TD	0.15	0.14	0.17	0.15	0.61
C-101-TD	0.15	0.15	0.16	0.14	0.60
C-102-TD	0.15	0.14	— ^b	0.13	0.56
C-103-TD	0.14	0.14	0.15	0.14	0.57
C-104-TD	0.21	0.22	0.23	0.20	0.86
C-105-TD	0.14	0.13	0.16	0.13	0.56
C-106-TD	0.17	0.18	0.19	0.16	0.70
C-107-TD	0.19	— ^b	0.20	0.16	0.73
C-108-TD	0.16	0.16	0.17	0.14	0.63
C-109-TD	0.21	0.20	0.23	0.18	0.82 ^c
C-110-TD	0.20	0.20	0.23	0.19	0.82 ^c
Mean	0.17	0.17	0.19	0.16	0.68
Std Dev	0.03	0.03	0.03	0.02	0.11

	[mrem]				
Mean	17	17	19	16	68
Std Dev	3	3	3	2	11

^a See Fig. 10-4 for sampling locations.

^b No data available for these samples; see Quality Assurance chapter.

^c When TLD data are missing, the annual dose is calculated as four times the average quarterly dose, as determined from available data.

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Introduction

Radiological doses to the public are due to both natural and man-made radiation. The total radiological dose to different populations from these sources is determined by extensive measurements and calculations. This chapter describes LLNL's radiological dose assessments, made to determine the impact of LLNL operations, and contains a discussion of the analysis we performed to establish LLNL's compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs).

Because this report is distributed outside the scientific community, we have included a brief preliminary discussion to enable the nontechnical reader to understand more easily the radiological dose assessment information we report. For more information the reader is referred to *Radiation: Doses, Effects, Risks* (U.N. Environment Programme 1985).

Natural and Man-Made Radiation

By far the greatest part of radiation received by the world's population comes from natural sources—primarily cosmic rays that impinge on Earth's atmosphere from space, and radionuclides naturally present in our environment, such as radioactive materials in soil and rocks. Among these terrestrial sources are carbon-14, potassium-40, rubidium-87, uranium-238, thorium-232, and the radioactive elements, such as radon, that arise following decay of uranium and thorium. The source of human exposure to natural radiation can be external (from substances staying outside the body) or internal (from substances inhaled in air or ingested in food and water). Individual doses vary with location. The level of cosmic radiation increases with altitude, because there is less air overhead to act as a shield, and the earth's poles receive more cosmic radiation than the equatorial regions, because the earth's magnetic field diverts the radiation. The levels of terrestrial radiation differ from place to place around the United States and around the world mainly due to variations in soil and rock composition.

Adding to this pervasive natural or background radiation is man-made radiation from radionuclides used in medicine, consumer products, the production of energy, and the production of nuclear weapons. Exposure to man-made sources can be controlled more readily than exposure to most natural sources. However, nuclear explosives tested in the atmosphere in the 1950s–

11. Radiological Dose Assessment

1960s spread radioactivity across the surface of the globe, and nuclear reactor accidents such as that at Chernobyl affected large areas. At present, medical treatment is the largest common source of public exposure to man-made radiation. Individual medical doses vary enormously—someone who has never had an x-ray examination may receive zero dose while patients undergoing treatment for cancer may receive many thousand times the annual average dose from natural radiation. Another source of public exposure to man-made radiation is consumer products, including luminous-dial watches, smoke detectors, airport x-ray baggage inspection systems, optical lenses, false teeth, and tobacco products.

Radioactivity

Generally, naturally occurring isotopes are stable, but notable exceptions include carbon-14, potassium-40, uranium-235, and uranium-238, which are naturally occurring but radioactive. Nuclear decay divides into three main categories: alpha, beta, and gamma. Alpha decay is the spontaneous emission of an alpha particle (a bound state of two protons and two neutrons—the nucleus of a helium atom) from a nucleus containing a large number of protons (82 or more most commonly). Beta decay is the spontaneous conversion of a neutron to a proton in the nucleus with the emission of an electron, and gamma decay is the spontaneous emission of high-energy photons (high-frequency light) by nuclei.

Radioisotopes decay at quite different rates; their “half-life,” or length of time for half of the atoms to decay, spans a wide range from fractions of a second to millions of years. For example, tritium (the radioactive form of hydrogen) has a 12.3-year half-life, compared to 24,131 years for plutonium-239.

Some radioisotopes undergo a decay chain, forming radioisotopes that decay into other radioisotopes until a stable state is achieved. As an example, an atom of uranium-238 can undergo alpha decay, leaving behind a daughter, thorium-234, which is also radioactive. The transformations of the decay chain continue, ending with the formation of lead-206, which is a stable isotope.

Radioactivity can be hazardous because radiation (alpha particle, beta particle, or gamma rays) is released with great energy. It is capable of altering the electronic configuration of atoms and molecules, especially by stripping one or more electrons off the atoms of the irradiated material, thereby disrupting the chemical activity in living cells. If the disruption is severe enough to overwhelm the normal restorative powers of the cell, the cell may die or become permanently damaged. Cells are exposed to many naturally occurring sources of chemical disruption, including toxic chemicals in food, microbes that cause disease, high-energy radiation from outer space (cosmic rays), heat and light (including the sun’s rays, which can cause sunburn and skin cancer). Consequently, cells and living organisms have evolved with the ability to survive

limited amounts of damage, including that due to naturally occurring radioactivity.

Three main factors determine the radiation-induced damage that might be caused to living tissue: the number of radioactive nuclei that are present, the rate they give off energy, and the effectiveness of energy transfer to the host medium, i.e., how the radiation interacts with the tissue. Alpha radiation can be halted by a piece of paper and can scarcely penetrate the dead outer layers of skin. Radioisotopes that give off alpha radiation are generally not health hazards unless they get inside the body through an open wound, or are ingested or inhaled. In those cases alpha radiation can be especially damaging, because its disruptive energy can be deposited within a small distance, resulting in significant energy deposited in a few cells. Beta radiation from nuclear decay typically penetrates a centimeter or two of living tissue. It therefore deposits energy over many cells, decreasing the insult to any single cell. Gamma radiation is extremely penetrating and can pass through most materials, only being significantly attenuated by thick slabs of dense materials, such as lead.

Measurement of Radioactivity and Dose

The rate that a nucleus decays is expressed in units of becquerels, abbreviated Bq, where one becquerel is one decay per second, or alternatively in curies, Ci, where one curie equals 3.7×10^{10} (37 billion) decays per second, or 3.7×10^{10} Bq (approximately equal to the decay rate of 1 gram of pure radium). Becquerels and curies are not measures of the effect of radiation on living tissue. This depends on the efficiency of energy deposition as the radiation traverses matter.

The amount of energy deposited in living tissue is called the "dose." The amount of radiation energy absorbed per gram of tissue is called the "absorbed dose," and is expressed in units of rads or grays (G), where 1 G equals 100 rads. Because an absorbed dose produced by alpha radiation is more damaging to living tissue than the same dose produced by beta or gamma radiation, the absorbed dose is multiplied by a "quality factor" to give the dose equivalent. The quality factor for alpha radiation is 20; for beta and gamma, 1. The dose equivalent is measured in units of rem or sievert (Sv); 1 Sv equals 100 rem. Also commonly used are millirem (mrem) and millisievert (mSv), which are one-thousandth of a rem and sievert, respectively.

Just as one type of radiation can be more damaging than others, some parts of the body are more vulnerable to radiation damage than others, so the different parts of the body are given weightings. For example, a given radiation dose is more likely to cause cancer in the lung than in the thyroid. The reproductive organs are of particular concern, because of the potential risk of genetic damage. Once particular organs are weighted appropriately, the dose equivalent becomes the "effective dose equivalent" (EDE), also expressed in rem or sievert.

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The effective dose equivalent describes doses to individuals. When individual effective dose equivalents received by a group of people are summed, the result is called the "collective effective dose equivalent" and is expressed in person-sievert or person-rem. Finally, to account for the long-term effects of radionuclides as they continue to decay and affect generations of people, we calculate the dose over many years, summing the effect over time. This is termed the "collective effective dose equivalent commitment." Most of our discussion in this chapter deals with the effective dose equivalent and the collective effective dose equivalent.

Sources of Natural Radioactivity

The average radiation dose from natural sources in the United States is 3.0 mSv/y (300 mrem/y). Approximately 0.3 mSv/y (30 mrem/y) of this exposure comes from high-energy radiation from outer space (cosmic rays). Terrestrial sources, mainly radionuclides in rock and soil, account for approximately 0.3 mSv/y (30 mrem/y) of the average natural dose. Another significant part of the dose comes from radionuclides we ingest through food and drink, resulting in approximately 0.4 mSv/y (40 mrem/y). Potassium-40 and carbon-14 are common radionuclides in food.

The remaining 67% of the average dose from natural sources in the United States comes from radon gas. Radon is one of the major radionuclides produced by uranium decay, and our inhalation dose is dominated by the short-lived decay products of radon. The dose varies with geographic location, but the average U.S. citizen receives approximately 2 mSv/y (200 mrem/y) of natural exposure from radon.

Radon gas seeps out of the earth worldwide. Radon in water and natural gas provide additional, but less important, sources of radon in homes. Consumption of water high in radon is not the main exposure source; a greater exposure is believed to arise from inhalation of radon in water vapor from showers. The U.S. Environmental Protection Agency (EPA) has instituted a major program to educate the public regarding the effects of naturally occurring radon (U.S. Environmental Protection Agency 1986).

Medical treatment is the largest common source of public exposure to man-made radiation, and most of it is from medical x rays. These contribute 0.39 mSv (39 mrem) to the average whole-body dose in the United States, but individual doses vary enormously. For example, a typical dental x-ray series results in a skin dose (not whole body) of approximately 2.5 mSv (250 mrem). Nuclear medicine contributes 0.14 mSv (14 mrem) to the average, and consumer products add 0.1 mSv (10 mrem). For a typical member of the public, radiation from medical procedures and consumer products result in a dose of approximately 0.63 mSv/y (63 mrem/y). The average dose from other man-made sources,

including fallout from nuclear testing, is about 0.02 mSv (2 mrem). Figure 11-1 shows the distribution of annual radiation doses from various sources.

Radiation Sources, Control Measures, and Standards

Radionuclides at LLNL

A wide variety of radioisotopes is used at LLNL, including transuranics, biomedical tracers, tritium, mixed fission products, and other radioisotopes for general research and nuclear weapons research. Radioisotope handling procedures and work enclosures are determined for each project, depending on the isotope, the quantity being used, and the type of operations being performed. Radioisotope handling and working environments include glove boxes, exhaust hoods and laboratory bench tops. Exhaust paths to the atmosphere range from triple-filtered stacks and direct small hood roof vents at the Livermore site, to direct dispersal of depleted uranium during non-nuclear explosives testing at Site 300.

LLNL's Radiation Control Program

Protection of employees and the public from the uncontrolled release of radioactive materials into the environment is a primary consideration of LLNL. This effort consists of four stages. First, when an operation or facility is designed, a thorough assessment of potential radiation hazards is conducted, and

engineering controls are specified to minimize exposure and release of dangerous quantities of radioactivity. These controls might include, but are not limited to, physical access control, shielding, and remote handling equipment. Facility Safety Analysis Reports and Facility Safety Procedures are written to document the need for these measures and to specify the requirements for maintenance, training, emergency response, and other administrative control measures.

The other three stages of the radiation control program come into play when a facility is occupied for use. The second part of the program takes place when, prior to the conduct of an operation in the facility, an Operational Safety

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Procedure (OSP) is written that specifies the actions to be taken in conducting a research or development project. This procedure is reviewed by analysts in the Environmental Protection Department and by industrial hygienists and health physicists in the Hazards Control Department. These reviews assess the safety of the operation, its compliance with current occupational health and environmental standards, and the adequacy of proposed engineering and administrative controls.

The OSP also specifies training requirements for personnel performing the procedure. This third part of the control program enables LLNL personnel who work with radiation and radioactivity to recognize and prevent the execution of unsafe operations.

The last stage of the radiation control program involves direct monitoring of the work environment and physical sampling of air and surfaces in facilities where radioactive materials are handled. Additionally, personal dosimetry and bioassay programs monitor for potential worker exposure to direct radiation and exposure to radioactive isotopes. This monitoring program measures the effectiveness of a facility's radiation control program, as well as providing information on worker exposures.

Radiation Protection Standards

DOE environmental radiation protection standards are provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, which incorporates standards for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection (ICRP 1977, 1980) and the National Council on Radiation Protection and Measurements (NCRP 1976a, b). The primary DOE radiation standards for protection of the public are 1 mSv/y (100 mrem/y) effective dose equivalent for prolonged exposure, and 5 mSv/y (500 mrem/y) effective dose equivalent for occasional exposure. These limits are based on the dose to the maximally exposed individual in an uncontrolled area.

The limits apply to the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from radioactive materials that may be ingested or inhaled during a calendar year, and that may therefore remain in the body for many years.

DOE and LLNL also comply with the EPA's standard for radiation protection. This EPA radiation dose standard, which applies to air emissions, is defined in 40 CFR 61. It limits to 0.1 mSv/y (10 mrem/y) the whole-body effective dose equivalent to members of the public from DOE activities. Before December 15, 1989, the standard was 0.25 mSv/y (25 mrem/y) dose equivalent for whole-body exposures from the air pathway, and 0.75 mSv/y (75 mrem/y) dose equivalent for exposure of any organ from the air pathway.

Because the EPA standard is small compared to natural exposures to radioactivity, it would be difficult to prove compliance with the standard by measuring the effects of the dispersal of radioactivity in the atmosphere. EPA has therefore developed computer codes that implement its approved dosimetry model, and mandated that these codes be used to calculate potential doses to the public for compliance demonstrations. Calculations reported here used either the EPA's AIRDOS or CAP88-PC code. The latter is a recently developed, improved and expanded computer code, incorporating a modified version of AIRDOS as one of its component codes. The models used in these codes to evaluate radiological doses and consequent risk contain conservative assumptions that are expected to result in calculated doses larger than ones actually received by members of the public.

Radiological Doses from Air Emissions

In accordance with DOE environmental protection orders and other federal and state requirements, LLNL assessed the radiological impact from operations at the Livermore site and Site 300 during 1992. Small amounts of radioactive materials from LLNL operations were discharged to the environment with air and sewer effluents (see Chapter 4 on Air Monitoring and Chapter 5 on Sewage Monitoring). Because sewer effluents are not consumed, they do not represent an ingestion or inhalation pathway for radiation exposure. Therefore, doses are calculated only for material that enters the environment via air releases.

Potential radiological doses to the public are either determined from measurements of radionuclides in the environment or calculated using EPA-approved computer codes. These calculations of the potential public dose use theoretical models for transport of radionuclides through the environment, including dispersion in air, into water and food, and finally into human beings through inhalation or ingestion. Although LLNL seeks to obtain sufficient samples of the local environment to assure that its impacts are well understood, sampling for radioactivity cannot occur at all locations. The theoretical calculations are important because they set an absolute upper bound on the potential radiological impacts of LLNL operations. The radionuclide source terms used in the codes are based on measured effluents and facility inventories.

The results of the measurements and calculations reported in this chapter are an important indicator of the success of LLNL's discharge control program. Development of the Livermore Valley and the San Joaquin Valley have decreased the distance between sources of emissions and the residents and workers that might be exposed. In all directions, people live and work within several hundred meters of LLNL's boundaries. It is therefore vital that our assessments provide the best information possible regarding the impact of LLNL operations.

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Monitored Releases of Radioactive Materials

General surveillance air monitoring for tritium and for radioactive particulates has been in place since the 1970s and will continue. The data from this monitoring network provide continuous measures of the concentrations of radionuclides present in the air at the Livermore site, Site 300, and in the surrounding areas. This network allows for direct measurements of the overall impact of LLNL operations, as discussed in detail in Chapter 4, Air Monitoring. Beyond the general monitoring, site-specific surveillance air monitors are placed in the vicinity of "diffuse" emission sources on site, such as those (described below) associated with Buildings 292, 331, 514, and 612, and in and around the southeast quadrant of the Livermore site. The data from these monitoring networks reveal the concentrations of radionuclides present in the air near these sources and allow a direct and accurate determination of their environmental impact. This practice will continue at these locations and will be instituted for any newly identified diffuse sources.

Radionuclide concentrations measured in environmental media are presented in the chapters in this report covering each specific medium. In particular, measurements of external direct radiation reported in Chapter 10, Environmental Radiation Monitoring, show no difference between doses measured in the immediate environs of LLNL's Livermore site and Site 300, as compared to measurements made at remote locations. While the Livermore-site boundary measurements of external gamma doses averaged 0.65 mSv (65 mrem), Livermore Valley locations averaged 0.66 mSv (66 mrem). Site 300 boundary locations average 0.78 mSv (78 mrem), while off-site samples showed 0.65 to 0.81 mSv (65 to 81 mrem). These measurements indicate that operations at the two sites did not significantly increase the possibility for public exposure to gamma radiation.

Routine LLNL operations during 1992 released a total of 6.55×10^{12} Bq (177 Ci) of tritium to the atmosphere; of that, 3.7×10^{12} Bq (100 Ci) was in the form of tritiated water. An additional 9.77×10^{12} Bq (264 Ci) was released by Sandia National Laboratories, California (SNL/CA), with approximately 4.81×10^{12} Bq (130 Ci) in the form of tritiated water. LLNL's electron-positron linear accelerator was not activated in 1992, thereby eliminating the releases of the short half-life radioisotopes ^{13}N (half-life of ten minutes) and ^{15}O (half-life of two minutes) that we reported in previous years. The amount of radioactivity released from LLNL during 1992 was less than during 1991, and was also below the range of previous years (see tables in Chapter 4, Air Monitoring).

There were no accidental radionuclide releases to the atmosphere at either the Livermore site or Site 300 during 1992.

Air Emissions Data

Reported annual releases are based on inventory data and unabated EPA potential release fractions (discussed below) for unmonitored sources, and on actual emission measurements for continuously monitored facilities. The continuously monitored facilities at LLNL are Buildings 175, 231, 251, 332, 419, 490, and 491. Many of the monitored facilities show zero emissions. The data are based on limit-of-sensitivity (LOS) results from the analysis of 100 samples. Use of zero values for LOS data in this case can be justified based on facility knowledge; the use of tested, multiple-stage, high efficiency particulate air (HEPA) filters (see next paragraph) in all significant release pathways; and isotopic analyses of selected filters, by alpha spectroscopy, which demonstrate that measured activity on filters comes from naturally occurring radionuclides such as radon daughters and polonium. In any case, given the level of HEPA filtration, it is likely that actual concentrations are closer to zero than they are to the LOS. Furthermore, even if the LOS values are substituted in screening dose calculations (a very conservative assumption), the total dose attributable to LLNL activities is not significantly affected.

HEPA filters are used in many LLNL facilities to control particulate emissions. For some discharge points, scrubbers and electrostatic precipitators aid the control of emissions. No stack emission control systems are implemented for tritium. The operational performance of all HEPA filtration systems is tested on a routine basis. The efficiency of a single-stage HEPA filter is 99.97%. Double-staged filter systems are in place at some discharge points. Triple-stage HEPA filters are used on glove-box ventilation systems in the Building 332 Plutonium Facility and in a portion of Building 251.

Some LLNL facilities have intermittent monitoring systems that function when operations are taking place. Other facilities have no effluent monitoring systems. All effective dose equivalents (EDEs) for unmonitored and non-continuously monitored facilities are based on radionuclide inventories and unabated emissions using EPA methodology. Such reported EDEs overestimate the actual LLNL impact. EDEs associated with continuously monitored facilities are based on the actual air emission monitoring data and are therefore more realistic estimators of potential dose.

LLNL Buildings with Radionuclide Release Potential

We have reviewed all LLNL buildings that contain radioactive materials management areas (RMMAs), i.e., areas in which radionuclides are used or activation products potentially occur. There are 56 buildings containing RMMAs—48 on the Livermore site and 8 at Site 300. **Table 11-1** lists these buildings, gives the number of potential radionuclide discharge points, the types of operations occurring in each facility, the calculated maximum effective dose equivalent that

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a member of the public could experience at or beyond the site boundary due to discharge points modeled for each facility, and cites the NESHAPs quarterly report(s) where the pertinent dose calculations were presented.

In **Table 11-1**, detailed information is given for all point source emissions from 43 Livermore-site buildings. Three Livermore-site facilities (Buildings 363, 365, and 366) are referenced, but operations using radionuclides no longer occur in those buildings, or the radionuclides are encapsulated or sealed. Two Livermore-site facilities (Buildings 514 and 612) are treated as area sources with detailed information given in the discussion of "diffuse sources" in the following section; three other diffuse sources also are discussed in that section. **Table 11-1** also includes detailed information for three Site 300 explosive testing facilities: Buildings 801, 850, and 851 and their associated firing tables. Five other Site 300 facilities are referenced but radionuclides are not in use in those buildings, are encapsulated, or are sealed.

Calculations of Effective Dose Equivalents

Description of Dose Model, Input Parameters, and Defined Terms

The EPA-mandated AIRDOS or CAP88-PC models were used to carry out our radiological dose assessments, as noted above. Early last year, when CAP88-PC became available, we changed from AIRDOS to almost exclusive use of CAP88-PC to take advantage of the significant improvements made in the model. Separate determinations of the EDE, in particular at the location of the "site-wide maximally exposed individual" as defined below, from all potential discharge points at LLNL singly and collectively, were made for the Livermore site and Site 300. The CAP88-PC and AIRDOS codes tabulate EDE in mrem/y.

Required input parameters for the AIRDOS/CAP88-PC model runs include isotope type, emission rate in curies per year ($1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$), and stack characteristics including height, diameter, and emission velocity of the effluent gas. Meteorological data input for all model runs were actual Livermore-site or Site 300 annual average data, as pertinent, acquired from the respective on-site meteorological towers. No EPA meteorological default files were used.

Because AIRDOS and CAP88-PC do not contain all the radionuclides present at LLNL, surrogate radionuclides were used in some cases to estimate EDEs. In selecting the surrogates, we used the most restrictive lung class (whether clearance from the lungs takes place in days, weeks, or years). When possible, we used a surrogate radionuclide with similar lung class chemistry and similar values for "annual limits of intake via inhalation and derived air concentration." CAP88-PC contains a library of considerably more nuclides than AIRDOS. By rerunning calculations in CAP88-PC previously modeled with AIRDOS, we have found that the use of surrogates in the calculations result in conservative estimates of EDEs.

Calculations for noncontinuously monitored facilities were based on assumptions concerning the fraction of the annual inventory that potentially could be released. If the material was a sealed gas, then the release fraction 0.01 generally was used; for liquids and powders, 0.001 was used; and for solids, 0.000001 was used; all in accordance with 40 CFR part 61, Appendices D and E. In addition, no credit was taken for radionuclide emission control devices; emission inputs into the models were assumed to be unabated. Hence, when control devices were in use, actual emissions and exposures were much lower than reported.

For monitored facilities, actual measured emissions were used as input variables into the codes. The use of actual monitoring data is much more direct and more accurate than using assumptions based on inventory and release fractions.

Modeling releases to the atmosphere from explosive tests using depleted uranium at Site 300 requires special attention compared to conventional stack or area sources. During experiments, the explosive device being tested is placed on an open-air firing table and detonated. We have limited data to characterize the initial state of the cloud of explosive decomposition products created by the detonation because properties of the cloud are not typically measured in the experiments. Empirical scaling laws can, however, be used to define the cloud using the radionuclide and high-explosive inventories. We assume all of the depleted uranium is dispersed into the cloud, and the median particle size is assumed to be the CAP88-PC default value of 1 micrometer. The masses of the three uranium isotopes (with atomic weights 238, 235, and 234) are multiplied by their respective specific activities to get the total number of curies for each isotope in the cloud. CAP88-PC then simulates each shot as a low-level, steady-state, stack-type emission occurring over one year. EPA directed LLNL to use the CAP88-PC code for these calculations, despite the recognized difficulties in modeling explosive events.

Another category of sources requiring special attention is "diffuse emissions," including "fugitive emissions." Diffuse, or nonpoint, sources are difficult to quantify, and dose calculations associated with these types of sources are left to the discretion of the DOE facility. Four different modeling approaches were used for diffuse sources at LLNL in 1992. Elevated tritium levels in soil moisture near Building 292 required a calculation of the source term and the use of CAP88-PC; a small amount of tritium-contaminated equipment outside Building 331 required facility personnel knowledge to estimate emissions; for Building 514, housing the Hazardous Waste Management "tank farm," and Building 612, adjacent to waste processing and storage yards, standard CAP88-PC modeling techniques were used; and elevated levels of plutonium in the southeast quadrant of the Livermore site used direct ambient air monitoring to get data on which to base dose calculations. A description of each such source

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and the assumptions made regarding their emissions are given in our NESHAPs Annual Report for 1992 (Surano et al. 1993).

Doses are evaluated for the site-wide maximally exposed individual (SW-MEI), defined as the hypothetical member of the public (individual receptor) who could receive the greatest LLNL-induced EDE from all sources at a single location. At the Livermore site, the SW-MEI is located at the UNCLE Credit Union, about 10 meters outside the controlled eastern perimeter of the site. This location lies 948 meters from the principal radionuclide source, the Tritium Facility (Building 331), in an east-northeast direction. At Site 300, the SW-MEI is located in an experimental area termed "Bunker 2" operated by Physics International. Bunker 2 lies about 300 meters outside the east-central boundary of Site 300. This bunker is 2.38 kilometers southeast of the principal firing table at Building 801. Some of our calculations preceded the choice of SW-MEI and may not include a dose value for that specific location. The EDE values we quote in this document are either those at the location of the SW-MEI or the maximum to any member of the public, in any direction.

Appendix B gives an expanded discussion of the doses of major interest, and presents examples of explicit dose calculations for different exposure pathways.

Calculated Results Summary—Livermore Site and Site 300, 1992

Table 11-2 summarizes our calculations of the annual radiation dose from airborne radionuclides emitted by LLNL operations in 1992. These air pathway doses, expressed as EDEs, were calculated using CAP88-PC and as such include exposures from inhalation, air immersion, ingestion, and ground surface irradiation. CAP88-PC was run using specific meteorology for the Livermore site and Site 300, as appropriate. Table 11-2 lists the principal facilities, i.e., those accounting for 97% or more of the total EDE, and shows the dominant radionuclide(s) for each facility. The listed EDE is equal to or greater than that which would be experienced by the SW-MEI.

For the Livermore site, the contribution to the total dose calculated for the SW-MEI from point source emissions is 0.69 μSv (0.069 mrem) and from diffuse emissions is 0.1 μSv (0.010 mrem). Summing the contributions from both point and diffuse sources yields a total dose of 0.79 μSv (0.079 mrem) for the Livermore site in 1992. The main contributions to this total were 0.37 μSv (0.037 mrem) or 47% from the LLNL Tritium Facility (Building 331) emissions, and 0.12 μSv (0.012 mrem) or 15% from one discharge point in Building 177. Directly measured emissions (i.e., those for the eight continuously monitored facilities—Buildings 175, 231, 251, 331, 332, 419, 490, and 491—and the diffuse emissions from the southeast quadrant) comprised 49% of the total for the Livermore site. The remainder is estimated by CAP88-PC model runs assuming unabated emissions. This Livermore-site dose represents less than 1% of the EPA limit of

0.1 mSv/y (10 mrem/y) for airborne emissions. Compared to data of previous years, this value is much reduced: dose values reported for 1991 and 1990 were 2.34 μ Sv (0.234 mrem) and 2.40 μ Sv (0.240 mrem), respectively. Reduced emissions of tritium from Building 331 accounts for much of this decline.

The dose to the site-wide maximally exposed member of the public at Site 300 during 1992 was calculated to be 0.21 μ Sv (0.021 mrem) EDE. Explosive tests at the Building 801 firing table accounted for nearly all of this dose. Emissions from other potential discharge points at Site 300 were negligible in 1992. For example, the firing table associated with Building 851 contributed only 6.5×10^{-6} μ Sv (6.5×10^{-7} mrem), and radioactive materials in Site 300 buildings are either encapsulated or sealed; no operations are performed within these facilities that have the potential to release radionuclides to the atmosphere under normal operating conditions. The dose contributed by firing table operations to the SW-MEI at Site 300 has been steadily declining: in 1991 it was 0.44 μ Sv (0.044 mrem), and in 1990 it was 0.57 μ Sv (0.057 mrem).

Site 300 remains an isolated facility. Except for similar test facilities to the east and south and a vehicular recreation area, the land is devoted to wind farming and livestock husbandry. The population density within several kilometers of the site is extremely low.

The principal radionuclides contributing to these doses are tritium in the tritiated water form (HTO)—which accounts for about 50% of the 0.79 μ Sv (0.079 mrem) Livermore-site dose—and the isotopes of uranium with atomic weights 238, 234, and 235, accounting for all of the Site 300 dose and about 36% of the Livermore-site dose. The relative significance of inhalation and ingestion via the air pathway is different for these nuclides. Ingestion is slightly more important than inhalation in the case of tritium, with a ratio of about 52/48, while inhalation is far more important for uranium, contributing about 95% versus 5% for ingestion.

Table 11-3 compares the radiation doses due to atmospheric emissions at LLNL to other sources of radioactivity to which the U.S. population is exposed. The dose resulting from Livermore-site operations is lower by a factor of 3000 for the maximally exposed individual. **Table 11-3** shows that, among the sources of background radiation, radon emissions rank highest. Doses from LLNL operations are at the typical ambient outside levels for radon, with concentrations of 4×10^{-3} to 2×10^{-2} Bq (0.1 to 0.5 pCi) per liter of air. The EPA radon screening level is 0.1 Bq (4 pCi) per liter of air. To place the DOE radiation protection limit, 1 mSv/y (100 mrem/y), into perspective, during the same period the average resident of the Livermore Valley receives a dose of approximately 3.0 mSv/y (300 mrem/y) from natural background radiation, including the dose from radon.

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The CAP88-PC code was used to calculate the collective population dose. The collective effective dose equivalent for the population is the sum of the estimated doses to all individuals residing within an 80-kilometer radius of LLNL. The calculated collective EDE for the total population (which is estimated to be 6.3 million within 80 kilometers of the Livermore site, based on 1990 census information) was 0.015 person-Sv (1.5 person-rem) from Livermore-site emissions during 1992. The collective EDE due to emissions from the relatively isolated Site 300 was, surprisingly, nearly five times higher, estimated to be 0.071 person-Sv (7.1 person-rem) for the 5.4 million people within 80 kilometers of Site 300. The main reason is that the Site 300 explosion effluent gets thrown much higher into the air than conventional stack emissions, and the Gaussian dispersion model in CAP88-PC predicts that the concentration drops off very slowly with distance. In any case, these collective EDEs from the two LLNL sites are quite small compared to that from natural sources of radiation. Using 3.0 mSv (300 mrem) as a typical annual average from natural sources, the collective EDE due to natural sources during the same period was estimated to be 1.9×10^4 person-Sv (1.9×10^6 person-rem).

Summary and Conclusion

Calculations of effective dose equivalents for all Livermore site and Site 300 facilities having the potential to release radionuclides to the atmosphere have been completed. The annual dose from actual emissions (after control devices) of all facilities was found to be well below the applicable standards for radiation protection of the public, in particular the 100 $\mu\text{Sv}/\text{y}$ (10 mrem/y) NESHAPs standard. Three facilities at the Livermore site (Buildings 331, 332, and the hardened portion of Building 251) will maintain continuous monitoring systems, based on their potential for emissions exceeding 1 $\mu\text{Sv}/\text{y}$ (0.1 mrem/y) without emission control devices. No other facilities at either the Livermore site or Site 300 were found to require continuous monitoring systems, though five additional facilities have continuous monitoring in place.

Using the EPA-mandated computer models and actual LLNL meteorology, the 1992 calculated EDE to the individual site-wide maximally exposed member of the public from Livermore site radionuclide air emissions was 0.79 μSv (0.079 mrem). The main contribution, 0.37 μSv (0.037 mrem), was from the LLNL Tritium Facility (Building 331) emissions, which constituted 47% of the Livermore site EDE. The only other emission point contributing greater than 10% of the EDE was one discharge point in Building 177, whose emissions accounted for 15% of the EDE.

The EDE to the individual site-wide maximally exposed member of the public at Site 300 was calculated to be 0.21 μSv (0.021 mrem). Building 801 firing

table experiments accounted for nearly all of this EDE. No other Site 300 operations resulted in significant dose contributions.

The collective effective dose equivalent for LLNL 1992 operations was 0.015 person-Sv (1.5 person-rem) from the Livermore site and 0.071 person-Sv (7.1 person-rem) from Site 300, including all pathways (ingestion, air immersion, surface exposure, and inhalation pathways). The dose was calculated out to a distance of 80 kilometers from both sites in all directions using 1990 census population data comprising 6.3 million people for the Livermore site and 5.4 million for Site 300.

These potential radiological doses from LLNL operations were approximately three thousand times less than the doses normally received by this population from natural background radiation sources, even though highly conservative assumptions were used in the calculations. Thus, the maximum credible doses show that LLNL's use of radionuclides had no significant impact on public health during 1992.

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Table 11-1. LLNL buildings containing RMMAs.

Bldg	Facility	Potential discharge points	Max EDE ^a ($\mu\text{Sv/y}$)	Quarter reported ^b	Operations
131	Engineering	2	4.0×10^{-3}	Dec. 91	Handling, storing, machining, characterizing, assembling, sorting, and transferring materials, repackaging of waste
151	Nuclear Chemistry	23	2.1×10^{-2}	Sept. 91 Dec. 92	Chemical separation, crushing/dissolving, aliquot preparation and storage, gas analysis, radiochemical separations, preparation of radioactive counting standards
171	Lasers	1	3.1×10^{-8}	Sept. 92	Melting of uranium under vacuum
175	MARS	6 ^c	2.4×10^{-1}	Dec. 92	Cleaning/disassembly of uranium parts
177	Lasers	6	1.2×10^{-1}	May 93 Annual	Vaporization and coating of uranium
179	Lasers	2	1.3×10^{-3}	Sept. 92	Melting of uranium under vacuum
190	Physics	1	0.0	Mar. 92	Accelerator
194	Physics	2	3.2×10^{-2}	Dec. 91 Dec. 92	Accelerator
212	Physics	2	1.8×10^{-9}	Sept. 92	Environmental, safety, and health surveillance for shutdown of accelerator
222	Chemistry	16	2.8×10^{-2}	Sept. 91 Dec. 92	Radioanalytical analyses and tracer use
226	Chemistry	1	8.1×10^{-8}	Mar. 92	Radioactive and mixed waste chemical analyses
227	Chemistry	3	8.2×10^{-5}	Sept. 91	Uranium bonding and testing
231	Mechanical Engineering	5	1.5×10^{-4}	Mar. 92	Materials research and testing, plastics shop work, electron beam welding
	Mechanical Engineering Vault	1 ^c	0.0	Sept. 92	Storage, handling, and shipping of radionuclides
235	WMRDF	8	2.7×10^{-6}	Dec. 91	Welding, actinide and uranium catalyst research
241	Physics	2	2.1×10^{-5}	Sept. 92	Materials development, measurement, and testing
243	Energy Research	1	0.0	Mar. 92	Earth sciences and geological studies
251	Heavy Elements				Heavy-element research
	hardened area	4 ^c	— ^d	Dec. 92	
	unhardened areas	44 ^c	7.8×10^{-1}	Dec. 92	
253	Hazards Control	1	6.3×10^{-14}	Sept. 92	Radiochemical analyses
254	Hazards Control	1	0.0	Sept. 92	Radiochemical analyses of bioassays
255	Hazards Control	1	4.1×10^{-6}	Sept. 92	Instrument calibration
2581	Test Program	1	1.0×10^{-7}	Sept. 92	Foil testing
281	Nuclear Chemistry	4	5.1×10^{-3}	Sept. 91	Preparation and storage of radiochemical stock solutions
282	Nuclear Chemistry	1	8.2×10^{-3}	Sept. 91 Mar. 92	Use of tritium gas in spectrometer experiment

...continued

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Table 11-1. LLNL buildings containing RMMAs (*continued*).

Bldg	Facility	Potential discharge points	Max EDE ^a (μSv/y)	Quarter reported ^b	Operations
292	Physics	3	7.8×10^{-7}	Sept. 92	Tritium contamination from prior operations
298	Laser Fusion	2	1.8×10^{-3}	Sept. 92	Handling and assembly of tritium-filled targets; sputtering uranium
321	Materials Fabrication	5	4.0×10^{-3}	Dec. 91	Machining
331	Tritium	2 ^c	1.9×10^{-1d}	May 93 Annual	Cryogenic tritium experiments and cryogenic experiments on deuterium-tritium
332	Plutonium	11 ^c	— ^d	Dec. 92	Machining and metallurgy
341	Physics	1	4.2×10^{-6}	Mar. 92	High-energy research
361	Biomedical Research	16	1.1×10^{-5}	Sept. 91 Dec. 92	Radiolabeling and use of tracers for biomedical research
363	Biomedical Research	— ^e	0.0	Sept. 91	Biomedical research
365	Biomedical Research	4	0.0	Sept. 91	Radiolabeling and use of tracers for biomedical research
366	Biomedical Research	— ^e	0.0	Sept. 91	Biomedical research
377	Environmental Research	3	8.8×10^{-5}	Mar. 92	Radiolabeling and use of tracers for environmental research
378	Environmental Research	2	1.6×10^{-6}	Mar. 92	Radiolabeling and use of tracers for environmental research
381	Laser Research	2	1.9×10^{-4}	Sept. 92	Neutron generation
391	NOVA	3	2.0×10^{-3}	Sept. 92	Vaporization of targets
412	Environmental Research	— ^e	0.0	Mar. 92 Dec. 92	Environmental monitoring of soils and other media
419	Decontamination	2 ^c	0.0	Dec. 92	Decontamination of equipment (in process of being closed)
490	Laser Isotope Separation	4 ^c	4.6×10^{-2}	Mar. 92 Dec. 92	Melting and vaporization of uranium, isotope separation
491	Laser Isotope Separation	1 ^c	0.0	Mar. 92	Refurbishment of separator components
493	Support Facility	— ^e	0.0	Dec. 92	Isotope storage
513	Hazardous Waste Management	3	6.3×10^{-4}	Sept. 91	Storage, solidification, and shredding of waste
514	Hazardous Waste Management	1	5.0×10^{-2}	Sept. 91 Dec. 92	Waste treatment
594	Environmental Research	— ^e	0.0	Dec. 92	Tracer experiments for atmospheric pollution
612	Hazardous Waste Management	5	5.6×10^{-4}	Sept. 91	Lab packing, bulking, compacting, baling, and handling of waste; drum crushing

...continued

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Table 11-1. LLNL buildings containing RMMAs (*concluded*).

Bldg	Facility	Potential discharge points	Max EDE ^a (μSv/y)	Quarter reported ^b	Operations
614	Hazardous Waste Management	— ^e	0.0	Dec. 92	Storage of waste
625	Hazardous Waste Management	— ^e	0.0	Dec. 92	Container storage
801	Site 300	— ^e	0.0	Mar. 93	Electron beam accelerator/machining/firing table
	Site 300 Firing Table at 801	— ^f	2.1×10^{-1}	May 93 Annual	Detonation of explosives
804	Site 300	— ^e	0.0	Mar. 93	Low-level-waste storage area
810A	Site 300	— ^e	0.0	Mar. 93	Storage of parts
810B	Site 300	— ^e	0.0	Mar. 93	Storage of parts
822B	Site 300	— ^e	0.0	Mar. 93	Storage of parts
850	Site 300	— ^e	0.0	Mar. 93	Firing table bunker
	Site 300 Firing Table at 850	— ^f	0.0	May 93 Annual	Detonation of explosives
851	Site 300	— ^e	0.0	Mar. 93	Electron beam accelerator/firing table
	Site 300 Firing Table at 851	— ^f	6.5×10^{-6}	May 93 Annual	Detonation of explosives
854F	Site 300	— ^e	0.0	Mar. 93	Storage of mixed fission products

^a The maximum effective dose equivalent occurring at or beyond the site boundary from a single discharge point, among all discharge points modeled for a facility.

^b Date of quarterly or annual NESHAPs report submission to EPA.

^c Facility has an air effluent sampling system on at least one discharge point.

^d The effluents from the facility are and will continue to be monitored.

^e Radionuclides are not in use, are encapsulated or sealed, or the quantities fall below the screening levels for modeling.

^f Open air dispersal in 1992.

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Table 11-2. Annual radiation dose via airborne emissions, 1992.

Facility or operation ^a	Dominant radionuclide(s)	EDE at SW-MEI	
		μSv/y	mrem/y
Livermore site			
B331/Tritium Facility	³ H	0.37	0.037
B177/Lasers	²³⁸ U, ²³⁴ U, ²³⁵ U	0.166	0.0166
B151/Nuclear Chemistry	²³⁹ Pu, ²⁴⁰ Pu, ¹⁵² Eu, ¹⁴¹ Ce, ²¹⁰ Pb	0.078	0.0078
B222	²³² Th, ²³⁸ U, ¹⁴¹ Ce	0.028	0.0028
B321	²³⁸ U	0.017	0.0017
B282	³ H	0.016	0.0016
B514 ^b	²³⁸ U, ²³⁵ U	0.069	0.0069
SE Quadrant ^b	²³⁹ Pu	0.019	0.0019
B331 ^b	³ H	0.0089	0.00089
Sum of other sources	various	0.018	0.0018
		Total = 0.79 ^{c,d}	0.079 ^{c,d}
Site 300			
B801/firing table	²³⁸ U, ²³⁴ U, ²³⁵ U	0.21 ^c	0.021 ^c

^a The facilities cited here are discussed in the text of this report, and in more detail in NESHAPs quarterly and annual reports.

^b Diffuse sources (see text).

^c These Livermore site and Site 300 totals represent 0.8% and 0.2%, respectively, of the federal standard.

^d Directly measured emissions (mainly those from B331 stacks and SE quadrant diffuse emissions) comprise 49% of this total; the remainder is estimated by CAP88-PC calculations assuming unabated emissions (see text).

11. Radiological Dose Assessment

Table 11-3. Comparison of radiation doses, LLNL, 1992.

Location/source	Individual dose ^a		Population dose ^b	
	(mSv)	(mrem)	(person-Sv)	(person-rem)
Livermore-site sources				
Atmospheric emissions	0.00079	0.079	0.015	1.5
Site 300 sources				
Atmospheric emissions	0.00021	0.021	0.071	7.1
Other sources^c				
Natural radioactivity ^d				
Cosmic radiation	0.3	30	1,900	190,000
Terrestrial radiation	0.3	30	1,900	190,000
Internal (food consumption)	0.4	40	2,500	250,000
Radon	2.0	200	12,500	1,250,000
Medical radiation (diagnostic procedures) ^e	0.53	53	3,300	330,000
Weapons test fallout ^e	0.011	1.1	68	6,800
Nuclear fuel cycle ^e	0.004	0.4	25	2,500

^a This dose represents that experienced by the site-wide maximally exposed individual 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 6.3 million people for the Livermore site and 5.4 million for Site 300), calculated with respect to distance and direction from each site.

^c From National Council on Radiation Protection (NCRP 1987).

^d These values vary with location.

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

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Introduction

The previous chapters on environmental media monitored by LLNL presented data from the monitoring activities, and Chapter 11 discusses the radiological dose assessments. In this chapter, the data on nonradiological pollutants are summarized graphically and compared to regulatory limits. These results demonstrate LLNL's continued compliance with regulatory requirements, as well as the effectiveness of LLNL's operational controls.

Air Monitoring

LLNL conducts surveillance air monitoring, which involves measurement of particles collected on filters, to determine if airborne hazardous materials are being released by Laboratory operations. To comply with the Clean Air Act National Emissions Standards for Hazardous Air Pollutants, concentrations of beryllium are monitored at the Livermore-site perimeter, at off-site locations near the Livermore site, and at Site 300. Concentrations of lead are also monitored at Site 300. The annual average concentration of airborne beryllium at the Livermore site is 23.5 pg/m³ and is less than 0.3% of the monthly ambient concentration guide of 10,000 pg/m³ established by the Bay Area Air Quality Management District (BAAQMD). These levels are attributed to suspension of surface soil containing naturally occurring beryllium. At Site 300, the annual average airborne beryllium concentration is 26.3 pg/m³ and is also less than 0.3% of the monthly ambient concentration guide. **Figure 12-1** shows the monthly mean concentration of beryllium on air filters at the Livermore-site perimeter and at Site 300.

The estimated release from exempt and permitted sources of air pollutants at the Livermore site can be compared with the most recent estimate of 1992 daily release of air pollutants for the entire Bay Area. For example, the total estimated oxides of nitrogen released in the Bay Area is 500 metric tons per day, compared to LLNL's 0.079 metric tons per day (0.02% of total Bay Area emissions). The BAAQMD estimate for reactive organic emissions (ROG) is 743 metric tons/day,

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versus Livermore site's 0.013 metric tons/day (0.002% of total Bay Area emissions) in 1992.

Sewage Monitoring

LLNL discharges wastewater to the Livermore Water Reclamation Plant (LWRP) under a permit that limits the concentrations of certain contaminants to prevent disruption of the treatment plant operations. To demonstrate compliance with those conditions, LLNL conducts a self-monitoring program that includes metals, organic toxins, and water quality indicators. A flow-proportional sampling system is used to acquire the necessary samples. Weekly composites of these samples are analyzed for metals, and once each month special samples are analyzed for a broad range of water quality parameters.

The data gathered in 1992 are presented in Chapter 5, Sewage Monitoring, and summarized in **Figure 12-2**. The results of the weekly metals analyses show that, on average, metals concentrations remained well below the discharge guideline. The results for the quarterly water-quality and toxic chemicals monitoring were also generally unexceptional.

LWRP issued one Notice of Violation to LLNL during 1992, for discharges of oil and grease above the permit limit of 100 mg/L. Because the LWRP uses an oil and grease separator to prevent buildup of grease in sensitive components of the treatment process, no enforcement action was pursued beyond the issuance of a formal Notice of Violation. However, the LWRP recommended changes to the LLNL sampling protocol. Prior to August 1992, the oil and grease analysis was performed on a single grab sample of LLNL's effluent, so the results represented concentrations only at that single point in time. The LWRP suggested that LLNL take a number of grab samples during a 24-hour period and average the sample results to obtain a daily average oil and grease value, providing a more representative measure of LLNL's impact on the LWRP. Finally, LLNL reviewed discharge controls at facilities that are known to generate large quantities of oil and grease (three on-site cafeterias), identifying potential problems and specifying improvements to be made to those operations. These improvements are planned for implementation during FY93.

LLNL maintains equipment that continuously monitors for high concentrations of radioactivity, metals, and acids or caustics. Although less sensitive than

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the off-line chemical analysis, this system is capable of detecting discharges that might have a serious impact on LWRP operations. In such circumstances, LLNL's Sewer Diversion Facility (SDF) is automatically activated, thereby preventing release of all except the first few minutes of the affected sewage. During 1992, ten possible problem releases were identified but none represented a threat to LWRP operations. Following analysis to make certain the retained sewage met discharge requirements, effluent diverted into the SDF was returned to the sanitary sewer.

Water Monitoring

Water sources that are analyzed for nonradiological constituents include ground water, surface water, and domestic water supplies. Samples are analyzed using standard EPA methods for solvents, metals, and pesticides.

Of the various types of water sources tested, specific regulatory concentration limits exist only for drinking water supplies (22 CCR 64443). At Site 300, on-site water supply Wells 18 and 20 are sampled quarterly for metals (beryllium, chromium, copper, and lead) and monthly for volatile organic compounds (VOCs). The locations of these wells are shown in **Figure 6-5** in Chapter 6 on Surveillance Water Monitoring. **Figure 12-3** shows that the only analytes detected in 1992 were chromium, copper, lead, TCE, and 1,1,1-trichloroethane. None of the observed concentrations of positively detected analytes exceed 30% of the applicable primary drinking water standard.

Off-site drinking water supply Wells CARNRW2, CDF1, CON1, and GALLO1 are sampled quarterly for metals (beryllium, chromium, copper, and lead) and for VOCs; these wells are sampled concurrently with the two on-site wells during each quarter as part of routine ground water surveillance monitoring. As shown in **Figure 12-3**, the concentrations of positively detected analytes were all 40% or less of their applicable primary or secondary drinking water standard. Trihalomethanes were detected in CARNRW2 during 1992, caused by sample contamination from the well chlorination system; in 1993, the procedures were changed to eliminate this problem. The elevated levels of selenium and arsenic in wells in the Site 300 area are believed to result from natural rather than man-made causes (Buddemeier et al. 1987).

Annual samples are collected from five wells located near Site 300. Although these wells are used primarily to supply livestock and fire protection water, human consumption of the water from these wells is not precluded. Therefore, primary drinking water standards are used as the most conservative standard for comparison. The average concentrations of detected analytes were all below 75% of the standard (see **Figure 12-3**). Again, the elevated levels of selenium and arsenic are believed to occur from natural geologic conditions in the area.

Soil and Sediment Monitoring

Sediment samples from the arroyos and other drainages at and near LLNL were collected in 1992, continuing a monitoring effort begun in 1988. Analyses were conducted for a full suite of nonradiological constituents, including metals, pesticides, PCBs, VOCs, and semivolatile organic compounds, to determine if significant buildup of pollutants had occurred. Because there are no standards directly written for sediments, the standards against which the results are compared are state standards for waste (22 CCR Chapters 11 and 18).

Small amounts of metals and organic compounds were detected in sediments. In general, the levels detected were trace amounts, often at or near the analytical detection limit; these levels are indicative of background concentrations. Current analytical techniques for detection of organic compounds are much improved compared to those in the past. Therefore, traces

Figure 12-3. Comparison of maximum values of nonradiological water pollutants at Site 300 locations to their regulatory limits.

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of a variety of compounds (many of which were undetectable before 1989) were observed in some samples. When compared with regulatory limits, all the measured concentrations were small fractions of their respective standards (Figure 12-4). Most of the measured concentrations were less than 1% of their respective standard, and all concentrations were less than 10% of the standard. Also, the average values (means and medians) used to generate the comparisons included analytical detection limit values even when the results were reported as less than the detection limit. This means that the averages are conservative, and that actual concentrations were likely to be lower.

The metals and organic compounds that were detected in arroyo sediments generally can

be expected near any urban area. Many of the organic compounds are common solvents (or fuel constituents) and are expected in areas that collect storm water runoff, such as in the LLNL drainages and arroyos.

Also during 1992, surface soil samples collected from the Livermore Valley and at Site 300 were analyzed for beryllium. Beryllium, a potentially toxic metal that is used at both the Livermore site and Site 300, is also a naturally occurring metal in soils worldwide. The beryllium concentrations detected in surface soils in the Livermore Valley and at Site 300 are within the range of worldwide natural background concentrations, although the concentrations in samples from Site 300 were approximately twice that of samples from the Livermore Valley. The mean concentrations from both areas were small fractions of the beryllium regulatory limit for waste (Figure 12-4); neither mean concentration was above 0.01 of the regulatory limit.

In summary, nonradiological analyses of sediments and surface soils indicate that the impact of LLNL operations on the nonradiological constituents in these

media during 1992 did not change from previous years and remains insignificant. All analytes were detected at background concentrations, in trace amounts, or could not be detected at all.

Noise Monitoring

On the basis of meteorological measurements made prior to a test, a limit is set on the weight of high explosives (HE) that can be detonated without noise impact on populated areas. To monitor this limit, six microbarograph sensors are maintained in or near the City of Tracy.

LLNL conducted 269 high-explosives tests at Site 300 during 1992. Microbarograph measurements in the vicinity of Site 300 and the City of Tracy demonstrated that the peak noise limit of 126 dB (400 μ bar) was not exceeded during any of these tests. There were no complaints of noise or overpressure from residents in the vicinity of Site 300, and none of the 269 tests produced noise levels above 120 dB (200 μ bar) at any of the six stations. (See Figure 12-5 for noise monitoring locations.)

Environmental Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations, including the 5000 series of DOE Orders, DOE Order 5000.3A, *Occurrence Reporting and Processing of Operations Information*, and DOE Order 5484.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements*. DOE Order 5000.3A, issued in May 1990, provides guidelines for contractor facilities to categorize and report environmental occurrences to DOE. The Order divides occurrences into three categories: emergencies, unusual occurrences, and

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off-normal occurrences. (DOE Order 5000.3B has been issued with an effective date of February 22, 1993; however, the contract between the University of California and DOE requires a 60-day review period for UC to respond to DOE Orders; therefore, LLNL will continue to refer to DOE Order 5000.3A until further notice.)

The Environmental Protection Department (EPD) responds to all reports of spills or other environmental occurrences through a well-established reporting process. EPD has established a 7-days-a-week, 24-hours-a-day, on-call, rotational position called the Environmental Duty Officer (EDO), who can be reached by pager or by cellular phone at any time. The EDO determines the reporting requirements, works with environmental analysts and with Laboratory management on the process of notifying local, state, and federal regulatory agencies and DOE, and provides advice on immediate cleanup and monitoring necessary to protect the environment.

EPD responded to 11 incidents during 1992 through the first quarter of 1993 that required agency notification. Two of these incidents qualified as an unusual occurrence in the DOE Order 5000.3A reporting scheme; the other incidents were reported as off-normal occurrences (any incident that requires notification of an environmental regulatory agency is considered an off-normal occurrence). None of these incidents caused any adverse impact to human health or the environment. These incidents are described below.

A blocked sewage line on February 22, 1992, resulted in a 95-liter sewage release into the storm system between Trailers 3725 and 3726. The sewage line was cleared and the area was sprayed with disinfectant. The San Francisco Bay Regional Water Quality Control Board was notified.

On April 21, 1992, 5680 liters of low-conductivity cooling water (LCW) were released in Building 341, Room 1304, when a leak occurred in the LCW line. A portion of the spill flowed under the door of Room 1304 and out onto the asphalt and gravel north of the building. The source of the leak was identified and repaired. Approximately 500 liters of water inside the building were recovered and disposed of in the sanitary sewer following verification of sewerability.

On May 22, 1992, wastewater containing lead, chrome, and copper was observed to be leaking from a 55-gallon drum stored in the Building 612 Receiving, Segregation, and Container Storage Unit. Between 15 and 23 liters of wastewater were recovered from the secondary containment basin for the unit. The wastewater in the drum was transferred to a new container and the secondary containment basin was decontaminated. This was reported as an unusual occurrence.

On July 14, 1992, oil from a leaking hydraulic press spilled into a nearby sump that was connected to the storm drain system. Approximately 26 liters of oil were recovered from the storm drain manhole and disposed of as hazardous

waste. In addition, the storm drain line leading from the sump to the storm drain manhole was decontaminated.

On July 15, 1992, up to 8 liters of industrial wastewater, containing sewerable and nonhazardous levels of trace metals, sprayed out of a damaged underground retention system line onto the soil outside Building 231. The sink that discharged to the damaged pipe was closed off. The liquid in the underground collection tank was pumped to an aboveground tank to prevent additional liquid from leaking.

On August 18, 1992, 1890 liters of fire suppression water were released from open lines during installation of the fire suppression system in Building 153. A small volume escaped the building and spilled onto the ground outside the building. Water supplying the lines was shut off. Water in the building was mopped up and vacuumed. This water was inadvertently dumped onto the ground outside the building.

On August 25, 1992, between 190 to 380 liters of rinse water, generated during the rinsing of a tanker truck that previously contained sewerable wastewater, were released onto the asphalt yard of the Area 612 Facility. The rinse water flowed across the yard and entered an earthen storm drain ditch. Absorbent was used to dam off the entrance to the storm drain ditch, thereby preventing any additional rinse water from leaving the facility. All standing water was collected using wet/dry vacuums. Absorbent was used to absorb any remaining liquid in the facility yard and the drainage ditch.

On September 10, 1992, a release of 60 liters of treated wastewater occurred when water was being pumped from the tank farm to portable tanks at Building 514. Water spilled onto the asphalt and soil. Standing water was collected using a wet/dry vacuum and absorbent. The water was determined to be sewerable.

On September 17, 1992, a cap blew off a photoprocessing filter unit in Building 551W basement, discharging approximately 38,000 liters of uncontaminated filtered drinking water into utility trenches located on the floor of the basement. To avoid a potential electrical hazard, the water was pumped from the trenches to the outside parking lot, which drained to the Central Drainage Basin.

On September 21, 1992, 60 liters of liquid sewage were released to the ground southwest of Trailer 5627 as a result of a pump failure. No liquid sewage migrated off site, and the pump was subsequently repaired.

On October 22, 1992, between 19 to 38 liters of lead-contaminated oil spilled from a honing machine during transport near the intersection of East Gate Drive and South Outer Loop Road, south of Building 411. Absorbent was used to clean up residual oil spilled on the asphalt. All spent absorbent was disposed of as hazardous waste.

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Agencies notified of the incidents described above included the DOE, the Alameda County Department of Health Services, the U.S. Environmental Protection Agency, the California Environmental Protection Agency Department of Toxic Substances Control, the San Francisco Regional Water Quality Control Board, Office of Emergency Services, and the National Response Center. None of the incidents caused any adverse impact to human health or the environment.

Superfund Amendments and Reauthorization Act (SARA) Title III Reporting Requirements

SARA Title III also is known as the Emergency Planning and Community Right-to-Know Act. It requires owners/operators of facilities that have certain hazardous chemicals on site to provide information on the manufacture, use, and storage of those chemicals to organizations responsible for emergency-response planning. In California, this information must be provided to the California Office of Emergency Services, the county, and the local fire department.

An initial physical inventory of all chemicals subject to reporting under SARA Title III was conducted during November and December 1988. The inventory included the chemical name, location, weight, type of container, and physical state of the substance. The inventory included the Livermore site, Site 300, and leased space off site. In early 1989, the data were entered into a computerized database system and reports were generated for local emergency planning agencies. In subsequent years, EPD continued periodic updates of the inventory to reflect changes in chemicals handled on site.

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Introduction

Quality Assurance (QA) requirements for environmental monitoring of Department of Energy (DOE) facilities are mandated by a number of DOE documents: DOE Order 5400.1 identifies QA requirements for radiological effluent and surveillance monitoring and specifies that a QA program consistent with DOE Order 5700.6B be established; DOE Order 5700.6B sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs; finally, the DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) requires the preparation of an Environmental Monitoring Plan containing a QA section that discusses the applicable elements of the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989).

During 1992, LLNL conducted QA activities at the Livermore site and Site 300 in accordance with a plan based on DOE Order 5700.6B and ANSI/ASME NQA-1 (Holland 1987). Sampling was conducted according to procedures published in the LLNL *Environmental Monitoring Plan* (Gallegos et al. 1992b).

Environmental monitoring samples are analyzed by LLNL or commercial laboratories using EPA standard methods when available. When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. The radiochemical methods used by LLNL's Radiation Analytical Sciences laboratory are described in their procedures. When analyses are performed by independent contractors, LLNL requires that their laboratories be certified by the State of California. In addition, LLNL requires all analytical laboratories to maintain adequate quality assurance programs and documentation of methods. Laboratory audits are performed annually as required by the QA plan (Holland 1987). Furthermore, both internal and independent audits of LLNL's monitoring program are performed annually.

Deviations and Changes to the Sampling Program

The sections below describe changes to the environmental sampling effort made during 1992, deviations from planned environmental sampling, and regularly scheduled samples for which data are not reported because they could not be collected or were lost during analysis.

Sampling Location Designators

Tables 13-1 and 13-2 decode sampling location designators and provide a cross-reference for current designators and those used in previous years.

Air Sampling Program

One Quality Assurance duplicate sampler was added to the air tritium network in July 1992. No other changes were made to either the air tritium or the air particulate network. During 1992, 546 of 561 possible air particulate samples and 482 of 498 possible air tritium samples were collected as part of the routine monitoring program. These represent sample recovery rates of 97% for both matrices. [The Quality Assurance Plan (Holland 1987) sets a minimum sample recovery rate of 85%.] Lost air particulate samples were usually caused by sampler malfunction or loss of electric power. Air tritium sample loss was due to sampler malfunction or breakage of sample flasks.

Sewage Monitoring Program

Modest changes were made to the sewer monitoring network during 1992. The sampling location for Sandia National Laboratories, California (SNL/CA) effluent was moved when, as part of a planned upgrade, SNL/CA re-routed its sewage flow to combine with LLNL sewerage just west of LLNL Building 111. The new location became operational in May. Secondly, LLNL altered the methodology for sampling the combined LLNL and SNL/CA effluent as it enters the City of Livermore collection system. Previously, flow-proportional compliance samples were collected from the flow that runs through the continuous monitoring system. The Livermore Water Reclamation Plant (LWRP) felt that this sample was inappropriate for compliance metals analysis because maceration and chlorination were performed before the flow reached the compliance sampler. An upstream sampler was installed in October. The location designators for sewer sampling were updated in 1992 as indicated in Table 13-1.

Sample and data capture in the compliance sampling program was high: 913 of 927 samples were acquired and analyzed, for a total data capture of 98%. Missed samples resulted from sampling equipment failure and personnel turnover at the LWRP where City of Livermore employees collect some samples for LLNL. The sampler used to acquire daily composites of SNL/CA's discharges to LLNL was unreliable and resulted in a low data capture at that location: only

161 of 366 samples, or 44%. The sampler was replaced in November with a more reliable model.

Routine Water Sampling Program

Routine water sampling networks include Livermore Valley wells, other Livermore Valley waters, Livermore-site storm water runoff, and Livermore Valley rain. A sample for these networks is defined to be one bottle, even though many bottles may be taken at the same time and location in order to determine the presence of different analytes.

Valley wells are sampled annually at 19 locations and two duplicate samples are taken for quality control purposes. Samples are obtained and given to LLNL by water providers in the Livermore Valley. Of 21 planned samples, 19 were collected and analyzed in 1992, resulting in a sample recovery rate of 90%.

Other Livermore Valley waters are sampled quarterly at 11 locations and monthly at the LLNL swimming pool. Two duplicate quality control samples are taken. A total of 128 samples was planned for 1992; 124 were collected and analyzed, resulting in a 97% recovery rate. Location DUCK was dry during the third quarter sampling window (two samples lost) and two planned LLNL pool samples were overlooked in December.

Livermore-site storm water runoff was sampled at 10 locations for 18 different storms during 1992. Duplicate samples were taken at one location for each storm for quality control purposes. Nineteen bottles were taken at each sampling location, resulting in a total planned sample size of 3762. Six locations could not be sampled because of insufficient water flow, resulting in the loss of 114 samples. Total sample recovery was 97%.

Livermore Valley rain was sampled at 19 locations for 20 storms during 1992. Duplicate quality control samples were taken at two locations during each storm. One sample was planned at each location for each storm, resulting in 420 total possible samples. The samples that were successfully collected and analyzed numbered 396, for a recovery rate of 94%. Of the 24 samples lost, 6 were of insufficient volume for analysis, and 18 could not be taken because the sampling buckets were missing.

Vegetation and Foodstuff Sampling Program

No changes were made to the vegetation sampling program in 1992. All 92 planned samples were collected and analyzed, giving a 100% recovery rate.

The sampling program for wine was reduced due to budgetary constraints. A decrease in the number of California wines sampled was justified by consistency in results over the years and across geographical areas. Wine samples included 12 Livermore wines (down from 14 in 1991), 4 other California wines (down from 8 in 1991), and 5 European wines (down from 13 in 1991). He-3 mass spectrometry was used exclusively as the analytical method for tritium. A total of

26 wine samples was planned and all of them were successfully collected and analyzed.

Due to the seven-year California drought, it was difficult to locate honey producers in 1992, and no honey sample was taken from the on-site location. Other honey sampling locations, the sampling method, and the analytical methods remained the same as those used in previous years. A total of seven honey samples was submitted—three from Livermore, three from other California locations, and one duplicate of one of the non-Livermore samples. All submitted samples were successfully analyzed.

Three goat's milk suppliers went out of business in 1992. Location MZF went out of business in April and was not replaced. Location LUP went out of business in August 1992 and was replaced by WOOD. Location RIP went out of business and was replaced by MOD2 in April 1992. In August 1992, the MOD2 goats were moved to Stevenson and the location was renamed STEV. An existing goat's milk supplier, WRD, began supplying cow's milk during 1992 and three cow's milk samples were collected and analyzed. As occurs every year, goat's milk was not available from any providers in January and December because goats do not produce milk during these months.

Out of 65 planned milk samples, 61 were collected and analyzed, giving a recovery rate of 94%.

Environmental Radiation Monitoring Program

No major changes were made to the environmental radiation monitoring program in 1992. A recovery of 100% was achieved for the site perimeter thermoluminescent dosimeters, 91% for Livermore Valley locations (179 out of 196 samples), and 83% for Site 300 (66 out of 80 samples). Dosimeter loss usually is a result of construction activities, destruction by cows, or vandalism. Of the 24 planned neutron probes, 23 were collected and analyzed, giving a 96% recovery rate.

Meteorology Monitoring Program

Data recovery from the meteorological monitoring program during 1992 was 99%, both at the Livermore site and at Site 300. Missing data were caused by routine maintenance or modem problems. Equipment at both meteorological towers was operational for the entire year. Calibrated sensors (traceable to National Institute for Standards and Technology) for air temperature, wind speed, wind direction, and relative humidity were routinely replaced with newly calibrated instruments twice during the year.

Soils/Sediments Monitoring Program

Soils were sampled at 21 locations at the Livermore site and in Livermore Valley and at 14 locations at Site 300. All planned samples were obtained and

successfully analyzed for radionuclides and beryllium. No changes to soil sampling locations were made during 1992.

Ten of eleven planned sediment samples at the main site were collected and analyzed for radionuclides, metals, and organic compounds, giving a recovery rate of 91%. One location, located at the center of the LLNL Central Drainage Basin, could not be sampled because of construction at the site. As a special study, additional samples of sediment material were taken from a more shallow depth at each of the ten locations sampled.

Compliance Ground Water Sampling Program

Upgradient wells K1-01C and K1-07 were temporarily buried during Pit 1 landfill closure capping activities, and downgradient well NC7-48 was temporarily buried during Pit 7 landfill closure capping activities in the third quarter of 1992, rendering them inaccessible for sample collection. All of these wells were restored and sampling resumed during the fourth quarter.

Well K7-09 was analyzed for metals (barium, beryllium, lead, and vanadium) and radiological compounds (gross alpha, gross beta, tritium, and uranium isotopes) during the first quarter of 1992. As these analytes had not been regularly monitored at this location, additional analyses were performed to provide both comparison and consistency with other wells in the Pit 7 Complex.

Monitoring of well K7-09 was discontinued in the second quarter of 1992. Volatile organic compounds have not been detected in this well since April of 1989 and have never been detected in well K7-10, which monitors the shallower water-bearing zone in the same area.

Compliance well K7-07 and piezometers NC7-22 and -37 have been dry since 1987. In the future, results from these locations will be reported only when water levels are sufficient for sample collection; however, the water level at these locations will continue to be monitored quarterly.

Well NC7-48 was added to the Pit 7 complex monitoring network during the second quarter. Analyses performed on samples from this location include metals (beryllium, barium, lead, and vanadium) along with EPA Method 624 organic compounds and radiological compounds (gross alpha and beta, tritium, uranium isotopes, and also ^{226}Ra if gross alpha exceeds 5 pCi/L). Because additional Method 624 compounds were not detected, samples in subsequent quarters were analyzed by EPA Method 601, which is both sufficient for well NC7-48 and consistent with the analyses performed on samples from other Pit 7 Complex area wells.

Previously used analytical methods for determining the presence of Title 22 pesticides and herbicides provided a level of detection (LOD) above the respective Maximum Contaminant Limits (MCLs). During the third quarter of 1992, these methods were replaced with EPA-approved methods providing

lower levels of detection. Total suspended solids (TSS) were not analyzed by the analytical laboratory as requested for Pit 1 wells during the third quarter of 1992.

Routine Ground Water Monitoring

Analytical method improvements to the drinking water wells (Well 01, Well 18, and Well 20) were made during the first quarter of 1992. These wells are now analyzed by EPA Method 524.2, which offers a lower level of detection for volatile compounds than the previously used EPA Methods 601 and 602.

Quality Assurance Activities

A full-time Quality Assurance/Training Coordinator was added to the environmental monitoring program in 1992, facilitating the completion and distribution of 24 of 60 QA and sampling procedures. These procedures cover the areas of monitoring and sampling methods, sampling locations, and instrument calibrations for each medium; emergency monitoring and response; dose assessment; data management and analysis; document preparation and archiving; reporting; training; and other quality assurance activities. Work is continuing in this area, and it is expected that the balance of the procedures, as well as a revised environmental monitoring QA plan based on the new DOE Order 5700.6C, will be completed and implemented during 1993.

A total of 123 Nonconformance Reports (NCRs) was written during 1992. The major source of NCRs was the analytical laboratories used to evaluate environmental samples. One step taken to address the problems with the laboratories was to build teams consisting of representatives from the environmental monitoring program and from an analytical laboratory, which met to improve communications and clearly define both groups' expectations. Other significant sources of NCRs include equipment failure and vandalism (e.g., power turned off or missing samples).

During 1992, the environmental monitoring program was audited by the LLNL Assurance Review Office (ARO), by the DOE Environmental, Safety, & Health Progress Assessment, and by DOE's Technical Safety Appraisal revisit. Major areas of concern in these audits include training, quality assurance, air monitoring, and the Environmental Monitoring Plan (EMP). LLNL expects to complete and begin to implement a revised environmental monitoring QA plan and related procedures as well as a new training plan in 1993. A technical review and revision of the EMP are also planned for 1993.

Participation in Laboratory Intercomparison Studies

During 1992, LLNL's Radiation Analytical Sciences (RAS) laboratory and the Hazards Control Department's analytical laboratory both participated in the EPA's Environmental Monitoring Systems Laboratory Intercomparison Studies Program. Table 13-3 shows the comparison of analyses by these laboratories

with known values. The normalized deviation from the known value is considered acceptable if it falls between -3 and $+3$. However, normalized deviations that fall between -3 and -2 and those which fall between $+2$ and $+3$ are considered suspect and could indicate a potential problem with laboratory accuracy. For the RAS results, one value during 1992, the October value for tritium in water, is in the suspect range. RAS personnel are aware of this potential problem, and will take further action if future results are outside the -3 to $+3$ range. The Hazards Control laboratory's results for gross beta analysis fell within the suspect range in January and outside of specified control limits in May and September of 1992. Upon further inquiry, it was discovered that the EPA had changed the calibration standard it was using for gross beta. The laboratory is in the process of further investigation of the problem and determining appropriate corrective action.

The Hazards Control laboratory participated in two California Department of Health Services Environmental Laboratory Accreditation Program (ELAP) Water Pollution Studies for metals during 1992. The Hazards Control analytical laboratory measures metals in sewage effluent for the LLNL environmental monitoring program. All ELAP intercomparison values for these metals were found to be acceptable in studies performed in June and December of 1992 and the data are presented in **Table 13-4**.

RAS also participated in the 1992 intercomparison studies by the DOE Environmental Measurements Laboratory (EML). The data from this study are presented in **Table 13-5**. September results for ^{239}Pu in air, soil, and water as originally reported to EML were incorrect due to samples being mislabeled. This led to unacceptable results. When the problem was recognized by the laboratory, the values were recalculated. Revised, acceptable results appear directly below the original results in **Table 13-5**.

Additional problems with EML results occurred for tritium in water, both in March and in September. RAS experienced significant staff turnover during 1992 and both tritium analyses were performed by chemists who were in the process of being trained to do the analyses required for the EML studies.

Because of the problems mentioned above, RAS has established a system of independent checks at each stage of its measurement and data reduction system. Analysis, measurement, and data reduction processes are checked by a coworker at each step of the procedure. In addition, the laboratory worksheet has been modified to ensure that all pertinent data are recorded. It is expected that these steps, along with the completion of training for RAS chemists, will eliminate future errors in these analyses.

Contract laboratories are also required to participate in laboratory intercomparison programs; however, permission to publish their results for comparison purposes has not been granted.

Duplicate Analyses

Table 13-6 presents selected data generated by the duplicate sampling regime. Samples from both the Livermore site and Site 300 are included to provide a larger data set for statistical analysis. Only data pairs with at least one value above the detection limit are used in this analysis. If there are fewer than eight suitable data pairs, the ratios of the individual duplicate sample pairs are averaged. The average ratio should be between 0.7 and 1.3. When eight or more suitable data pairs are available, precision and regression analyses are performed. The confidence interval limits for precision should be within $\pm 50\%$. The slope of the regression line should be between 0.7 and 1.3, and the intercept should be $\pm$ the detection limit. The coefficient of determination (r^2) should be >0.8 .

The analyses for these sample media show reasonable agreement between routine samples and quality assurance duplicates, with the exception of ^3H in ground water, sewage and air, and ^{239}Pu in air. The ^3H deviation in ground water is due to a single routine and duplicate sample pair for which the agreement is poor. Results excluding this pair are given in parentheses in Table 13-6. The ^{239}Pu deviations, also seen in 1989 through 1991, are thought to be caused by the proximity of the levels to the detection limit.

Statistical Methods

Statistical methods used in this report have been implemented pursuant to the DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991). These methods reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Data review and analyses are conducted in accordance with the environmental monitoring Quality Assurance Plan (Holland 1987) and the *Environmental Monitoring Plan* (Gallegos et al. 1992b). Both documents contain detailed information regarding the acceptability of data and the procedures that are followed for the identification, notification, and correction of suspect data.

Radiological Data

The precision of radiological analytical results is displayed in the data tables as 2σ counting errors. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a 2σ counting error greater than 100% is said to be below the detection criterion and is presented in the tables with a less-than symbol ($<$) to indicate its status. No value of error is reported for values below the detection criterion. Calculation of

summary statistics uses the reported value in accordance with the procedures described below.

Nonradiological Data

Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than symbol (<). As with the radiological data, the actual detection limit values are used in the calculation of summary statistics as explained below.

Statistical Comparisons

Standard comparison techniques (regression, t-test, and ANOVA) have been used where appropriate to determine the statistical significance of trends or differences between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word "significant" in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance, and are based on professional judgment.

Summary Statistics

Determinations of measures of central tendency and associated measures of dispersion are calculated according to DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) protocols. For data sets not containing values below the detection criterion, measures of central tendency are reported as the arithmetic mean plus or minus one standard deviation.

For data sets containing one-third or fewer values below the detection criterion, measures of central tendency are reported as less than the arithmetic mean. If no values below the detection criterion are above the calculated mean, dispersion is reported as greater than one calculated standard deviation. If any values below the detection criterion are above the calculated mean, dispersion is not reported. Statistics are calculated using the reported detection limit value for nonradiological data or the reported value for radiological data.

For data sets containing more than one-third but less than one half values below the detection criterion, the central tendency is reported as the median value. If all values below the detection criterion are sufficiently below the median value (determined on a case-by-case basis), dispersion is reported as the median absolute deviation. If calculation of the absolute median deviation is not appropriate, dispersion is not reported. Statistics are calculated using the reported detection limit value for nonradiological data or the reported value for radiological data.

13. Quality Assurance

For data sets containing greater than or equal to one half values below the detection criterion, the central tendency is reported as less than the median value. Dispersion is not reported.

Radiation Units

Data for 1992 have been reported in SI units, to conform with standard scientific practices and federal law. Values in the text are reported in becquerel per liter (Bq/L) and millisievert (mSv); equivalent values in picocuries (pCi) and millirem (mrem) are given in parentheses, as these were the reporting units used in previous environmental reports, and will be useful for making data comparisons. Values in graphic figures are given only in SI units; SI units are used in tables with summary statistics including values for both sets of units.

Table 13-1. LLNL/Livermore Valley sampling location designators.

Medium/location	Current designator	Previous designator(s)
Air particulate		
NW Perimeter (Met Tower)	L-MET	90-13
Cowbarn	L-COW	90-15
E Perimeter (Visitors Center)	L-VIS	90-14
East & Greenville Aves. (Salvage)	L-SALV	90-01
South Cafeteria (East Ave.)	L-CAFE	90-12
Mesquite Way	L-MESQ	90-02
UNCLE Credit Union	L-CRED	—
Near Building 531	L-B531	—
East Ave. Firehouse	L-FIRE	90-17
Sandia Tanks	L-TANK	90-03
Zone 7	L-ZON7	90-04
Patterson Pass	L-PATT	90-05
Altamont Pass	L-ALTA	90-07
Residence (N. Vasco Rd.)	L-RRCH	90-06
FCC Station	L-FCC	90-08
Livermore City Corp. Yard	L-LCCY	90-09
LWRP Sewer Plant	L-LWRP	90-16
Livermore VA Hospital	L-HOSP	90-10
Residence (Mines Rd.)	L-ERCH	90-11
Air tritium		
NW Perimeter (Met Tower)	L-MET	93-13
Cowbarn	L-COW	93-15
E Perimeter (Visitors Center)	L-VIS	93-14
East & Greenville Aves. (Salvage)	L-SALV	93-01
East Ave. "South" Cafeteria	L-CAFE	93-12
West Parking Lot (Mesquite Way)	L-MESQ	93-02
LLNL Pool	L-POOL	—
Building 331 Yard	L-B331	—
Building 292 Area	L-B292	—
Building 514 Yard	L-B514	—
Building 624 (612 Yard)	L-B624	—
East Ave. Firehouse	L-FIRE	93-17
West of Sandia (Veterinarian)	L-VET	93-S2
East of Sandia (Crossroad)	L-XRDS	93-S1
Zone 7	L-ZON7	93-04
Altamont Pass	L-ALTA	93-07
Livermore City Corp. Yard	L-LCCY	93-09

...continued

Table 13-1. LLNL/Livermore Valley sampling location designators (*continued*).

Medium/location	Current designator	Previous designator(s)
Cow's milk		
Residence (Greenville Rd.)	L-WRD	—
Goat's milk		
Residence (Greenville Rd.)	L-WRD	91-05
Residence (Edwards)	L-COOL	—
Cartoned Milk	C-CART	91-97
Pre-Pasturized (Turlock)	C-TUR	—
Residence (Stevenson)	C-STEV	— replaced C-MOD2
Residence (Brentwood)	C-WOOD	— replaced L-LUP
Residence (Tesla Rd.)	L-MZF	91-07 abandoned
Residence (Modesto)	C-MOD	— abandoned
Residence (Hixon)	C-RIP	— replaced
Residence (Modesto)	C-MOD2	— replaced
Residence (Lupin Way)	L-LUP	91-13 replaced
Vegetation		
Patterson Pass	L-PATT	95-04
Zone 7	L-ZON7	95-15
I-580 & Greenville Rd.	L-I580	95-20
Aqueduct	L-AQUE	95-23
N of LLNL (Railroad Tracks)	L-RAIL	95-29
Tesla Rd. (West)	L-TESW	95-32
FCC Station	L-FCC	95-33
Met Tower	L-MET	— replaced L-VASW
Calaveras Reservoir	L-CAL	—
Camp Parks	L-PARK	—
Visitors Center	L-VIS	—
Mesquite Way	L-MESQ	— replaced L-VASW
Residence (Danville)	L-DAN	—
Residence (Modesto)	C-MOD	—
Vasco Rd. (W of LLNL)	L-VASW	95-31 replaced
Arroyo sediment		
Central Drainage Basin	L-CDB	CDB
Arroyo Las Positas East	L-ALPE	ALPE
Arroyo Las Positas West	L-ALPW	ALPW

...continued

Table 13-1. LLNL/Livermore Valley sampling location designators (*continued*).

Medium/location	Current designator	Previous designator(s)	
Arroyo sediment			
Arroyo Seco West	L-ASW	L-ASN	renamed
Arroyo Seco South #2	L-ASS2	—	replaced L-ASS
4th and A Streets	L-4THA	—	
Arroyo Las Positas North	L-ALPN	—	
Greenville Rd., NE Perimeter	L-GRNE	—	
Central Drainage Basin 2	L-CDB2	—	
East of Building 438	L-438E	—	
W Perimeter Drainage Channel	L-WPDC	—	
Arroyo Seco South	L-ASS	ASS	replaced
Arroyo Seco East	L-ASE	ASE	abandoned
Soil			
Mesquite Way	L-MESQ	L-02	
Sandia Tanks	L-TANK	L-03	
Zone 7	L-ZON7	L-04	
Patterson Pass	L-PATT	L-05	
FCC Station	L-FCC	L-08	
Livermore VA Hospital	L-HOSP	L-10	
NW Perimeter (Met Tower)	L-MET	L-13	
E Perimeter (Visitors Center)	L-VIS	L-14	
Cowbarn	L-COW	L-15	
NE Corner Perimeter Fence	L-NEP	L-18	
LWRP Sewer Plant (1/3 N)	L-WRP1	L-19	
LWRP Sewer Plant (2/3 N)	L-WRP2	L-20	
LWRP Sewer Plant (NW)	L-WRP3	L-21	
LWRP Sewer Plant (1/3 W)	L-WRP4	L-22	
LWRP Sewer Plant (2/3 W)	L-WRP5	L-23	
LWRP Sewer Plant (SW)	L-WRP6	L-24	
Salvage	L-SALV	—	
South Cafeteria (East Ave.)	L-CAFE	—	
Altamont	L-ALTA	—	
Residence (Mines Rd.)	L-ERCH	—	
Residence (N. Vasco Rd.)	L-RRCH	—	

...continued

Table 13-1. LLNL/Livermore Valley sampling location designators (*continued*).

Medium/location	Current designator	Previous designator(s)	
Sewage			
Building 196 (daily composite)	L-B196	LLNL	
Building 196 (weekly composite)	L-C196	—	replaced L-LWRP
LWRP (effluent)	L-WRPE	—	
LWRP (digester)	L-WRD1	—	
LWRP (digester)	L-WRD2	—	
Manhole 40B	L-M40	—	
Manhole 51A	L-M51	—	
Manhole 53A	L-M53	—	
Manhole 59A	L-M69	—	
Manhole 86B	L-M86	—	
Manhole 125C	L-M125	—	
Manhole 163A (Sandia)	L-163A	—	
Manhole 177E	L-M177	—	
Manhole 185F	L-M185	—	
Manhole 231A	L-M231	—	
Manhole 238C	L-M238	—	
LWRP	L-LWRP	LWRP	replaced
Run-Off			
Arroyo Las Positas (E of LLNL)	L-ALPE	01	
Central Drainage Basin	L-CDB	02	
Arroyo Las Positas (NW boundary)	L-ALPW	03	
Arroyo Seco West (Vasco/East Ave.)	L-ASW	L-ASN;06	renamed
East of B-438	L-B438	—	
Arroyo Las Positas (N at cowbarn)	L-ALPN	—	
4th and A Streets	L-4THA	—	
West Perimeter Drainage Channel	L-WPDC	—	
Arroyo Seco South #2	L-ASS2	—	replaced L-ASS
Greenville Road (NE Perimeter)	L-GRNE	—	
Arroyo Seco East (influent to Sandia)	L-ASE	04	abandoned
Arroyo Seco South (West Parking Lot)	L-ASS	05	replaced

...continued

Table 13-1. LLNL/Livermore Valley sampling location designators (*concluded*).

Medium/location	Current designator	Previous designator(s)
Rain		
Zone 7	L-ZON7	—
Cowbarn	L-COW	—
FCC Station	L-FCC	—
DelValle/Zone 7	L-DEL7	—
Camp Parks	L-PARK	—
Vineyard	L-VINE	—
NW Perimeter (Met Tower)	L-MET	—
Residence (South L St.)	L-SLST	—
Residence (Buena Vista Ave.)	L-BVA	—
Visitors Center	L-VIS	—
Building 291	L-B291	—
Central Drainage Basin	L-CDB	—
Greenville and Tesla Rds.	L-GTES	—
East of Sandia	L-ESAN	—
Building 343	L-B343	—
Aqueduct	L-AQUE	—
East & Greenville Aves. (Salvage)	L-SALV	—
Altamont	L-ALTA	—
Patterson Pass	L-PATT	—
Water		
Central Drainage Basin	L-CDB	—
Del Valle Lake	L-DEL	92-11
Zone 7	L-ZON7	92-15
Springtown Duck Pond	L-DUCK	92-16
Gas Station Tap Water	L-GAS	92-19
Arroyo de Laguna (Sunol)	L-ALAG	92-24
Shadow Cliffs	L-SHAD	92-26
Calaveras Reservoir	L-CAL	92-29
Building 151 Tap Water	L-TAP	92-30
Residence (Palm Ave.)	L-PALM	92-31
Private Well	L-ORCH	92-34
Residence (Bell Ave.)	L-BELL	92-37
LLNL Pool	L-POOL	92-43

Table 13-2. Site 300 sampling location designators.

Medium/location	Current designator	Previous designator(s)
Air particulate		
East Observation Point	3-EOBS	40-01
East Control Post	3-ECP	40-02
West Control Post	3-WCP	40-03
Linac Rd.	3-LIN	40-04
Near Well #4 (Golf Course)	3-GOLF	40-05
Tracy Firehouse	3-TFIR	40-06
North Power Station	3-NPS	40-08
West Observation Point	3-WOBS	40-09
East of Building 801	3-801E	40-10
Soil		
West of Building 834	3-834W	3ESEI01 or 1103
Near Building 858	3-858S	3WSWI01 or 1104
North of Building 856	3-856N	3WXXK01 or 1106
North of Road to Building 851	3-851N	3WNWI01 or 1107
North of East Observation Point	3-EOBS	3NNWL01 or 1112
North of Well #8 (ERD Evaporator)	3-EVAP	3WNWK01 or 1109
North Power Station	3-NPS	3NWXP01 or 1110
West Landfill (Disp. Site West)	3-DSW	3NWXP02 or 1111
West of Building 801	3-801W	3NNWG01 or 1113
East of Building 801	3-801E	3NXXH01 or 1114
Behind Building 812	3-812N	3NXXC01 or 1115
West of Cafeteria (Golf Course)	3-GOLF	3SEXL01 or 1116
West Observation Point	3-WOBS	3WNWN01 or 1108
North of Building 801	3-801N	1117
Vegetation		
Carnegie	3-CARN	45-01
Golf Course	3-GOLF	45-02
Geodetic	3-GEO	45-03
Disposal Site West	3-DSW	45-06
Behind Building 801	3-801E	45-12
Near Well #8 (ERD Evaporator)	3-EVAP	45-13

...continued

Table 13-2. Site 300 sampling location designators (*concluded*).

Medium/location	Current designator	Previous designator(s)
Water		
Well 1	3-WELL01	42-01
Private Well	3-CON1	42-07
Private Well	3-CON2	—
Well 18	3-WELL18	42-22
Geodetic Creek	3-GEOCRK	42-14
Rain	3-RAIN	42-20
812 Creek	3-812CRK	42-21
Carnegie Retention Well 1	3-CARNRW1	42-23
Carnegie Retention Well 2	3-CARNRW2	42-24
Well 20	3-WELL20	42-31
Private Well	3-GALLO1	42-28
Private Well	3-GALLO2	—
CDF Well	3-CDF1	42-27
Private Well	3-MUL1	—
Private Well	3-MUL2	—
Private Well	3-VIE1	—
Private Well	3-VIE2	—
Private Well	3-STN	—

abandoned

Table 13-3. Results from the EPA Environmental Monitoring Systems Laboratory (EMSL) Intercomparison Program, 1992.

Analysis	Date	Medium	Units	LLNL	Known	Normalized deviation from the known value ^a
³ H ^b	February	water	pCi/L	7985.67	7904.0	0.18
	June		pCi/L	2184.00	2125.0	0.29
	October		pCi/L	6818.00	5962.0	2.49 ^a
²³⁹ Pu ^b	January	water	pCi/L	15.90	16.8	-0.92
	August		pCi/L	9.07	9.0	0.13
¹³⁷ Cs ^b	March	air	pCi/filter	13.00	10.0	1.04
	August		pCi/filter	19.67	18.0	0.58
Total K ^b	April	milk	mg/L	1776.67	1710.0	1.34
¹³¹ I ^b			pCi/L	83.67	78.0	1.23
¹³⁷ Cs ^b			pCi/L	40.67	39.0	0.58
Gross alpha ^c	January	water	pCi/L	26.00	30.0	-0.87
	May		pCi/L	16.00	15.0	0.35
	September		pCi/L	41.67	45.0	-0.52
Gross beta ^c	January	water	pCi/L	22.33	30.0	-2.66 ^a
	May		pCi/L	56.33	44.0	4.27 ^a
	September		pCi/L	39.00	50.0	-3.81 ^a

^a Deviations are acceptable if they are between -3 and +3; however, deviations between +2 and +3 or between -2 and -3 are indicative of potential problems with laboratory accuracy.

^b All data were provided by LLNL's Radiation Analytical Sciences laboratory.

^c Data were provided by LLNL's Hazards Control analytical laboratory.

Table 13-4. Results from the California Department of Health Services Environmental Laboratory Accreditation Program (ELAP) Water Pollution Studies.^a

Analysis	Date	Sample	LLNL value ^b	True value ^b	Acceptable limits	Warning limits
Aluminum	6/22/92	1	2080	2100	1790-2420	1870-2340
		2	954	950	778-1130	823-1090
	12/21/92	1	70.5	65.9	40.1-100	47.7-92.6
		2	563	548	435-645	462-619
Arsenic	6/22/92	1	108	100	71.8-127	78.7-120
		2	458	430	348-508	368-488
	12/21/92	1	142	140	113-168	120-161
		2	15.1	15.0	11.1-19.4	12.2-18.4
Beryllium	6/22/92	1	96.1	100	74.9-126	81.4-120
		2	38.8	40	30.0-50.9	32.6-48.2
	12/21/92	1	15.7	16.8	12.4-21.4	13.5-20.2
		2	630	609	497-714	525-686
Cadmium	6/22/92	1	242	250	210-290	220-280
		2	38.3	40	32.8-48.7	34.8-46.7
	12/21/92	1	16.6	16.8	12.2-21.5	13.4-20.4
		2	381	380	319-440	334-425
Chromium	6/22/92	1	758	800	658-927	691-893
		2	307	315	266-371	279-358
	12/21/92	1	599	620	516-717	541-691
		2	8.90	8.11	3.37-12.3	4.49-11.2
Copper	6/22/92	1	776	790	714-877	735-856
		2	127	130	113-144	117-140
	12/21/92	1	5.80	6.33	3.68-8.58	4.30-7.97
		2	242	241	213-267	219-260
Iron	6/22/92	1	1430	1500	1310-1690	1360-1650
		2	515	540	471-613	489-595
	12/21/92	1	696	711	625-800	647-778
		2	86.6	83.0	68.2-97.7	71.9-94.0
Mercury	6/22/92	1	4.70	5.30	3.89-6.65	4.24-6.30
		2	0.628	0.330	0.0869-0.620	0.154-0.552
Nickel	6/22/92	1	730	740	660-814	680-794
		2	2200	2200	1970-2410	2020-2360
	12/21/92	1	31.1	31.7	25.5-37.4	27.0-35.9
		2	580	569	498-632	515-616

...continued

13. Quality Assurance

Table 13-4. Results from the California Department of Health Services Environmental Laboratory Accreditation Program (ELAP) Water Pollution Studies^a (*concluded*).

Analysis	Date	Sample	LLNL value ^b	True value ^b	Acceptable limits	Warning limits
Lead	6/22/92	1	544	550	474–623	493–604
		2	142	150	120–179	127–172
	12/21/92	1	956	959	831–1080	862–1050
		2	1560	1500	1300–1680	1350–1630
Zinc	6/22/92	1	364	360	318–406	329–395
		2	1430	1400	1230–1570	1270–1520
	12/21/92	1	17.6	17.0	11.3–22.9	12.8–21.4
		2	625	612	536–689	555–670
Silver	6/22/92	1	0.82	1.03	0.652–1.40	0.748–1.30
		2	9.87	10.6	8.45–12.6	8.98–12.1
	12/21/92	1	5.58	5.59	4.20–7.01	4.56–6.66
		2	14.1	14.0	11.1–16.8	11.8–16.1

^a All data were provided by LLNL's Hazards Control analytical laboratory.

^b All results reported in micrograms per liter.

Table 13-5. Results from the DOE Environmental Measurements Laboratory (EML) Quality Assurance Program, 1992.^a

Analysis	Date	Medium	LLNL value	EML value	Ratio
⁷ Be	Mar.	air (Bq/filter)	30.9	28.6	1.08
	Sept.		321	308	1.04
⁵⁴ Mn	Mar.		6.33	5.97	1.06
	Sept.		25.7	25.9	0.99
⁵⁷ Co	Mar.		7.89	7.93	0.99
	Sept.		6.03	6.40	0.94
⁶⁰ Co	Mar.		5.83	5.81	1.00
	Sept.		3.25	3.06	1.06
¹³⁴ Cs	Mar.		5.09	4.44	1.15
	Sept.		3.73	3.72	1.00
¹³⁷ Cs	Mar.		6.26	5.76	1.09
	Sept.		5.94	5.82	1.02
¹⁴⁴ Ce	Mar.		74.1	63.9	1.16
	Sept.		38.1	43.3	0.88
²³⁸ Pu	Mar.		0.309	0.270	1.14
	Sept.		0.426	0.0420	10.14 ^b
	Sept.		0.0364 ^c	0.0420	0.87 ^c
²³⁹ Pu	Mar.		0.318	0.285	1.12
	Sept.		0.148	0.0450	3.29 ^b
	Sept.		0.0430 ^c	0.0450	0.96 ^c
²³⁸ U	Mar.		0.208	0.200	1.04
⁴⁰ K	Mar.		704	719	0.98
	Sept.		380	384	0.99
¹³⁷ Cs	Mar.		5.96	5.23	1.14
	Sept.		312	285	1.09
²³⁹ Pu	Mar.		50	25.5	1.96 ^b
	Sept.		1.99	7.76	0.26 ^b
	Sept.		6.86 ^c	7.76	0.88 ^c
³ H	Mar.	water (Bq/L)	156	227	0.69 ^b
	Sept.		158	118	1.34 ^b
	Sept.		135 ^d	118	1.14 ^d
¹³⁷ Cs	Mar.		86.2	84.6	1.02
	Sept.		31.2	29.0	1.08
²³⁹ Pu	Mar.		0.666	0.580	1.15
	Sept.		2.01	0.238	8.45 ^b
	Sept.		0.245 ^c	0.238	1.03 ^c

^a All data were provided by LLNL's Radiation Analytical Sciences Section.

^b These values are outside the required tolerance levels of $\pm 2\sigma$.

^c Recalculated LLNL results and ratios. Original results as published by EML were incorrect due to labeling errors. Corrected results and ratios are shown as second set of September data.

^d Recalculated LLNL results and ratio. Original results as published by EML were incorrect due to calculation errors. Corrected results and ratios are shown as second set of September data.

Table 13-6. Quality assurance duplicate sampling, selected parameters, 1992.^a

Media	Parameter	Precision ^b (%)	Coefficient of determination	Intercept	Slope	Mean ratio ^c
Sewage						
	³ H (μCi/mL)	-136 to 221	0.999	2.9×10^{-8}	0.93	
	Zinc (mg/L)	-4 to 4	0.95	1.3	0.95	
Water						
Ground	³ H (pCi/L)	-1404 to 2231 (-23 to 20) ^d	0.99	-3526	1.06	
	TOC (mg/L)	-34 to 34	0.86	-0.13	1.15	
	Conductivity (μmhos/cm)	-9 to 9	0.98	20.3	0.98	
	As (mg/L)	-16 to 10	0.98	-0.0009	1.02	
Surface	³ H (pCi/L)	-32 to 29	0.999	-4.01	1.16	
Rain	³ H (pCi/L)	-87 to 120	0.98	-2.59	0.97	
Runoff	³ H (pCi/L)	-62 to 72	0.99	0.93	0.94	
Vegetation						
	³ H (pCi/L)	-72 to 168	0.99	41.0	0.96	
Air						
	³ H (pCi/L)	-183 to 272	0.66	0.002	1.09	
	²³⁹ Pu (μCi/mL)	-94 to 29	0.09	1.65×10^{-19}	0.46	
	Beryllium (pG/m)	-80 to 99	0.74	1.89	0.89	
Soil						
	²³⁹ Pu (μCi/g)					0.66
	²²⁸ Ra (pCi/g)					0.98

^a Only calculated for data sets with more than eight valid data pairs.

^b Calculated according the methodology in *Quality Assurance Handbook for Air Pollution Measurement Systems* (U.S. Environmental Protection Agency 1979) for data sets with more than eight valid data pairs.

^c Only used for data sets with fewer than eight valid data pairs.

^d Indicates result with a single highly influential data pair removed.

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A	Absorbed dose	The amount of energy deposited by radiation in a given amount of material. The unit of absorbed dose is the rad.
	Absorption	The process by which the number and energy of particles or photons entering a body of matter is reduced by interaction with the matter.
	Accuracy	The closeness of the result of a measurement to the true value of the quantity measured.
	ACEHS	Alameda County Environmental Health Services.
	ACG	Ambient concentration guide.
	Action Level	Defined by regulatory agencies, it is the level of pollutants which, if exceeded, requires regulatory action.
	ALARA	As Low As Reasonably Achievable. A U.S. Department of Energy (DOE) and Nuclear Regulatory Commission policy for radiation exposures. It is an approach to radiation exposure control or management where the exposures and resulting doses are maintained as far below the limit specified for the appropriate circumstances as social, economic, technical, and practical considerations permit.
	Alluvium	Sediment deposited by flowing water.
	Alpha particle	A positively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of a helium nucleus (two protons and two neutrons).
	Ambient air	The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.
	Analyte	A constituent that is being analyzed.
	Anion	A negatively charged ion.

Glossary

ANOVA	Analysis of variance. A test of whether two or more sample means could have been obtained from the same statistical population.
ANSI	American National Standards Institute.
Aquifer	A saturated layer of rock or soil below the ground surface that can supply usable quantities of ground water to wells and springs. Aquifers can be a source of water for domestic, agricultural, and industrial uses.
Aquitard	A geologic unit that functions as an upper or lower boundary of an aquifer.
ASME	American Society of Mechanical Engineers.
ATA	Advanced Test Accelerator.
Atom	The smallest particle of an element capable of entering into a chemical reaction.
Atomic absorption spectroscopy	Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor. Abbreviated AA.
AVLIS	Atomic Vapor Laser Isotope Separation.
B BAAQMD	Bay Area Air Quality Management District. The local agency responsible for regulating stationary air emission sources (including the Livermore site) in the San Francisco Bay Area.
BAT	Best available technology (economically achievable).
Beta particle	A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.
Blank sample	A control sample that is identical, in principle, to the sample of interest, except that the substance being analyzed is absent. The measured value or signals in blanks for the substance being analyzed is believed to be due to artifacts and should be subtracted from the measured value to give a net result reflecting the amount of substance in the sample of interest.

Blind sample	A control sample of known concentration in which the expected values of the constituent are unknown to the analyst.
Biota	The animal and plant life of a particular region considered as a total ecological entity.
BOD	Biochemical (biological) oxygen demand. A measure of the amount of oxygen in biological processes that break down organic matter in water; a measure of the organic pollutant load. It is used as an indicator of water quality.
Bq	Becquerel. The SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.
C CAP88	Computer code required by the EPA for modeling air emissions.
Cation	A positively charged ion.
CCR	California Code of Regulations.
CEQA	California Environmental Quality Act of 1970. CEQA requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions. CEQA also requires that adverse environmental impacts be mitigated through mitigation measures or project alternatives.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980. Administered by EPA, this program, also known as Superfund, requires private parties to notify the EPA after the release of hazardous substances and undertake short-term removal and long-term remediation. If conditions exist that could create the threat of hazardous substances being released, the Act also requires the remediation of those conditions. In 1986, the Superfund Amendments and Reauthorization Act (SARA) was enacted, which amended and reauthorized CERCLA for five years at a total funding level of \$8.5 billion.
CFR	Code of Federal Regulations. A codification of all regulations promulgated by federal government agencies.

Glossary

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.
Chlorocarbon	A compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethylene.
COD	Chemical oxygen demand. A gross analytical test for the presence of organic compounds in water.
Collective dose equivalent	The sums of the dose equivalents of all individuals in an exposed population within a certain radius, and expressed in units of person-rem (or person-sievert).
Collective effective dose equivalent	The sums of the effective dose equivalents of all individuals in an exposed population within a certain radius, and expressed in units of person-rem (or person-sievert).
Committed dose equivalent	The predicted total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of sievert (or rem).
Committed effective dose equivalent	The sum of the committed dose equivalents to various tissues, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of sievert (or rem).
Cosmic radiation	Radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.
CRP	Community Relations Plan.
CRWQCB	California Regional Water Quality Control Board.
CRWQCBCVR	California Regional Water Quality Control Board, Central Valley Region.
Curie (Ci)	A unit of measurement of radioactivity, defined as the amount of radionuclide in which the decay rate is 2.22×10^{12} disintegrations per minute (3.7×10^{10} disintegrations per second), which 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.
DCG	Derived Concentration Guide. Concentrations of radionuclides in water and air that could be continuously consumed or inhaled (365 days/y) and not exceed the DOE primary radiation protection standard to the public (100 mrem/y effective dose equivalent).
DCL	Discharge Concentration Limit (City of Livermore Ordinance 13.32).
Disintegration (nuclear)	A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.
DOE	U.S. Department of Energy. The federal agency that is responsible for conducting energy research and regulating nuclear materials used for weapons production.
Dose	The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.
Dose commitment	The dose which an organ or tissue would receive during a specified period of time (e.g., 50 or 100 years) as a result of intake of one or more radionuclides from one year's release.
Dose equivalent	The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert). The dose equivalent to an organ, tissue, or whole body in a year will be that received from the direct exposure plus the committed dose equivalent received from radionuclides taken into the body during the year.
Dosimeter	A portable detection device for measuring the total accumulated exposure to ionizing radiation.
Dosimetry	The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation measurement instruments.
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control.

Glossary

DWS	Drinking water standard. A standard established by the State of California and found in Title 22 of the California Code of Regulations.
E EA	Environmental Assessment. An environmental review document that identifies environmental impacts from any federally approved or funded project. If an EA shows significant impact, an EIS is required.
EDE	Effective dose equivalent. An estimate of the total risk of potential effects from radiation exposure. It is the sum of the committed effective dose equivalent from internal deposition and the effective dose equivalent from external penetrating radiation received during a calendar year. The committed effective dose equivalent is the sum of the individual organ committed dose equivalents multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body.
EDO	Environmental Duty Officer.
EFA	East Firing Area (LLNL Site 300).
Effluent	A liquid or gaseous waste discharged to the environment.
EIR	Environmental Impact Report. A detailed report, required by the California Environmental Quality Act, on the environmental impacts from any action carried out, approved, or funded by a California state, regional, or local agency.
EIS	Environmental Impact Statement. A detailed report, required by the National Environmental Policy Act, on the environmental impacts from a federally approved or funded project. An EIS must be prepared by a federal agency when a "major" federal action that will have "significant" environmental impacts is planned.
EMAD	Environmental Monitoring and Analysis Division (LLNL).
EML	U.S. Department of Energy Environmental Measurements Laboratory.

EMS	Environmental Monitoring Section in the Environmental Monitoring and Analysis Division of the Environmental Protection Department (at LLNL).
EPA	Environmental Protection Agency. The federal agency responsible for enforcing federal environmental laws. Although some of this responsibility may be delegated to state and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment.
EPD	Environmental Protection Department (LLNL).
EPSRU	Electrical Power System Replacements and Upgrades.
ERD	Environmental Restoration Division of the Environmental Protection Department at LLNL.
ES&H	Environmental, Safety, and Health.
ETA	Environmental Test Area (at LLNL).
ETA II	Experimental Test Accelerator II.
F Federal facility	A facility that is owned or operated by the federal government. Federal facilities are subject to the same requirements as other responsible parties once placed on the Superfund National Priorities List.
Federal Register	A document published daily by the federal government containing notification of government agency actions. The Federal Register contains notification of EPA and DOE actions, including notification of EPA and DOE decisions concerning permit applications and rule-making.
FFA	Federal Facility Agreement. A negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, DHS, RWQCB, and DOE).
FFCA	Federal Facilities Compliance Agreement.
FHC	Fuels and aromatic hydrocarbon.
Fissile	Any material fissionable by neutrons of all energies (e.g., ²³⁵ U and ²³⁹ Pu).

Glossary

Fluvial	Produced by the action of a stream or river.
FONSI	Finding of No Significant Impact.
FS	Feasibility Study. A study based on a Remedial Investigation to evaluate and develop remedial action alternatives to prevent, or mitigate, the migration or the release of hazardous substances or contaminants.
G g	Gram, the standard metric measure of weight approximately equal to 0.035 ounce.
Gamma ray	High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies the emission of alpha or beta particles. Gamma rays are identical to x rays except for the source of the emission.
Gray (G)	The SI unit of measure for absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One gray corresponds to one joule per kilogram.
GWP	Ground Water Project.
H Half-life (radiological)	The time required for one-half the radioactive atoms in a given amount of material to decay. After one half-life, 50 out of 100 atoms will have changed; during the next half-life, 25 more will decay, and so on, exponentially.
Hazardous waste	Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). In addition, EPA has listed as hazardous other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term more generally refers to any waste that EPA believes could pose a threat to human health and the environment if managed improperly.
HE	High explosives. Materials that release large amounts of energy when detonated.
HLW	High-level radioactive waste.
HMX	Cyclotetramethyltetramine, a high-explosive compound.

HPLC	High-pressure liquid chromatograph. A technique used to separate and quantify chemicals.
HT	Tritiated hydrogen gas. Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 years.
HTO	Tritiated water (and water vapor). (See HT.)
HWCA	California Hazardous Waste Control Act. This legislation specifies requirements for the management of hazardous wastes in California.
HWM	Hazardous Waste Management.
HWMD	Hazardous Waste Management Division at LLNL.
Hydraulic gradient	In an aquifer, the rate of change of total head (water-level elevation) per unit distance of flow at a given point and in a given direction.
Hydrology	The science dealing with the properties, distribution, and circulation of natural water systems.
I ICP	Inductively coupled plasma emission spectroscopy—An analytical technique generally used to quantify metals, such as chromium, copper, and zinc.
ICRP	International Commission on Radiological Protection. An international organization that studies radiation, including its measurement and effects.
Inorganic compounds	Compounds that either do not contain carbon or do not contain hydrogen along with carbon. Inorganic compounds include metals, salts, and various carbon oxides (carbon monoxide, carbon dioxide).
In situ	A term that can be used to refer to the treatment of contaminated areas without excavation or other removal, as in the in situ treatment of soils through biodegradation of contaminants on site.

Glossary

Interim status	A legal classification that applies to hazardous waste incinerators or other hazardous waste management facilities that were under construction or in operation by November 19, 1980, and can meet other interim status requirements. Interim status facilities may operate while EPA considers their permit application.
Ion	An atom or compound that carries an electrical charge.
Isopleth	A line on a map connecting points at which a given variable has a specified constant value, such as topographic contour lines.
Isotopes	Forms of an element having the same number of protons in their nuclei but differing numbers of neutrons.
J Joule	The SI unit of work or energy equal to 10 ⁷ ergs or approximately 0.7375 foot-pound. (A foot-pound is the amount of energy to move one pound the distance of one foot.)
L L	Liter, the SI measure of capacity approximately equal to 1.057 quart.
Land Ban	A regulatory program that identifies hazardous wastes that are restricted from land disposal. The regulations incorporate a phasing-in of restrictions in three stages.
LEDO	Laboratory Emergency Duty Officer. A senior LLNL management official with authority to commit LLNL resources on the behalf of the Director during an emergency.
LEL	Lower explosive limit.
Less than detection limits	A phrase indicating that a chemical constituent was either not identified or not quantified at the lowest level of sensitivity of the analytical method being employed by the laboratory. Therefore, the chemical constituent either is not present in the sample, or it is present in such a small concentration that it cannot be measured by the analytical procedure.
LLD	Lower limit of detection. The smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.
LLNL	Lawrence Livermore National Laboratory.

LLW	Low-level waste.
LOD	Level of detection.
LWRP	Livermore Water Reclamation Plant. The City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.
M MAD	Median absolute deviation—the median of the differences of all data values from the median.
MATHEW/ ADPIC codes	Transport and diffusion computer codes used to determine the concentration of pollutants at a distance from the source.
MCL	Maximum contaminant level in drinking water established by EPA or DTSC.
MDL	Minimum detection limit.
MOCVD	Metallorganic chemical vapor deposition.
mR	Milliroentgens—A unit of measurement used to express radiation exposure.
mrem	Millirem—A unit of measurement used to express radiation dose to a person—equal to 0.00001 sievert.
msl	Mean Sea Level—The average sea surface level for all stages of the tide over a 19-year period. This is usually determined by hourly height readings from a fixed reference level.
MTL	Multi-user Tandem Laboratory.
N NAAQS	National Ambient Air Quality Standards. Air standards established pursuant to the Clean Air Act to protect human health and the environment.
NCRP	National Council on Radiation Protection.
NEPA	National Environmental Policy Act. This federal legislation, enacted in 1969, requires all federal agencies to document and consider environmental impacts from federally funded or approved projects. DOE is responsible for NEPA compliance at LLNL.

Glossary

NESHAPs	National Emission Standards for Hazardous Air Pollutants. These standards are found in the Clean Air Act and set limits for arsenic, asbestos, beryllium, mercury, radionuclides, vinyl chloride, and benzene.
NIST	National Institute for Standards and Technology. The federal agency, formerly known as the National Bureau of Standards, responsible for reference materials against which laboratory materials are calibrated.
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).
NOI	Notice of Intent.
NOP	Notice of Preparation.
NOV	Notice of Violation.
NPDES	National Pollutant Discharge Elimination System. This federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways.
NPL	National Priorities List. EPA's list of the top-priority hazardous waste sites in the country that are subject to the Superfund program.
NRC	Nuclear Regulatory Commission. The federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense.
NTS	Nevada Test Site (DOE). The facility in the United States where nuclear weapons are tested.
Nuclide	A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable length of time.
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.
ORAD	Operations and Regulatory Affairs Division (LLNL).
OSHA	Occupational Safety and Health Act.
OSP	Operational Safety Procedure.
P Part B permit	The second, narrative section submitted by generators in the RCRA permitting process. It covers in detail the procedures followed at a facility to protect human health and the environment.
Performance standards	Specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in incinerator emissions.
Piezometer	Generally, a small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface.
pH	A measure of hydrogen-ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.
POC	Precursor organic compound.
Point source	Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack).
Porter-Cologne Act	The California law that was enacted to protect water quality in California and to protect the beneficial uses of California water.
POTW	Publicly Owned Treatment Works. A general term used for sewage treatment plants. The Livermore Water Reclamation Plant is the POTW that accepts sewage from the Livermore site.
PPAP	Pollution Prevention Awareness Plan.
ppb	Parts per billion. A unit of measure for the concentration of a substance in its surrounding medium. For example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion.

Glossary

ppm	Parts per million. A unit of measure for the concentration of a substance in its surrounding medium. For example, one million grams of water containing one gram of salt has a salt concentration of one part per million.
PRAP	Proposed Remedial Action Plan.
Precision	The closeness of approach of a value of similar or replicate results to a common value in a series of measurements.
Pretreatment	Any process used to reduce a pollutant load before it enters the sewer system.
Pretreatment regulations	National wastewater pretreatment regulations, adopted by EPA in compliance with the 1977 amendments to the Clean Water Act, which required that EPA establish pretreatment standards for existing and new industrial sources.
Priority pollutants	A set of organic and inorganic chemicals identified by EPA as indicators of environmental contamination.
Public comment period	A specified amount of time allowed for members of the public to express their views and concerns regarding an action by a public agency.
Public hearing	A formal gathering of officials and the public where the views and concerns of members of the public are verbally expressed regarding a public agency's action; public comments may be written or oral. The agency is required to consider the comments in its evaluation of the action being taken.
Public notice	Notification by an agency informing the public of agency actions (e.g., the issuance of a draft permit).
Q QA	Quality assurance. A system of activities whose purpose is to provide the producer or user of a product or service the assurance that it meets defined standards of quality with a stated level of confidence.
QAPP	Quality Assurance Project Plan—An LLNL plan that outlines methods and processes to ensure that the precision, accuracy, completeness, representativeness, and compatibility of project data are known and maintained at an acceptable level.

QC	Quality control.
Quality factor	The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than others.
R rad	The unit of absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One rad equals 0.01 joule per kilogram.
Radioactive decay	The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.
Radioactivity	The spontaneous emission of radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.
Radionuclide	An unstable nuclide. See nuclide and radioactivity.
RADRISK	EPA computerized simulation model.
RAIP	Remedial Action Implementation Plan.
RCRA	Resource Conservation and Recovery Act of 1976. RCRA is a program of federal laws and regulations that govern the management of hazardous wastes. RCRA is applicable to all entities that manage hazardous wastes.
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine, a high-explosive compound.
Reagent	Any substance used in a chemical reaction to detect or measure another substance, or to convert one substance into another by means of the reaction which it causes.
rem	Radiological unit of dose equivalent. This is the product of the absorbed dose (rad), quality factor (Q), distribution factor, and other necessary modifying factors. The unit rem describes the effectiveness of various radiations to produce biological effects (1 rem = 0.01 sievert).

Glossary

Response to comments	A document that addresses all significant public comments received by EPA during the public comment period on a proposed permit or action. The document includes a summary of each comment, as well as EPA's response to each comment.
RI	Remedial Investigation. An investigation conducted to fully assess the nature and extent of the release, or threat of release, of hazardous substances, pollutants, or contaminants and to gather necessary data to support the corresponding feasibility study.
Riparian	Inhabiting the bank area along or about a body of water.
Risk assessment	The use of established methods to measure the risks posed by an activity such as hazardous waste treatment. Risk assessments evaluate (1) the relationship between exposure to toxic substances and the subsequent occurrence of health effects, and (2) the potential for that exposure.
RMMA	Radioactive materials management areas.
ROD	Record of Decision.
Roentgen	A unit of exposure dose of x- or gamma-radiation such that the electrons and positrons liberated by this radiation produce, in air, when stopped completely, ions carrying positive and negative charges of 2.58×10^{-4} coulomb per kilogram of air. Abbreviated R.
ROV	Report of Violation.
RTRF	Real Time Radiography Facility.
RWQCB	Regional Water Quality Control Board. The California regional agency responsible for water quality standards and the enforcement of state water quality laws within its jurisdiction. California is divided into a number of RWQCBs; the Livermore site is regulated by the San Francisco Bay Region, and Site 300 is regulated by the Central Valley Region.
S SAL	State Action Level. See Action Level.

Sampling and Analysis Plan	A detailed document describing the procedures used to collect, handle, and analyze groundwater samples for detection or assessment-monitoring parameters. The plan details quality control measures that will be implemented to ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements.
Saturated zone	A subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone.
SARA	Superfund Amendments and Reauthorization Act of 1986. This act modifies and reauthorizes CERCLA. Title III of this act is also known as the Emergency Planning and Community Right-to-Know Act of 1986.
Screen zone	In well construction, the section of a formation that contains the screen, or perforated pipe that allows water to enter the well.
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.
SFRWQCB	San Francisco Regional Water Quality Control Board.
SI	<i>Système International d'Unités</i> . An international system of physical units. Units of measure in this system include meters (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).
Sievert	The SI unit of dose equivalent. This is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. The unit Sv describes the effectiveness of various radiations to produce biological effects; $1 \text{ Sv} = \text{Gy} \times \text{Q} \times \text{N} = 100 \text{ rem}$.
Site 300	LLNL's high-explosives test facility, located approximately 15 miles east of the Livermore site.
SDM	Standard deviation of the mean. (See standard deviation.)

Glossary

SJCHD	San Joaquin County Health District. The local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.
SJCPHS	San Joaquin County Public Health Services.
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District. The local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County.
SNL/CA	Sandia National Laboratories, California.
SPPP	Stormwater Pollution Prevention Plan.
Std dev	Standard deviation. An indication of the dispersion of a set of results around their average (mean).
STLC	Soluble Threshold Limit Concentration. A value that can be used to determine if a waste is hazardous.
Superfund	The common name used for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). California has also established a "State Superfund" under provisions of the California Hazardous Waste Control Act.
Surface impoundment	A facility or part of a facility that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials, although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons.
SWRCB	State Water Resources Control Board. The state agency that develops and adopts statewide water quality plans and policies, issues permits to use water, and acts as an appellate agency for actions of the Regional Water Quality Control Boards.
T TCLP	Toxicity Characteristic Leaching Procedure. An analytical method designed to determine the mobility of both organic and inorganic compounds present in liquid, solid, and multiphase wastes. It is used to determine applicability of Land Ban to a waste.

TDS	Total Dissolved Solids. The portion of solid material in a waste stream that is dissolved and passed through a filter.
TFA	Treatment Facility A.
TFB	Treatment Facility B.
TFF	Treatment Facility F.
TLD	Thermoluminescent dosimeter. A device used to measure external gamma radiation levels.
TOC	Total organic carbon—The sum of the organic material present in a sample.
TOX	Total organic halides—The sum of the organic halides present in a sample.
TPH-G	Total petroleum hydrocarbons as gasoline.
Tritium	Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 years.
TRU	Transuranic waste.
TSCA	Toxic Substances Control Act. The law governing the manufacture, processing, and use of chemical substances.
T-test	A type of ANOVA that determines the significance of the difference between two sample means.
TTO	Total toxic organic compounds. A list of organic compounds for which EPA has established discharge limits for specific processes or industries.
TTU	Transportable Treatment Unit.
Tuff	A fragmental rock consisting of the smaller kinds of volcanic detritus, usually more or less stratified.
Turbidity	A measure of the concentration of sediment or suspended particles in solution.
U U-AVLIS	Uranium-Atomic Vapor Laser Isotope Separation.
UC	University of California.

Glossary

Unsaturated zone	That portion of the subsurface in which the pores are only partially filled with water. The direction of water flow is vertical in this zone; which is also referred to as the vadose zone.
USGS	U.S. Geological Survey. The federal agency responsible for maintaining maps of the United States.
UST	Underground storage tank. A stationary device designed to contain an accumulation of hazardous materials or waste. A tank is constructed primarily of nonearthen material, but the entire surface area of the tank is totally below the surface of, and covered by, the ground.
V Vadose zone	The partially saturated or unsaturated region above the water table that does not yield water to wells.
VHS	Volatile halogenated solvent. A term used by LLNL for analysis of the solvents detectable by EPA Method 601.
VOC	Volatile organic compound. Liquid or solid organic compounds that have a tendency to spontaneously pass into the vapor state.
VPL	Vacuum Process Laboratory.
VSI	Visual Site Inspection. An inspection required by EPA as part of the RCRA permit process to identify solid waste management units that could have had, or continue to have, releases of hazardous constituents to the environment.
W WAA	Waste Accumulation Area. An officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Hazardous Waste Management Division for off-site disposal.
WFA	West Firing Area (LLNL Site 300).
Wastewater treatment system	A collection of treatment processes and facilities designed and built to reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.

Water table	The water level surface below the ground at which the unsaturated zone ends and the saturated zone begins. It is the level to which a well that is screened in the unconfined aquifer would fill with water.
WDR	Waste Discharge Requirements. Issued by the California Regional Water Quality Control Board.
Weighting factor	A value used to calculate dose equivalents. It is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. The weighting factors used in this report are recommended by the ICRP (Publication 26).
Wind rose	A diagram that shows the frequency and intensity of wind from different directions at a particular place.
WMP	Waste Minimization Project.
X XRFA	X-Ray Fluorescence Analysis. The identification of elements through characteristic x rays generated by excitation. The sewer-monitoring system uses this technology for metal detection.
Z Zone 7	The common name for the Alameda County Flood Control and Water Conservation District. Zone 7 is the water management agency for the Livermore-Amador Valley with responsibility for water treatment and distribution. Zone 7 is also responsible for management of agricultural and surface water and the groundwater basin.

Appendix A. 1992 EPD Publications

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Appendix B. Methods of Dose Calculations

Robert J. Harrach
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Introduction

The effective dose equivalents shown in this report have been calculated using EPA-approved computer models, as described in Chapter 11. In particular, the technique used to calculate environmental transport and to estimate dose and risk in the CAP88-PC model are detailed in Chapter 8 of the EPA's *Users Guide for CAP88-PC, Version 1.0* (Parks 1992).

Insight into these code results is provided by the explicit dose calculation methods described here. The methods are based on the NRC Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent* (U.S. Nuclear Regulatory Commission 1977). The dose and dose-rate conversion factors used in these calculations were obtained from the committed dose equivalent tables for DOE dose calculations. These dose conversion factors are consistent with those specified in ICRP 30, *Limits of Intakes of Radionuclides by Workers* (ICRP 1980). Examples of these calculations and assumptions are presented below, following a brief description of the types of doses of major interest.

1. External perimeter dose. The dose rate at points along the perimeter of LLNL is a measure of the maximum external dose at locations of nearest uncontrolled public access. Dose rates from external penetrating radiation (primarily gamma rays and neutrons) are measured using environmental dosimeters (thermoluminescent dosimeters and neutron detectors). The environmental dosimeters measure dose rates from all external radiation sources, including cosmic radiations, naturally occurring radioactivity in the environment, fallout from nuclear weapons testing, and any contribution from LLNL operations. Hence, these doses are not solely attributable to LLNL, and in most instances they are a measure of regional background. This is determined by comparing the perimeter measurements with those made at off-site (Livermore Valley) locations. Moreover, these off-site measurements are made at points of maximum exposure and assume an occupancy of 24 hours per day, 365 days per year. In actuality, no member of the public resides at these locations for extended periods of time; therefore, these estimates are conservative.

2. Ingestion dose. Potential doses from ingestion of locally produced foodstuff and surface water are based on actual measurements of radionuclide concentrations in the various media (determined by sampling). Conservative exposure data and current ICRP dosimetric factors are used to estimate doses to

Appendix B. Methods of Dose Calculations

the individual. The following radionuclide exposure pathways are assessed by means of field measurements: tritium in water, tritium in milk, tritium in wine, and tritium in vegetation (which includes the forage-cow-milk pathway).

3. Inhalation immersion dose. Air pathway doses are calculated for each airborne radioactive discharge to the atmosphere. Inhalation and immersion doses are calculated for the site-wide maximally exposed individual (SW-MEI), as defined and discussed in Chapter 11, and at other perimeter points of interest. The amount of radioactivity released by LLNL usually is too low to measure radionuclide concentrations accurately in ambient air and to determine dose. Therefore, environmental transport and exposure pathway models are used to calculate potential doses from effluent emissions.

Dose calculations were made using the AIRDOS and CAP88-PC computer codes, as discussed in Chapter 11. These codes utilize the Gaussian plume model (Peterson et al. 1976) and provide concentrations through sixteen 22.5-degree compass sectors and distances up to 80 kilometers from potential release points. Local meteorological data is input to the codes. These data were obtained from sensors on the LLNL meteorological tower from heights of 10 and 40 meters. From records of these data, wind speed, wind direction, and atmospheric stability estimates were tabulated at one-quarter-hour intervals during the calendar year.

4. Maximally exposed individual dose. This dose represents the maximum credible dose to a "hypothetical" member of the public. Examples are the dose to the SW-MEI as described in Chapter 11, or the maximum dose at or beyond the site perimeter in any direction. Contributions from all potential exposure pathways are included and this dose is derived using the most conservative but realistic exposure data and assumptions. This hypothetical person is assumed to reside at the point of highest ground-level radionuclide air concentration continuously for 24 hours per day, 365 days per year. During this occupancy period, a portion of this person's diet consists of locally produced foodstuffs and drinking water containing the highest measured radionuclide concentration. Thus, this is not a dose actually received by any individual and should be viewed as a conservative estimate (i.e., overestimate) of the highest possible dose to any member of the public.

5. Collective population dose. The collective population dose is the dose for all individuals residing within an 80-kilometer radius of the site. It is calculated by summing for each sector the average individual dose multiplied by the number of individuals residing in the sector. The collective population dose is referred to as the "collective effective dose equivalent"; it is expressed in terms of person-sievert (person-rem).

The following dose calculation methods for water, vegetation, meat and milk ingestion pathways, and for air inhalation and immersion pathways are outlined

Appendix B. Methods of Dose Calculations

in conventional activity units of picocuries (pCi) and dose units of millirem (mrem). Below are the conversion constants that apply when converting to Système International (SI) activity units of becquerels (Bq) and dose units of sieverts (Sv):

$$\begin{aligned}1 \text{ pCi} &= (3.7 \times 10^{-2}) \text{ Bq} \\1 \text{ mrem} &= (1 \times 10^{-5}) \text{ Sv} = 10 \text{ } \mu\text{Sv} = 1 \times 10^{-2} \text{ mSv}\end{aligned}$$

These conversions can be applied universally throughout any section of this appendix.

Annual Dose from Potable Water

Based on the assumption that all water sampled is available as drinking water, the annual whole-body dose for tritium in mrem/y can be calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem/y}) = C_w \times U_w \times D_w$$

where

C_w = concentration of tritium in water (pCi/L)

U_w = intake rate (L/y) = 730 L/y for maximally exposed individual

D_w = dose factor (mrem/pCi)
= 6.3×10^{-8} mrem/pCi for tritium for the whole-body ingestion pathway for an adult

$D_{\text{whole body}}$ = effective dose equivalent (mrem/y) from ingestion of 730 L of potable water with concentration C_w

Annual Dose from Forage-Cow-Milk Pathway for Tritium in Vegetation

Based on the assumption that all feed for the cattle was pasture grass, the effective dose equivalent per $\mu\text{Ci/mL}$ of tritiated water (HTO) for the maximum exposed individual can be calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem/y}) = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}}$$

where

D_{veg} = dose from ingestion of vegetables

Appendix B. Methods of Dose Calculations

D_{meat} = dose from ingestion of meat

D_{milk} = dose from ingestion of milk

Vegetation

$$D_{\text{veg}}(\text{leafy}) = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}}$$

where

U_{veg} = intake rate (kg/y): 64 kg/y for maximally exposed individual

C_{veg} = concentration (pCi/kg): $10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])$

D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway

thus,

$$D_{\text{veg}}(\text{mrem/y}) = (0.40 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])$$

Meat

$$D_{\text{meat}}(\text{mrem/y}) = U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}}$$

where

U_{meat} = intake rate (kg/y): 110 kg/y for maximally exposed individual

$C_{\text{meat}} = (F_f) \times (Q_f) \times (C_{\text{veg}}) \times (e^{-\lambda_i t_s})$

D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway

F_f = fraction of daily intake of nuclide per kg of animal/fish (pCi/kg in meat per pCi/d ingested by the animal) (d/kg)

Q_f = amount of feed consumed (kg/d)

Appendix B. Methods of Dose Calculations

$$C_{veg} = \text{concentration (pCi/kg): } 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}$$

$$\times (C_{veg} [\mu\text{Ci/mL measured}])$$

$$\lambda_i = \text{radiological decay constant (d}^{-1}\text{)}$$

$$t_s = \text{time between slaughter to consumption (d)}$$

$$\begin{aligned} C_{meat} &= (1.2 \times 10^{-2} \text{ d/kg}) \times (50 \text{ kg/d}) \times (C_{veg} [\mu\text{Ci/mL}]) \\ &\times \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \right) \times (e^{[-1.5 \times 10^{-4}] \times [20]}) \\ &= \left(0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \right) \times (C_{veg} [\mu\text{Ci/mL measured}]) \end{aligned}$$

thus,

$$\begin{aligned} D_{meat}(\text{mrem/y}) &= (110 \text{ kg}) \times \left(\left[0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \right] \times [C_{veg} \{\mu\text{Ci/mL measured}\}] \right) \\ &\times (6.3 \times 10^{-8} \text{ mrem/pCi}) \\ &= (0.41 \times 10^4) \times (C_{veg} [\mu\text{Ci/mL measured}]) \end{aligned}$$

Milk

$$D_{milk}(\text{mrem/y}) = U_{milk} \times C_{milk} \times D_{HTO}$$

where

$$U_{milk} = \text{intake rate (L/y): 310 L/y for maximally exposed individual}$$

$$D_{HTO} = \text{dose factor (mrem/pCi): } 6.3 \times 10^{-8} \text{ mrem/pCi for } ^3\text{H for the adult whole-body ingestion pathway}$$

$$C_{milk} = (F_m) \times (Q_f) \times (C_{veg}) \times (e^{[-\lambda_i t]})$$

$$F_m = \text{fraction of daily intake of nuclide per liter of milk (pCi/L in milk per pCi/d ingested by the animal) (d/L)}$$

$$Q_f = \text{amount of feed consumed (kg/d)}$$

$$C_{veg} = \text{concentration (pCi/kg): } \left(10^9 \frac{\text{pCi/mL}}{\mu\text{Ci/mL}} \right) \times (C_{veg} [\mu\text{Ci/mL measured}])$$

$$\lambda_i = \text{radiological decay constant (d}^{-1}\text{)}$$

Appendix B. Methods of Dose Calculations

$$\begin{aligned}
 t_f &= \text{transport time from milking to milk consumption (d)} \\
 C_{\text{milk}} &= (1.0 \times 10^{-2} \text{ d/L}) \times (50 \text{ kg/d}) \times (C_{\text{veg}} [\mu\text{Ci/mL}]) \\
 &\quad \times \left(10^9 \frac{\text{pCi/mL}}{\mu\text{Ci/mL}} \right) \\
 &\quad \times \left(e^{[-1.5 \times 10^{-4}] \times (2)} \right) \\
 &= \left(0.5 \times 10^9 \frac{\text{pCi/mL}}{\mu\text{Ci/mL}} \right) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])
 \end{aligned}$$

thus,

$$\begin{aligned}
 D_{\text{milk}} (\text{mrem/y}) &= (310 \text{ L/y}) \times (6.3 \times 10^{-8} \text{ mrem/pCi}) \\
 &\quad \times \left[\left(0.5 \times 10^9 \frac{\text{pCi/L}}{\mu\text{Ci/mL}} \right) \times [C_{\text{veg}} \{\mu\text{Ci/mL measured}\}] \right] \\
 &= (0.97 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])
 \end{aligned}$$

Whole Body

$$\begin{aligned}
 D_{\text{whole body}} (\text{mrem/y}) &= ([0.40 \times 10^4] \times [C_{\text{veg}} \{\mu\text{Ci/mL measured}\}]) \\
 &\quad + ([0.41 \times 10^4] \times [C_{\text{veg}} \{\mu\text{Ci/mL measured}\}]) \\
 &\quad + ([0.97 \times 10^4] \times [C_{\text{veg}} \{\mu\text{Ci/mL measured}\}])
 \end{aligned}$$

thus,

$$D_{\text{whole body}} (\text{mrem/y}) = [1.78 \times 10^4] \times [C_{\text{veg}} \{\mu\text{Ci/mL measured}\}]$$

Inhalation/Immersion Dose

Inhalation Dose (³H)

$$D_{\text{whole body}} (\text{mrem/y}) = C \times U \times D$$

where

$$\begin{aligned}
 C &= \text{radionuclide concentration at the receptor} \\
 &\quad ([F] \times [\chi/Q] \times [Q]) \\
 F &= \frac{1 \times 10^{12} \text{ pCi/Ci}}{3.15 \times 10^7 \text{ s/y}} = 3.17 \times 10^4 \\
 \chi/Q &= \text{diffusion parameter (s/m}^3\text{) (calculated)} \\
 Q &= \text{release rate, Ci/y}
 \end{aligned}$$

Appendix B. Methods of Dose Calculations

U = intake rate (inhalation rate for adult is $8,400 \text{ m}^3/\text{y}$)

D = dose conversion factor (for ^3H : $9.45 \times 10^{-8} \text{ mrem/pCi}$; the tritium dose conversion factor was obtained by multiplying the inhalation dose factor, $6.3 \times 10^{-8} \text{ mrem/pCi}$, by 1.5 to include absorption through the skin)

thus

$$D_{\text{wholebody}}(\text{mrem/y}) = \left(3.17 \times 10^4 \left[\frac{\text{pCi/Ci}}{\text{s/y}} \right] \right) \times (\chi / Q[\text{s/m}^3]) \times (Q[\text{Ci/y}]) \\ \times (8,400 [\text{m}^3/\text{y}]) \times (D [\text{mrem/pCi}])$$

External Immersion Dose (^{13}N and ^{15}O)

This dose calculation was not used for 1992 because we had no ^{13}N and ^{15}O emissions.

$$D_{\text{whole body}} (\text{mrem/y}) = C \times (DRF)$$

where DRF , the dose-rate factor, is the external dose-equivalent rate per unit

radionuclide concentration, $\frac{\text{mrem/y}}{\text{pCi/m}^3}$

$$\text{For } ^{13}\text{N}, DRF = 5.11 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

$$\text{For } ^{15}\text{O}, DRF = 5.12 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

and

C = radionuclide concentration at the receptor ($[F] \times [\chi/Q] \times [Q]$)

$$F = \frac{1 \times 10^{12} \text{ pCi/Ci}}{3.15 \times 10^7 \text{ s/y}} = 3.17 \times 10^4$$

χ/Q = diffusion parameter (s/m^3) (calculated)

Q = release rate, Ci/y

Appendix B. Methods of Dose Calculations

thus,

$$D_{\text{wholebody}}(\text{mrem}/\text{y}) = \left(3.17 \times 10^4 \left[\frac{\text{pCi}/\text{Ci}}{\text{s}/\text{y}} \right] \right) \times \left(\chi / Q [\text{s} / \text{m}^3] \right) \times (Q [\text{Ci} / \text{y}]) \\ \times \left(\text{DRF} \left[\frac{\text{mrem} / \text{y}}{\text{pCi} / \text{m}^3} \right] \right)$$

Annual Population Dose

For population dose, the diffusion parameters and population figures for a sector (*i*) within 80 kilometers of LLNL are summed over all directions (*n*). These values are determined in person-mrem.

$$\text{Dose (person-mrem/y)} = (F) \times \left(\sum_i^n [\chi / Q]_i P_i \right) \times Q \times U \times D$$

where

$$F = \frac{1 \times 10^{12} \text{ pCi}/\text{Ci}}{3.15 \times 10^7 \text{ s}/\text{y}} = 3.17 \times 10^4$$

$$\left(\sum_i^n [\chi / Q]_i P_i \right) = \begin{array}{l} \text{Summation of the calculated } (\chi / Q) \text{ values for sector } i \\ \text{times the population in sector } i (P_i) \text{ for all regions } n, \\ \text{person-s}/\text{m}^3 \end{array}$$

Q = release rate, Ci/y

U = inhalation rate, average adult individual, is 8400 m³/y

D = dose factor, mrem/pCi

Appendix C. Ground Water Protection Tables

Table C-1. Parameters sampled in Well NC2-07, Site 300, 1992.

Parameters	NC2-07	Parameters	NC2-07
Purgeable pollutants (EPA Method 601 µg/L)		Radiologicals (Bq/L)	
1,1,1-Trichloroethane	4 n.d at <0.5	Gross alpha	0.12 ± 0.13
1,1,2,2-Tetrachloroethane	4 n.d at <0.5		0.19 ± 0.13
1,1,2-Trichloroethane	4 n.d at <0.5	Gross beta	0.22 ± 0.07
1,1-Dichloroethane	4 n.d at <0.5		0.23 ± 0.05
1,1-Dichloroethene	4 n.d at <0.5	Tritium	-1.9 ± 3.4
1,2-Dichlorobenzene	4 n.d at <0.5		-0.7 ± 3.9
1,2-Dichloroethane	4 n.d at <0.5		
1,2-Dichloroethene (total)	4 n.d at <0.5		
1,2-Dichloropropane	4 n.d at <0.5		
1,3-Dichlorobenzene	4 n.d at <0.5		
1,4-Dichlorobenzene	4 n.d at <0.5		
2-Chloroethylvinylether	4 n.d at <0.5		
Bromodichloromethane	4 n.d at <0.5		
Bromoform	4 n.d at <0.5		
Bromomethane	4 n.d at <0.5		
Carbon tetrachloride	4 n.d at <0.5		
Chlorobenzene	4 n.d at <0.5		
Chloroethane	4 n.d at <0.5		
Chloroform	4 n.d at <0.5		
Chloromethane	4 n.d at <0.5		
cis-1,2-Dichloroethene	4 n.d at <0.5		
cis-1,3-Dichloropropene	4 n.d at <0.5		
Dibromochloromethane	4 n.d at <0.5		
Dichlorodifluoromethane	4 n.d at <0.5		
Freon-113	4 n.d at <0.5		
Methylene chloride	4 n.d at <0.5		
Tetrachloroethene	4 n.d at <0.5		
trans-1,2-Dichloroethene	4 n.d at <0.5		
trans-1,3-Dichloropropene	4 n.d at <0.5		
Trichloroethene	4 n.d at <0.5		
Trichlorofluoromethane	4 n.d at <0.5		
Vinyl chloride	4 n.d at <0.5		

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992.

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
Physical and chemical (mg/L)				
Ammonia nitrogen (as N)	0.02	0.02	0.02	
	0.04	0.04	0.06	
	0.04	0.03	0.03	
	0.033	<0.03	<0.03	
Arsenic	0.011	0.01	0.012	0.01
	0.01	0.009	0.015	0.011
	0.011	0.01	0.013	0.01
	0.01	0.01	0.013	0.011
Barium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Beryllium	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002
Bicarbonate alk (as CaCO ₃)	150	140	150	150
	150	140	150	150
	160	150	150	300
	160	150	150	150
Cadmium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Calcium	51	47	48	52
	47	54	51	45
	47	50	44	46
	51	51	42	45
Carbonate alk (as CaCO ₃)	4 n.d. at	4 n.d. at <1	4 n.d. at <1	3 n.d. at <1
				1 n.d. at <2
Chloride		53	34	36
	38	52	35	39
	40	53	37	76
	38	55	34	38
Chromium	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Conductivity (μmhos/cm)	540	650	530	560
	480	530	490	490
	490	540	440	490
	470	590	450	510
Copper	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05	3 n.d. at <0.05
				1 n.d. at <0.1
Fluoride	0.4	0.4	0.3	0.4
	0.4	0.4	0.3	0.4
	0.4	0.3	0.3	0.8
	0.32	0.3	0.31	0.38
Hydroxide alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1	3 n.d. at <1
				1 n.d. at <2
Iron	4 n.d. at <0.1	4 n.d. at <0.1	4 n.d. at <0.1	3 n.d. at <0.1
				1 n.d. at <0.2

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
Physical and chemical (mg/L)				
Ammonia nitrogen (as N)	0.02	<0.02	0.02	0.02
	<0.02	<0.02	<0.02	<0.02
	0.08	0.04	0.04	0.04
	<0.03	<0.06	<0.03	<0.03
Arsenic	0.014	0.014	0.014	0.013
	0.012	0.013	0.013	0.015
	0.015	0.013	0.014	0.014
	0.013	0.013	0.013	0.013
Barium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Beryllium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Bicarbonate alk (as CaCO ₃)	130	140	130	250
	130	280	90	130
	130	140	130	130
	130	280	130	130
Cadmium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Calcium	42	44	43	82
	37	39	40	40
	36	38	39	42
	41	76	40	38
Carbonate alk (as CaCO ₃)	4 n.d. at <1	2 n.d. at <1	4 n.d. at <1	3 n.d. at <1
		2 n.d. at <2		1 n.d. at <2
Chloride	36	36	36	70
	36	72	38	35
	36	37	37	37
	38	75	37	38
Chromium	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Conductivity (µmhos/cm)	520	550	570	540
	480	460	480	490
	460	440	450	470
	480	460	520	440
Copper	4 n.d. at <0.05	2 n.d. at <0.05	4 n.d. at <0.05	<0.1
		2 n.d. at <0.1		<0.05
Fluoride	0.5	0.5	0.5	1
	0.5	1	0.5	0.5
	0.4	0.4	0.4	0.4
	0.48	0.84	0.48	0.5
Hydroxide alk (as CaCO ₃)	4 n.d. at <1	2 n.d. at <1	4 n.d. at <1	3 n.d. at <1
		2 n.d. at <2		1 n.d. at <2
Iron	4 n.d. at <0.1	2 n.d. at <0.1	4 n.d. at <0.1	3 n.d. at <0.1
		2 n.d. at <0.2		1 n.d. at <0.2

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
Lead	0.006	0.007	0.002	0.002
	0.006	0.002	0.02	
	0.006		0.002	
	0.002			
Magnesium	16	18	15	16
	18	23	19	16
	19	22	17	34
	18	23	16	16
Manganese	0.06	<0.05	<0.05	<0.05
	<0.05	<0.05	<0.05	<0.05
	<0.05	<0.05	<0.05	<0.1
	<0.05	<0.05	<0.05	<0.1
Mercury			0.0002	
	4 n.d. at <0.0002	4 n.d. at <0.0002	3 n.d. at <0.0002	4 n.d. at <0.0002
Nickel	<0.005	<0.005	<0.005	<0.005
	<0.1	<0.1	<0.1	<0.1
	<0.005	<0.005	<0.005	<0.005
	0.046	0.006	0.006	<0.005
Nitrate plus nitrite (as N)	7.1	7	6.4	5.5
	6	5.8	5.2	4.6
	7.5	7	6.2	10.9
	7.3	7.1	6.7	5.6
Nitrate (as NO ₃)	31	31	28	24
	25	25	23	20
	33	31	28	24
	32	31	30	25
Nitrite (as N)	<0.01	<0.01	<0.01	<0.02
	0.09	<0.01	<0.01	<0.01
Nitrite (as NO ₂)	<0.03	<0.03	<0.03	<0.06
	0.3	<0.03	<0.03	<0.03
Total Kjeldahl nitrogen	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5
				1 n.d. at <1
Low level phenolics	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005	3 n.d. at <0.005
				1 n.d. at <0.01
pH	7.5	7.5	7.6	7.6
	7.6	7.6	7.6	7.6
	7.6	7.5	7.4	7.5
	7.1	7.1	7.2	7.1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
Lead	0.003	0.005	<0.002	0.002
	<0.002	<0.002	<0.002	<0.002
		<0.002	<0.002	<0.002
		<0.002	<0.002	<0.002
Magnesium	17	17	16	32
	18	35	17	18
	16	18	17	16
	18	36	17	17
Manganese	<0.05	<0.05	<0.05	<0.1
	<0.05	<0.1	<0.05	<0.05
	<0.05	<0.05	<0.05	<0.05
	<0.05	<0.1	<0.05	<0.05
Mercury	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002
Nickel	<0.005	<0.005	0.008	<0.005
	<0.1	<0.1	0.2	<0.1
	<0.005	<0.005	0.006	<0.005
	<0.005	<0.005	<0.005	<0.005
Nitrate plus nitrite (as N)	8.5	7.7	8.3	16.8
	8.4	15.4	8.4	8.3
	8.2	7.5	8	8
	8.6	15.2	8.7	8.3
Nitrate (as NO ₃)	37	34	37	37
	37	34	37	36
	36	33	35	35
	38	32	38	37
Nitrite (as N)	<0.01	<0.01	<0.01	<0.01
	<0.01	<0.02	<0.01	<0.01
Nitrite (as NO ₂)	<0.03	<0.03	<0.03	<0.03
	<0.03	<0.06	<0.03	<0.03
Total Kjeldahl nitrogen	4 n.d. at <0.5	2 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5
		2 n.d. at <1		1 n.d. at <1
Low level phenolics	4 n.d. at <0.005	2 n.d. at <0.005	4 n.d. at <0.005	3 n.d. at <0.005
		2 n.d. at <0.01		1 n.d. at <0.01
pH	7.6	7.6	7.6	7.7
	7.6	7.6	7.6	7.6
	7.5	7.5	7.6	7.5
	7.4	7.3	7.4	7.4

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
Potassium	3	2	2	2
	6	3	3	3
	6	3	2	3
	<5	<5	<5	<5
Selenium	0.003	0.002	0.003	<0.002
	<0.002	0.003	<0.002	0.003
	0.004	<0.002	0.004	0.005
	<0.002	<0.002	<0.002	<0.002
Silver	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Sodium	35	32	31	37
	34	38	38	35
	36	39	34	41
	35	38	29	36
Sulfate	42	64	39	54
	39	65	39	53
	40	60	40	107
	42	68	41	54
Total alkalinity (as CaCO ₃)	150	140	150	150
	150	140	150	150
	160	150	150	300
	160	150	150	150
Total organic carbon (TOC)	1	1.2	0.7	0.7
	1	0.8	0.6	0.6
	0.9	1	0.7	0.8
	0.7	0.8	0.7	0.6
Total organic halides (TOX)	8 n.d. at <0.02	8 n.d. at <0.02	8 n.d. at <0.02	8 n.d. at <0.02
Total dissolved solids (TDS)	340	400	340	360
	360	380	350	370
	360	400	350	750
	390	440	330	340
Total suspended solids (TSS)	2	<1	<1	<1
	4	<1	3	<1
	14	2	<1	<1
Vanadium	0.06	<0.05	<0.05	<0.05
	0.05	0.07	<0.05	<0.05
	<0.05	<0.05	<0.05	<0.05
	0.054	0.062	<0.05	0.054
Zinc	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05	3 n.d. at <0.05
				1 n.d. at <0.1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
Potassium	2	2	2	5
	3	6	3	3
	2	3	3	3
	<5	<10	<5	<5
Selenium	<0.002	<0.002	<0.002	<0.002
	<0.002	0.002	<0.002	<0.002
	0.002	0.004	0.003	0.003
	<0.002	<0.002	<0.002	<0.002
Silver	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Sodium	38	40	38	75
	44	45	40	43
	37	41	43	38
	42	79	39	40
Sulfate	42	44	45	96
	41	82	44	48
	45	45	46	49
	45	92	46	48
Total alkalinity (as CaCO ₃)	130	140	130	250
	130	280	90	130
	130	140	130	130
	130	280	130	130
Total organic carbon (TOC)	0.9	0.8	0.7	0.7
	0.8	0.8	0.8	0.7
	0.7	0.7	0.7	0.7
	0.7	0.7	0.6	0.7
Total organic halides (TOX)	8 n.d. at <0.02	8 n.d. at <0.02	8 n.d. at <0.02	8 n.d. at <0.02
Total dissolved solids (TDS)	330	340	340	670
	310	760	360	360
	360	360	360	350
	310	750	320	320
Total suspended solids (TSS)	<1	<1	<1	10
	1	1	<1	1
	<1	10	<1	3
Vanadium	0.07	0.07	0.07	<0.05
	0.07	0.06	0.07	0.07
	<0.05	<0.05	<0.05	<0.05
	0.063	0.093	0.066	0.072
Zinc	4 n.d. at <0.05	2 n.d. at <0.05	4 n.d. at <0.05	3 n.d. at <0.05
		2 n.d. at <0.1		1 n.d. at <0.1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
Purgeable pollutants (EPA Method 601, µg/L)				
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
Purgeable pollutants (EPA Method 601, µg/L)				
1,1,1-Trichloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1,2-Trichloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1-Dichloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,1-Dichloroethene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichlorobenzene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloroethene (total)	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,2-Dichloropropane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,3-Dichlorobenzene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
1,4-Dichlorobenzene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
2-Chloroethylvinylether	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromodichloromethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromoform	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Bromomethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Carbon tetrachloride	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chlorobenzene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloroethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloroform	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Chloromethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
cis-1,2-Dichloroethene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Title 22 herbicides (µg/L)				
2,4,5-TP (Silvex)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1	3 n.d. at <1 1 n.d. at <2
2,4-D	3 n.d. at <5 1 n.d. at <10	3 n.d. at <5 1 n.d. at <10	3 n.d. at <5 1 n.d. at <10	2 n.d. at <5 2 n.d. at <10
Title 22 pesticides (µg/L)				
BHC, gamma isomer (Lindane)	<0.03	<0.03	<0.03	<0.03
	<0.4	<0.4	<0.4	<0.4
	<0.3	<0.03	<0.03	<0.06
	<0.03	<0.03	<0.03	<0.03
Endrin	<0.05	<0.05	<0.1	<0.1
	<0.01	<0.01	<0.01	<0.01
	<0.5	<0.05	<0.05	<0.1
	<0.05	<0.05	<0.05	<0.05
Methoxychlor	<0.2	<0.2	<0.2	<0.2
	<10	<10	<10	<10
	<2	<0.2	<0.2	<0.4
	<0.2	<0.2	<0.2	<0.2
Toxaphene	<1	<1	<1	<1
	<0.5	<0.5	<0.5	<0.5
	<10	<1	<1	<2
	<1	<1	<1	<1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
cis-1,3-Dichloropropene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Dibromochloromethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Dichlorodifluoromethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Freon-113	2 <0.5 3 3	2 n.d. at <0.5 2 n.d. at <1	20 13 26 14	59 41 49 37
Methylene chloride	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Tetrachloroethene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
trans-1,2-Dichloroethene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
trans-1,3-Dichloropropene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Trichloroethene	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Trichlorofluoromethane	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Vinyl chloride	4 n.d. at <0.5	2 n.d. at <0.5 2 n.d. at <1	4 n.d. at <0.5	3 n.d. at <0.5 1 n.d. at <1
Title 22 herbicides (µg/L)				
2,4,5-TP (Silvex)	4 n.d. at <1	2 n.d. at <1 2 n.d. at <2	4 n.d. at <1	3 n.d. at <1 1 n.d. at <2
2,4-D	3 n.d. at <5 1 n.d. at <10	1 n.d. at <5 3 n.d. at <10	3 n.d. at <5 1 n.d. at <10	3 n.d. at <5 1 n.d. at <20
Title 22 pesticides (µg/L)				
BHC, gamma isomer (Lindane)	<0.03 <0.4 <0.03 <0.03	<0.03 <0.8 <0.03 <0.06	<0.03 <0.4 <0.03 <0.03	<0.06 <0.4 <0.03 <0.03
Endrin	<0.1 <0.01 <0.05 <0.05	<0.1 <0.02 <0.05 <0.1	<0.1 <0.01 <0.05 <0.05	<0.2 <0.01 <0.05 <0.05
Methoxychlor	<0.2 <10 <0.2 <0.2	<0.2 <20 <0.2 <0.4	<0.2 <10 <0.2 <0.2	<0.4 <10 <0.2 <0.2
Toxaphene	<1 <0.5 <1 <1	<1 <1 <1 <2	<1 <0.5 <1 <1	<2 <0.5 <1 <1

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K1-01C	K1-02B	K1-03	K1-04
Explosive compounds ($\mu\text{g/L}$)				
HMX	3 n.d. at <20	4 n.d. at <20	4 n.d. at <20	3 n.d. at <20 1 n.d. at <40
RDX	3 n.d. at <30	4 n.d. at <30	4 n.d. at <30	3 n.d. at <30 1 n.d. at <60
TNT	3 n.d. at <30	4 n.d. at <30	4 n.d. at <30	3 n.d. at <30
Radiologicals (Bq/L)				
Gross alpha	0.22 $\pm$ 0.14	0.09 $\pm$ 0.10	0.029 $\pm$ 0.087	0.039 $\pm$ 0.093
	0.18 $\pm$ 0.12	0.052 $\pm$ 0.081	0.043 $\pm$ 0.068	0.010 $\pm$ 0.087
	0.13 $\pm$ 0.10	-0.020 $\pm$ 0.078	0.023 $\pm$ 0.081	-0.016 $\pm$ 0.088
	0.18 $\pm$ 0.13	0.05 $\pm$ 0.08	0.04 $\pm$ 0.14	0.03 $\pm$ 0.09
Gross beta	0.113 $\pm$ 0.068	0.014 $\pm$ 0.078	0.067 $\pm$ 0.076	0.144 $\pm$ 0.083
	0.238 $\pm$ 0.080	0.042 $\pm$ 0.061	0.180 $\pm$ 0.067	0.225 $\pm$ 0.069
	0.157 $\pm$ 0.068	0.081 $\pm$ 0.073	0.045 $\pm$ 0.074	0.112 $\pm$ 0.069
	0.18 $\pm$ 0.08	0.18 $\pm$ 0.08	0.08 $\pm$ 0.07	0.13 $\pm$ 0.05
Tritium	4.0 $\pm$ 3.4	74.6 $\pm$ 6.0	1.5 $\pm$ 3.4	-1.4 $\pm$ 3.0
	1.3 $\pm$ 3.5	68.5 $\pm$ 5.7	0.8 $\pm$ 3.5	-0.8 $\pm$ 3.3
	3.6 $\pm$ 2.6	65.5 $\pm$ 4.9	3.6 $\pm$ 2.6	0.5 $\pm$ 2.3
	5.4 $\pm$ 3.6	84 $\pm$ 6	2.5 $\pm$ 3.5	-1.3 $\pm$ 3.2
Uranium-234	0.140 $\pm$ 0.017	0.049 $\pm$ 0.009	0.033 $\pm$ 0.008	0.041 $\pm$ 0.008
	0.162 $\pm$ 0.021	0.050 $\pm$ 0.009	0.033 $\pm$ 0.009	0.048 $\pm$ 0.010
	0.699 $\pm$ 0.053	0.078 $\pm$ 0.011	0.188 $\pm$ 0.019	0.045 $\pm$ 0.009
	0.176 $\pm$ 0.020	0.049 $\pm$ 0.010	0.036 $\pm$ 0.007	0.045 $\pm$ 0.007
Uranium-235	0.002 $\pm$ 0.003	0.000 $\pm$ 0.001	0.002 $\pm$ 0.002	0.001 $\pm$ 0.002
	0.003 $\pm$ 0.003	0.001 $\pm$ 0.002	0.001 $\pm$ 0.003	0.001 $\pm$ 0.002
	0.006 $\pm$ 0.003	0.006 $\pm$ 0.003	0.001 $\pm$ 0.002	0.001 $\pm$ 0.001
	0.005 $\pm$ 0.004	0.001 $\pm$ 0.002	0.0013 $\pm$ 0.0017	-0.0007 $\pm$ 0.0007
Uranium-238	0.080 $\pm$ 0.012	0.025 $\pm$ 0.006	0.017 $\pm$ 0.005	0.025 $\pm$ 0.006
	0.085 $\pm$ 0.014	0.034 $\pm$ 0.008	0.018 $\pm$ 0.007	0.022 $\pm$ 0.007
	0.090 $\pm$ 0.012	0.026 $\pm$ 0.006	0.015 $\pm$ 0.004	0.020 $\pm$ 0.006
	0.099 $\pm$ 0.014	0.030 $\pm$ 0.007	0.014 $\pm$ 0.004	0.026 $\pm$ 0.006
Radium-226	-0.022 $\pm$ 0.021	-0.002 $\pm$ 0.021	-0.005 $\pm$ 0.028	0.001 $\pm$ 0.020
	-0.016 $\pm$ 0.015	0.031 $\pm$ 0.141	-0.005 $\pm$ 0.019	0.038 $\pm$ 0.325
	-0.015 $\pm$ 0.018	0.005 $\pm$ 0.000	-0.005 $\pm$ 0.016	-0.008 $\pm$ 0.022
	0.026 $\pm$ 0.027	-0.006 $\pm$ 0.019	0.019 $\pm$ 0.014	0.024 $\pm$ 0.026

...continued

Appendix C. Ground Water Protection Tables

Table C-2. Parameters in the Pit 1 Area monitoring wells, Site 300, 1992
(concluded).

Parameters	Well			
	K1-05	K1-07	K1-08	K1-09
Explosive compounds ($\mu\text{g/L}$)				
HMX	4 n.d. at <20	2 n.d. at <20 2 n.d. at <40	4 n.d. at <20	3 n.d. at <20 1 n.d. at <40
RDX	4 n.d. at <30	2 n.d. at <30 2 n.d. at <60	4 n.d. at <30	3 n.d. at <30 1 n.d. at <60
TNT	4 n.d. at <30	2 n.d. at <30	4 n.d. at <30	3 n.d. at <30
Radiologicals (Bq/L)				
Gross alpha	-0.031 ± 0.085	0.057 ± 0.089	0.04 ± 0.11	-0.077 ± 0.081
	0.039 ± 0.072	0.041 ± 0.070	0.002 ± 0.069	0.007 ± 0.091
	-0.047 ± 0.068	0.045 ± 0.081	-0.010 ± 0.088	0.049 ± 0.068
	0.02 ± 0.13	0.05 ± 0.09	0.05 ± 0.15	-0.01 ± 0.14
Gross beta	0.083 ± 0.068	0.148 ± 0.095	0.121 ± 0.067	0.105 ± 0.080
	0.159 ± 0.069	0.089 ± 0.071	0.145 ± 0.070	0.092 ± 0.065
	-0.10 ± 0.11	0.077 ± 0.063	0.123 ± 0.067	0.019 ± 0.064
	0.11 ± 0.07	0.12 ± 0.07	0.09 ± 0.08	0.10 ± 0.07
Tritium	-3.0 ± 3.2	-1.2 ± 3.1	-1.2 ± 3.2	-2.8 ± 3.1
	-1.3 ± 3.3	-0.4 ± 3.2	1.8 ± 3.4	0.7 ± 3.4
	1.4 ± 3.3	-0.4 ± 3.2	-1.1 ± 3.1	0.4 ± 3.1
	-0.1 ± 3.3	1.7 ± 3.4	1.0 ± 3.4	0.7 ± 3.4
Uranium-234	0.043 ± 0.010	0.056 ± 0.011	0.036 ± 0.008	0.035 ± 0.008
	0.039 ± 0.008	0.057 ± 0.010	0.032 ± 0.007	0.035 ± 0.008
	0.259 ± 0.023	0.067 ± 0.008	0.049 ± 0.010	0.043 ± 0.009
	0.036 ± 0.007	0.050 ± 0.011	0.044 ± 0.007	0.044 ± 0.008
Uranium-235	0.001 ± 0.002	0.001 ± 0.002	0.001 ± 0.002	0.000 ± 0.002
	0.001 ± 0.002	0.000 ± 0.001	0.001 ± 0.002	0.000 ± 0.002
	0.001 ± 0.001	0.005 ± 0.003	0.001 ± 0.002	-0.001 ± 0.001
	0.0003 ± 0.0013	0.0022 ± 0.0022	0.0010 ± 0.0014	0.0012 ± 0.0024
Uranium-238	0.016 ± 0.006	0.028 ± 0.007	0.014 ± 0.005	0.013 ± 0.005
	0.020 ± 0.005	0.027 ± 0.007	0.015 ± 0.005	0.016 ± 0.005
	0.023 ± 0.005	0.025 ± 0.005	0.019 ± 0.006	0.020 ± 0.006
	0.019 ± 0.005	0.026 ± 0.007	0.017 ± 0.005	0.020 ± 0.005
Radium-226	-0.012 ± 0.024	-0.015 ± 0.016	0.011 ± 0.018	-0.003 ± 0.021
	0.006 ± 0.016	0.014 ± 0.018	0.019 ± 0.019	0.006 ± 0.016
	-0.006 ± 0.019	-0.012 ± 0.021	0.028 ± 0.016	0.002 ± 0.020
	0.038 ± 0.021	0.019 ± 0.023	0.020 ± 0.023	-0.002 ± 0.021

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-3. Parameters sampled in Pit 2 Area monitoring wells, Site 300, 1992.

Parameters	Well		
	K2-01C	K2-04D	K2-04S
Physical and chemical (mg/L)			
Ammonia nitrogen (as N)	0.06	<0.02	0.12
	0.06	0.13	0.06
	0.05	<0.03	0.03
Beryllium	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005
	1 n.d. at <0.0002	1 n.d. at <0.0002	1 n.d. at <0.0002
Lead	0.011		
	3 n.d. at <0.002	4 n.d. at <0.002	4 n.d. at <0.002
Nitrate plus nitrite (as NO ₃)	24	32	33
	29	35	36
	23	29	32
	21	32	36
Total Kjeldahl nitrogen	3 n.d. at <0.5	3 n.d. at <0.5	3 n.d. at <0.5
Purgeable pollutants (EPA Method 601, µg/L)			
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-3. Parameters sampled in Pit 2 Area monitoring wells, Site 300, 1992
(concluded).

Parameters	Well		
	K2-01C	K2-04D	K2-04S
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dichlorodifluoromethane	0.6 3 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Radiologicals (Bq/L)			
Gross alpha	0.22 ± 0.17	-0.024 ± 0.093	0.16 ± 0.14
	0.28 ± 0.15	0.037 ± 0.095	0.10 ± 0.13
	0.05 ± 0.15	0.057 ± 0.079	0.10 ± 0.12
	0.08 ± 0.09	0.08 ± 0.13	0.67 ± 0.20
Gross beta	0.174 ± 0.074	0.148 ± 0.069	0.111 ± 0.087
	0.163 ± 0.078	0.157 ± 0.072	0.215 ± 0.071
	0.141 ± 0.071	0.035 ± 0.075	0.048 ± 0.073
	0.071 ± 0.048	0.113 ± 0.048	0.340 ± 0.075
Tritium	345 ± 18	300 ± 16	327 ± 17
	490 ± 25	286 ± 15	330 ± 17
	340 ± 18	322 ± 17	340 ± 18
	433 ± 23	403 ± 22	422 ± 22

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992.

Parameters	Well		
	K6-01	K6-03	K6-04
Physical and chemical (mg/L)			
Ammonia nitrogen (as N)	0.1	0.24	0.03
	0.2	0.43	0.1
	0.17	0.34	0.04
	0.1	0.28	<0.03
Arsenic	0.013	0.02	0.016
	0.13	0.02	0.15
	0.013	0.02	0.016
	0.0086	0.016	0.013
Barium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Beryllium	1 n.d. at <0.0005	1 n.d. at <0.0002	1 n.d. at <0.0002
	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005
Bicarbonate alk (as CaCO ₃)	190	190	170
	200	190	170
	190	180	170
	200	180	170
Cadmium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Carbonate alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
Chloride	87	88	84
	88	88	85
	90	93	86
	85	91	79
Chromium	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Fluoride	0.4	0.5	0.5
	0.4	0.5	0.5
	0.5	0.5	0.5
	0.4	0.49	0.45
Hydroxide alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
Iron	0.4	0.2	0.1
	0.3	0.1	0.2
	0.33	2 n.d. at <0.1	2 n.d. at <0.1
	1 n.d. at <0.1		
Lead	4 n.d. at <0.002	0.0041	4 n.d. at <0.002
	3 n.d. at <0.002	3 n.d. at <0.002	
Low level phenolics	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Manganese	<0.05	<0.05	4 n.d. at <0.05
	0.07	0.08	
	0.08	0.09	
	0.062	0.074	
Mercury	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	EP6-07	EP6-08	EP6-09
Physical and chemical (mg/L)			
Ammonia nitrogen (as N)	0.23	0.03	0.02
	0.25	0.06	0.04
	0.35	0.05	0.03
	0.26	0.031	0.093
Arsenic	0.02	0.018	0.016
	0.02	0.019	0.016
	0.02	0.016	0.014
	0.016	0.014	0.011
Barium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Beryllium	1 n.d. at <0.0002	1 n.d. at <0.0002	1 n.d. at <0.0002
	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005
Bicarbonate alk (as CaCO ₃)	180	190	200
	190	190	200
	180	180	190
	190	200	190
Cadmium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Carbonate alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
Chloride	88	95	120
	88	94	110
	91	96	120
	85	90	110
Chromium	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Fluoride	0.5	0.4	0.4
	0.5	0.4	0.4
	0.5	0.4	0.4
	0.47	0.44	0.42
Hydroxide alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
Iron	0.1	4 n.d. at <0.1	4 n.d. at <0.1
	3 n.d. at <0.1		
Lead	4 n.d. at <0.002	<0.002	4 n.d. at <0.002
		3 n.d. at <0.002	
Low level phenolics	4 n.d. at <0.005	4 n.d. at <0.005	4 n.d. at <0.005
Manganese	0.12	4 n.d. at <0.05	4 n.d. at <0.05
	0.14		
	0.16		
	0.14		
Mercury	4 n.d. at <0.0002	4 n.d. at <0.0002	4 n.d. at <0.0002

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	K6-01	K6-03	K6-04
Nickel	3 n.d. at <0.005	0.0054	3 n.d. at <0.005
	1 n.d. at <0.1	2 n.d. at <0.005 1 n.d. at <0.1	1 n.d. at <0.1
Nitrate plus nitrite (as N)	2 n.d. at <0.1	2 n.d. at <0.1	1.6
			1.6
Nitrate (as NO ₃)	4 n.d. at <0.4	4 n.d. at <0.4	7.1
			6.9
			6.3
			7.3
Nitrite (as N)	2 n.d. at <0.01	2 n.d. at <0.01	2 n.d. at <0.01
Nitrite (as NO ₂)	2 n.d. at <0.03	2 n.d. at <0.03	2 n.d. at <0.03
Selenium	4 n.d. at <0.002	4 n.d. at <0.002	0.002
			0.0024
			2 n.d. at <0.002
Silver	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005
Sodium	130	130	110
	130	120	110
	160	140	130
	140	110	94
Sulfate	290	240	200
	320	250	190
	280	240	200
	280	250	200
Total alkalinity (as CaCO ₃)	190	190	170
	200	190	170
	190	180	170
	200	180	170
Total dissolved solids (TDS)	780	700	620
	790	710	640
	740	700	620
	760	700	620
Total Kjeldahl nitrogen	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Total organic carbon (TOC)	<0.5	0.7	0.5
	1.8	0.8	0.7
	<0.5	0.5	0.7
	0.57	<0.5	<0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	EP6-07	EP6-08	EP6-09
Nickel	3 n.d. at <0.005 1 n.d. at <0.1	3 n.d. at <0.005 1 n.d. at <0.1	3 n.d. at <0.005 1 n.d. at <0.1
Nitrate plus nitrite (as N)	2 n.d. at <0.1	0.5 0.6	0.9 1.1
Nitrate (as NO ₃)	4 n.d. at <0.4	2.9 2.2 2.4 2.6	4.7 4.1 4.5 4.7
Nitrite (as N)	<0.01 0.02	2 n.d. at <0.01	<0.01 0.013
Nitrite (as NO ₂)	<0.03 0.07	2 n.d. at <0.03	<0.03 0.043
Selenium	4 n.d. at <0.002	0.003 0.0031 2 n.d. at <0.002	0.002 0.002 0.0034 <0.002
Silver	4 n.d. at <0.0005	0.0007 3 n.d. at <0.0005	4 n.d. at <0.0005
Sodium	120 110 140	130 130 150	130 130 150
Sulfate	120 250 250 240 240	130 230 240 210 240	120 230 240 230 240
Total alkalinity (as CaCO ₃)	180 190 180 190	190 190 180 200	200 200 190 190
Total dissolved solids (TDS)	690 700 720 680	680 690 680 670	730 750 760 720
Total Kjeldahl nitrogen	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Total organic carbon (TOC)	0.5 0.6 0.7 <0.5	0.8 0.9 0.6 <0.5	<0.5 0.6 0.6 <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	K6-01	K6-03	K6-04
Total suspended solids (TSS)	<1	5	2
	<1	<1	<1
	1	1	1
	<1	<1	<1
TOX, 1st replicate	4 n.d. at <0.02	4 n.d. at <0.02	4 n.d. at <0.02
TOX, 2nd replicate	4 n.d. at <0.02	4 n.d. at <0.02	4 n.d. at <0.02
Vanadium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Specific conductance	1000	950	900
(µmhos/cm)	1130	950	900
	1000	990	920
	1100	1050	910
pH	7.7	7.7	7.7
	8	7.7	7.7
	7.7	7.7	7.7
	7.6	7.6	7.7
Purgeable pollutants (EPA Method 601, µg/L)			
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	EP6-07	EP6-08	EP6-09
Total suspended solids (TSS)	2	<1	1
	1	<1	<1
	2	1	1
	<1	<1	<1
TOX, 1st replicate	4 n.d. at <0.02	4 n.d. at <0.02	4 n.d. at <0.02
TOX, 2nd replicate	4 n.d. at <0.02	4 n.d. at <0.02	4 n.d. at <0.02
Vanadium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05
Specific conductance	970	1010	990
(µmhos/cm)	1040	860	1130
	1010	1030	1060
	1080	1050	1080
pH	7.8	7.6	7.8
	7.6	7.6	7.9
	7.7	7.6	7.7
	7.7	7.6	7.6
Purgeable pollutants (EPA Method 601, µg/L)			
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	0.6
			3 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	K6-01	K6-03	K6-04
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Title 22 herbicides (µg/L)			
2,4,5-TP (Silvex)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
2,4-D	3 n.d. at <5	3 n.d. at <5	3 n.d. at <5
	1 n.d. at <10	1 n.d. at <10	1 n.d. at <10
Title 22 pesticides (µg/L)			
BHC, gamma isomer	3 n.d. at <0.03	3 n.d. at <0.03	3 n.d. at <0.03
(Lindane)	1 n.d. at <0.4	1 n.d. at <0.4	1 n.d. at <0.4
Endrin	2 n.d. at <0.05	2 n.d. at <0.05	2 n.d. at <0.05
	2 n.d. at <0.1	2 n.d. at <0.1	2 n.d. at <0.1
Methoxychlor	3 n.d. at <0.2	3 n.d. at <0.2	3 n.d. at <0.2
	1 n.d. at <10	1 n.d. at <10	1 n.d. at <10
Toxaphene	1 n.d. at <0.5	1 n.d. at <0.5	1 n.d. at <0.5
	2 n.d. at <1	2 n.d. at <1	2 n.d. at <1
Explosive compounds (µg/L)			
HMX	4 n.d. at <20	4 n.d. at <20	4 n.d. at <20
RDX	4 n.d. at <30	4 n.d. at <30	4 n.d. at <30
TNT	4 n.d. at <30	4 n.d. at <30	4 n.d. at <30
Radiologicals (Bq/L)			
Gross alpha	0.03 ± 0.10	-0.072 ± 0.087	-0.01 ± 0.11
	-0.02 ± 0.10	-0.05 ± 0.12	-0.018 ± 0.089
	0.00 ± 0.14	-0.07 ± 0.12	-0.04 ± 0.11
	-0.09 ± 0.16	0.04 ± 0.13	0.01 ± 0.10
Gross beta	0.223 ± 0.074	0.272 ± 0.077	0.264 ± 0.075
	0.119 ± 0.086	0.294 ± 0.089	0.207 ± 0.090
	0.250 ± 0.086	0.336 ± 0.082	0.14 ± 0.12
	0.19 ± 0.08	0.28 ± 0.11	0.21 ± 0.06

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	EP6-07	EP6-08	EP6-09
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Tetrachloroethene	4 n.d. at <0.5	0.92	4 n.d. at <0.5
		3 n.d. at <0.5	
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	21
			25
			20
			15
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Title 22 herbicides (µg/L)			
2,4,5-TP (Silvex)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1
2,4-D	3 n.d. at <5	3 n.d. at <5	3 n.d. at <5
	1 n.d. at <10	1 n.d. at <10	1 n.d. at <10
Title 22 pesticides (µg/L)			
BHC, gamma isomer	3 n.d. at <0.03	3 n.d. at <0.03	3 n.d. at <0.03
(Lindane)	1 n.d. at <0.4	1 n.d. at <0.4	1 n.d. at <0.4
Endrin	2 n.d. at <0.05	2 n.d. at <0.05	2 n.d. at <0.05
	2 n.d. at <0.1	2 n.d. at <0.1	2 n.d. at <0.1
Methoxychlor	3 n.d. at <0.2	3 n.d. at <0.2	3 n.d. at <0.2
	1 n.d. at <10	1 n.d. at <10	1 n.d. at <10
Toxaphene	1 n.d. at <0.5	1 n.d. at <0.5	1 n.d. at <0.5
	2 n.d. at <1	2 n.d. at <1	2 n.d. at <1
Explosive compounds (µg/L)			
HMX	4 n.d. at <20	4 n.d. at <20	4 n.d. at <20
RDX	4 n.d. at <30	4 n.d. at <30	4 n.d. at <30
TNT	4 n.d. at <30	4 n.d. at <30	4 n.d. at <30
Radiologicals (Bq/L)			
Gross alpha	-0.09 ± 0.09	0.06 ± 0.12	0.00 ± 0.13
	-0.07 ± 0.13	0.02 ± 0.12	0.08 ± 0.14
	0.02 ± 0.11	0.01 ± 0.14	-0.02 ± 0.13
	0.00 ± 0.10	-0.02 ± 0.07	0.04 ± 0.11
Gross beta	0.251 ± 0.075	0.224 ± 0.074	0.263 ± 0.074
	0.258 ± 0.079	0.298 ± 0.109	0.293 ± 0.093
	0.293 ± 0.081	0.245 ± 0.076	0.313 ± 0.090
	0.26 ± 0.06	0.27 ± 0.05	0.28 ± 0.06

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well		
	K6-01	K6-03	K6-04
Tritium	1.0 ± 3.3	-0.4 ± 3.4	-0.7 ± 3.2
	0.0 ± 3.1	3.3 ± 4.3	-0.7 ± 3.3
	-1.7 ± 3.6	-2.5 ± 3.6	-5.2 ± 3.5
	3 ± 4	3 ± 4	1 ± 4
Uranium-234	0.015 ± 0.006	0.011 ± 0.005	0.022 ± 0.006
	0.009 ± 0.008	0.011 ± 0.003	0.026 ± 0.010
	0.015 ± 0.005	0.011 ± 0.004	0.025 ± 0.006
	0.027 ± 0.006	0.014 ± 0.005	0.023 ± 0.007
Uranium-235	0.000 ± 0.001	0.002 ± 0.003	0.001 ± 0.002
	0.000 ± 0.003	0.001 ± 0.001	0.003 ± 0.003
	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.002
	0.0003004 ± 0.0012	0.0004 ± 0.0017	0.0021 ± 0.0025
Uranium-238	0.013 ± 0.005	0.009 ± 0.004	0.021 ± 0.006
	0.011 ± 0.009	0.009 ± 0.002	0.020 ± 0.007
	0.011 ± 0.004	0.004 ± 0.003	0.015 ± 0.004
	0.0109 ± 0.0035	0.0040 ± 0.0022	0.0149 ± 0.0051
Radium-226	0.009 ± 0.028	0.008 ± 0.023	0.006 ± 0.008
	-0.009 ± 0.016	-0.008 ± 0.017	0.018 ± 0.019
	-0.012 ± 0.016	0.004 ± 0.013	-0.016 ± 0.019
	0.022 ± 0.017	0.011 ± 0.014	0.016 ± 0.021

...continued

Appendix C. Ground Water Protection Tables

Table C-4. Parameters sampled in the Pit 6 Area monitoring wells, Site 300, 1992
(concluded).

Parameters	Well		
	EP6-07	EP6-08	EP6-09
Tritium	1.9 ± 3.5	1.3 ± 3.3	-2.0 ± 3.3
	0.3 ± 3.6	-0.1 ± 3.3	1.7 ± 4.4
	-3.2 ± 3.4	1.0 ± 3.7	-5.3 ± 3.5
	2 ± 4	$-4. \pm 4$	3 ± 4
Uranium-234	0.011 ± 0.005	0.024 ± 0.006	0.040 ± 0.008
	0.011 ± 0.002	0.024 ± 0.004	0.040 ± 0.005
	0.010 ± 0.004	0.024 ± 0.006	0.051 ± 0.008
	0.013 ± 0.004	0.031 ± 0.006	0.045 ± 0.008
Uranium-235	0.000 ± 0.001	0.002 ± 0.002	0.001 ± 0.002
	0.001 ± 0.001	0.000 ± 0.001	0.002 ± 0.001
	0.000 ± 0.001	0.001 ± 0.002	0.001 ± 0.001
	-0.0006 ± 0.0011	0.0003 ± 0.0012	0.0017 ± 0.0013
Uranium-238	0.007 ± 0.004	0.016 ± 0.005	0.033 ± 0.007
	0.007 ± 0.002	0.017 ± 0.003	0.034 ± 0.004
	0.007 ± 0.003	0.016 ± 0.005	0.037 ± 0.007
	0.0038 ± 0.0024	0.0134 ± 0.0036	0.0347 ± 0.0065
Radium-226	-0.010 ± 0.018	-0.007 ± 0.024	0.003 ± 0.021
	0.004 ± 0.019	0.024 ± 0.020	0.014 ± 0.015
	0.029 ± 0.022	0.029 ± 0.000	0.019 ± 0.013
	0.002 ± 0.011	-0.002 ± 0.013	-0.005 ± 0.019

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992.

Parameters	Well			
	K7-01	K7-03	K7-06	K7-10
Physical and chemical (mg/L)				
Barium	0.17	0.07	0.07	4 n.d. at <0.05
	0.17	0.09	0.07	
	0.19	0.07	0.07	
	0.17	0.06	0.08	
Beryllium	1 n.d. at <0.0002	1 n.d. at <0.0002	1 n.d. at <0.0002	1 n.d. at <0.0002
	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005
Lead	0.004	0.004	0.003	0.003
	3 n.d. at <0.002	3 n.d. at <0.002	3 n.d. at <0.002	3 n.d. at <0.002
Vanadium	4 n.d. at <0.05	4 n.d. at <0.05	0.05	4 n.d. at <0.05
			3 n.d. at <0.05	
Purgeable pollutants (EPA Method 601/624, µg/L)				
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,1-Dichloroethene	1.3		4 n.d. at <0.5	4 n.d. at <0.5
	1	0.8		
	<0.05	2 n.d. at <0.05		
	2	0.78		
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	NC7-25	NC7-26	NC7-47	NC7-48
Physical and chemical (mg/L)				
Barium	0.05	4 n.d. at <0.05	4 n.d. at <0.05	0.12
	0.06			0.19
	0.06			
	0.06			
Beryllium	1 n.d. at <0.0002	1 n.d. at <0.0002	1 n.d. at <0.0002	<0.0005
	3 n.d. at <0.0005	3 n.d. at <0.0005	3 n.d. at <0.0005	<0.0002
Lead	0.002	0.003	0.003	2 n.d. at <0.002
	0.002	0.003	3 n.d. at <0.002	
	2 n.d. at <0.002	2 n.d. at <0.002		
Vanadium	4 n.d. at <0.05	3 n.d. at <0.05	0.051	2 n.d. at <0.05
		1 n.d. at <0.06	0.08	
			2 n.d. at <0.05	
Purgeable pollutants (EPA Method 601/624, µg/L)				
1,1,1-Trichloroethane	4 n.d. at <0.5	1.2	4 n.d. at <0.5	2 n.d. at <0.5
		3 n.d. at <0.5		
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K7-01	K7-03	K7-06	K7-10
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Trichloroethene	12	3.5	4 n.d. at <0.5	4 n.d. at <0.5
	10	7.6		
	11	6.7		
	11	3.1		
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Hexanone				
4-Methyl-2-pentanone				
Acetone				
Acrolein				
Acrylonitrile				
Benzene				
Carbon disulfide				
Ethylbenzene				
Methyl ethyl ketone				
Styrene				
Toluene				
Total xylene isomers				
Vinyl acetate				

...continued

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	NC7-25	NC7-26	NC7-47	NC7-48
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Chloroform	4 n.d. at <0.5	0.6 3 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5 1 n.d. at <2
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	2 n.d. at <0.5
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	0.9
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5
2-Hexanone				<0.5
4-Methyl-2-pentanone				<5
Acetone				<5
Acrolein				<5
Acrylonitrile				<5
Benzene				<0.5
Carbon disulfide				<0.5
Ethylbenzene				<0.5
Methyl ethyl ketone				<10
Styrene				<0.5
Toluene				<0.5
Total xylene isomers				<0.5
Vinyl acetate				<0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992
(continued).

Parameters	Well			
	K7-01	K7-03	K7-06	K7-10
Radioisotopes (Bq/L)				
Gross alpha	0.22 ± 0.13	0.15 ± 0.11	0.125 ± 0.094	0.01 ± 0.13
	0.44 ± 0.17	0.10 ± 0.13	0.032 ± 0.097	-0.06 ± 0.11
	0.15 ± 0.13	0.19 ± 0.12	0.046 ± 0.082	0.02 ± 0.12
	0.27 ± 0.15	0.10 ± 0.10	0.038 ± 0.042	0.15 ± 0.19
Gross beta	0.190 ± 0.076	0.088 ± 0.072	0.137 ± 0.072	0.534 ± 0.087
	0.300 ± 0.082	0.162 ± 0.079	0.111 ± 0.083	0.219 ± 0.077
	-0.02 ± 0.11	0.225 ± 0.073	0.087 ± 0.064	0.234 ± 0.075
	0.40 ± 0.08	0.19 ± 0.07	-0.023 ± 0.035	0.322 ± 0.081
Tritium	1882 ± 94	2540 ± 130	-4.7 ± 2.9	-4.0 ± 4.6
	1596 ± 79	6420 ± 320	0.9 ± 2.4	1.4 ± 3.4
	1438 ± 71	1600 ± 79	0.5 ± 3.4	1.5 ± 2.5
	1795 ± 89	1436 ± 72		-3.1 ± 3.9
Uranium-233, -234	0.239 ± 0.025	0.036 ± 0.008	0.027 ± 0.006	0.047 ± 0.009
	0.232 ± 0.014	0.075 ± 0.010	0.021 ± 0.003	0.027 ± 0.006
	0.255 ± 0.031	0.051 ± 0.009	0.192 ± 0.020	0.035 ± 0.006
	0.232 ± 0.029	0.031 ± 0.006	0.025 ± 0.006	0.018 ± 0.005
Uranium-235	0.016 ± 0.005	0.001 ± 0.002	0.000 ± 0.001	0.001 ± 0.002
	0.011 ± 0.003	0.003 ± 0.002	0.001 ± 0.001	0.002 ± 0.001
	0.010 ± 0.004	0.003 ± 0.002	0.002 ± 0.002	0.003 ± 0.002
	0.009 ± 0.006	0.0006 ± 0.0012	0.0003 ± 0.0019	0.0012 ± 0.0015
Uranium-238	0.224 ± 0.023	0.037 ± 0.008	0.017 ± 0.005	0.024 ± 0.006
	0.215 ± 0.014	0.078 ± 0.010	0.017 ± 0.003	0.019 ± 0.005
	0.233 ± 0.028	0.041 ± 0.008	0.021 ± 0.005	0.014 ± 0.004
	0.220 ± 0.028	0.029 ± 0.006	0.024 ± 0.005	0.017 ± 0.005
Radium-226	0.032 ± 0.024	0.006 ± 0.012		
	0.081 ± 0.031	0.000 ± 0.012		0.007 ± 0.018
	0.044 ± 0.019	0.005 ± 0.017		0.021 ± 0.015
	0.057 ± 0.025	0.023 ± 0.017		0.024 ± 0.024

...continued

Appendix C. Ground Water Protection Tables

Table C-5. Parameters sampled in the Pit 7 Complex Area monitoring wells, Site 300, 1992
(concluded).

Parameters	Well			
	NC7-25	NC7-26	NC7-47	NC7-48
Radiologicals (Bq/L)				
Gross alpha	0.29 ± 0.18	-0.008 ± 0.092	0.03 ± 0.10	0.57 ± 0.26
	0.63 ± 0.23	-0.047 ± 0.066	0.01 ± 0.11	0.05 ± 0.14
	0.32 ± 0.16	0.034 ± 0.088	0.01 ± 0.08	
	0.98 ± 0.26	0.00 ± 0.10	0.10 ± 0.10	
Gross beta	0.70 ± 0.10	0.104 ± 0.081	0.233 ± 0.075	1.16 ± 0.12
	0.593 ± 0.097	0.125 ± 0.076	0.272 ± 0.090	0.114 ± 0.072
	0.80 ± 0.11	0.080 ± 0.076	0.08 ± 0.11	
	0.80 ± 0.11	0.11 ± 0.05	0.18 ± 0.07	
Tritium	11060 ± 540	36.8 ± 5.4	-6.1 ± 3.9	4.1 ± 3.6
	11690 ± 574	40.1 ± 4.8	1.4 ± 3.6	2 ± 3
	8532 ± 417	32.1 ± 3.8	0.2 ± 2.3	1.5 ± 3.4
	10360 ± 511	29 ± 5	-0.63 ± 4.18	
Uranium-233, -234	0.423 ± 0.104	0.007 ± 0.003	0.048 ± 0.008	0.130 ± 0.017
	0.407 ± 0.033	0.005 ± 0.002	0.042 ± 0.005	0.69 ± 0.05
	0.443 ± 0.020	0.017 ± 0.003	0.060 ± 0.005	
	0.45 ± 0.04	0.012 ± 0.008	0.041 ± 0.008	
Uranium-235	0.018 ± 0.005	0.0004 ± 0.001	0.001 ± 0.001	0.008 ± 0.004
	0.019 ± 0.006	0.001 ± 0.001	0.001 ± 0.004	0.048 ± 0.010
	0.019 ± 0.003	0.001 ± 0.001	0.001 ± 0.001	
	0.018 ± 0.005	-0.0012 ± 0.0023	0.0021 ± 0.0016	
Uranium-238	0.338 ± 0.030	0.002 ± 0.002	0.026 ± 0.005	0.326 ± 0.031
	0.347 ± 0.030	0.003 ± 0.002	0.027 ± 0.004	1.38 ± 0.09
	0.383 ± 0.018	0.005 ± 0.002	0.023 ± 0.003	
	0.392 ± 0.035	0.007 ± 0.006	0.029 ± 0.007	
Radium-226	0.036 ± 0.031			0.169 ± 0.040
	0.017 ± 0.022			1.310 ± 0.093
	0.016 ± 0.022			
	0.039 ± 0.028			

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-6. Parameters sampled in Well K8-01, Site 300, 1992.

Parameters	K8-01	Parameters	K8-01
Physical and chemical (mg/L)		Sulfate	78
Aluminum	<0.2		76
Ammonia nitrogen (as N)	0.02	Total alkalinity (as CaCO ₃)	200
	0.049		210
Arsenic	0.017	Total dissolved solids (TDS)	500
	0.014		550
Barium	2 n.d. <0.05	Total Kjeldahl nitrogen	2 n.d. <0.5
Beryllium	<0.0005	Total organic carbon (TOC)	4.4
	<0.0002		3.79
Bicarbonate alk (as CaCO ₃)	200	Total organic halides (TOX)	0.021
	210		8 n.d. <0.02
Cadmium	2 n.d. <0.0005	Specific conductance (µmhos/cm)	670
Carbonate alk (as CaCO ₃)	2 n.d. <1		740
Chloride	64	pH	7.6
	68		7.6
Chromium	0.022	Purgeable pollutants (EPA Methods 601/624, µg/L)	
	0.026	1,1,1-Trichloroethane	3 n.d. <0.5
Fluoride	0.5	1,1,2,2-Tetrachloroethane	3 n.d. <0.5
	0.44	1,1,2-Trichloroethane	2 n.d. <0.5
Hydroxide alk (as CaCO ₃)	2 n.d. <1		1 n.d. <0.6
Lead	<0.002	1,1-Dichloroethane	1 n.d. <0.4
	0.0025		2 n.d. <0.5
Low level phenolics	2 n.d. <0.005	1,1-Dichloroethene	1 n.d. <0.2
Mercury	2 n.d. <0.0002		2 n.d. <0.5
Nitrate plus nitrite (as N)	9.2	1,2-Dichlorobenzene	2 n.d. <0.5
	8.8		1 n.d. <4
Nitrate plus nitrite (as NO ₃)	41	1,2-Dichloroethane	2.7
	39		2.6
Nitrite (as N)	2 n.d. <0.01		2.1
Nitrite (as NO ₂)	2 n.d. <0.03	1,2-Dichloroethene (total)	1 n.d. <0.4
Selenium	0.003		2 n.d. <0.5
	0.0029	1,2-Dichloropropane	3 n.d. <0.5
Silica (as SiO ₂)	66	1,3-Dichlorobenzene	2 n.d. <0.5
	65		1 n.d. <2
Silver	<0.0005	1,4-Dichlorobenzene	2 n.d. <0.5
	<0.05		1 n.d. <4
Sodium	62		
	60		

...continued

Appendix C. Ground Water Protection Tables

Table C-6. Parameters sampled in Well K8-01, Site 300, 1992 (*concluded*).

Parameters	K8-01	Parameters	K8-01
2-Chloroethylvinylether	<0.5	Methyl ethyl ketone	<10
	<2		<5
	<1	Methylene chloride	2 n.d. <2
2-Hexanone	2 n.d. <0.5		1 n.d. <0.5
4-Methyl-2-pentanone	<0.5	Styrene	2 n.d. <0.5
	<5	Tetrachloroethene	3 n.d. <0.5
Acetone	2 n.d. <5	Toluene	2 n.d. <0.5
Acrolein	<5	Total xylene isomers	2 n.d. <0.5
	<10	trans-1,2-Dichloroethene	1 n.d. <0.4
Acrylonitrile	2 n.d. <5		2 n.d. <0.5
Benzene	2 n.d. <0.5	trans-1,3-Dichloropropene	2 n.d. <0.5
Bromodichloromethane	2 n.d. <0.5		1 n.d. <0.6
	1 n.d. <0.7	Trichloroethene	6
Bromoform	1 n.d. <0.7		4.4
Bromomethane	1 n.d. <0.7		3.2
Carbon disulfide	2 n.d. <0.5	Trichlorofluoromethane	1 n.d. <0.4
Carbon tetrachloride	2 n.d. <0.5		2 n.d. <0.5
	1 n.d. <0.6	Vinyl acetate	2 n.d. <0.5
Chlorobenzene	2 n.d. <0.5	Vinyl chloride	3 n.d. <0.5
	1 n.d. <0.7		
Chloroethane	2 n.d. <0.5	Explosive compounds (µg/L)	
	1 n.d. <1	HMX	2 n.d. at <20
Chloroform	0.9	RDX	2 n.d. at <30
	2 n.d. <0.5	TNT	2 n.d. at <30
Chloromethane	0.5		
	<0.5	Radiologicals (Bq/L)	
	<0.6	Gross alpha	0.11 ± 0.11
cis-1,2-Dichloroethene	1 n.d. <0.4	Gross beta	0.19 ± 0.07
	2 n.d. <0.5	Tritium	0.0 ± 4.8
cis-1,3-Dichloropropene	3 n.d. <0.5		-1.6 ± 3.4
Dibromochloromethane	2 n.d. <0.5		2.7 ± 3.4
	1 n.d. <0.6	Uranium-233,-234	0.16 ± 0.01
Dichlorodifluoromethane	<1	Uranium-235	0.00 ± 0.01
Ethylbenzene	2 n.d. <0.5	Uranium-238	0.10 ± 0.01
Freon-113	<0.5	Radium-226	0.00 ± 0.00
	<1	Radium-228	0.00 ± 0.15
	<0.6		

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992.

Parameters	Well				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
Physical and chemical (mg/L)					
Antimony	4 n.d. at <0.2	4 n.d. at <0.2	4 n.d. at <0.2		4 n.d. at <0.2
Arsenic	0.041	0.043	0.044		0.052
	0.04	0.051	0.025		0.031
	0.044	0.047	0.045		0.046
	0.045	0.046	0.044		0.053
	0.044	0.05	0.047		0.055
	0.027	0.038	0.038		0.031
	0.046	0.046	0.045		0.046
	0.05	0.053	0.044		0.055
	0.039	0.046	0.045		0.047
	0.041	0.045	0.039		0.048
	0.037	0.043	0.043		0.043
	0.04	0.043	0.039		0.043
	0.041	0.044	0.042		0.038
	0.043	0.048	0.042		0.048
	0.045	0.047	0.044		0.053
	0.025	0.018	0.051		0.054
Barium	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05		4 n.d. at <0.05
Beryllium	0.0005	4 n.d. at <0.0002	4 n.d. at <0.0002		4 n.d. at <0.0002
	4 n.d. at <0.0002	12 n.d. at <0.0005	12 n.d. at <0.0005		12 n.d. at <0.0005
	11 n.d. at <0.0005				
Bicarbonate alk (as CaCO ₃)	260	240	250		250
	260	240	250		250
	260	240	250		250
	250	240	250		230
Cadmium	4 n.d. at <0.0005	4 n.d. at <0.0005	4 n.d. at <0.0005		4 n.d. at <0.0005
Calcium	14	38	22		22
	13	41	23		23
	13	41	21		22
	15	37	19		19
Carbonate alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1		20
					3 n.d. at <1
Chloride	140	280	220		220
	150	290	220		230
	150	290	230		240
	140	300	230		230
Chromium	0.008	16 n.d. at <0.005	0.01		0.0052
	0.007		0.008		0.006
	14 n.d. at <0.005		0.005		14 n.d. at <0.005
			13 n.d. at <0.005		
Cobalt	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05		4 n.d. at <0.05
Copper	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05		4 n.d. at <0.05
Hydroxide alk (as CaCO ₃)	4 n.d. at <1	4 n.d. at <1	4 n.d. at <1		4 n.d. at <1

...continued

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992 (*continued*).

Parameters	Well				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
Iron	0.2 3 n.d. at <0.1	4 n.d. at <0.1	4 n.d. at <0.1		4 n.d. at <0.1
Lead	0.002 0.004 0.002 0.005 12 n.d. at <0.002	0.002 15 n.d. at <0.002	16 n.d. at <0.002		0.003 14 n.d. at <0.002 1 n.d. at <0.004
Magnesium	5 5.7 5 5.3	17 20 18 15	10 11 9.5 9.4		9.8 10 9.7 8.5
Manganese	4 n.d. at <0.05	3 n.d. at <0.05	3 n.d. at <0.05		3 n.d. at <0.05
Mercury	4 n.d. at <0.0002	4 n.d. at <0.0002	0.0002 3 n.d. at <0.0002		4 n.d. at <0.0002
Molybdenum	3 n.d. at <0.2 1 n.d. at <0.1	3 n.d. at <0.2 1 n.d. at <0.1	3 n.d. at <0.2 1 n.d. at <0.1		3 n.d. at <0.2 1 n.d. at <0.1
Nickel	2 n.d. at <0.1 2 n.d. at <0.005	1 n.d. at <0.1 3 n.d. at <0.005	1 n.d. at <0.1 3 n.d. at <0.005		1 n.d. at <0.1 3 n.d. at <0.005
Nitrate plus nitrite (as N)	17 20 17 40	20 23 20 21	17 23 21 21		21 24 22 22
Nitrate (as NO ₃)	75 90 76 79	90 100 87 91	75 100 92 93		94 110 96 95
Nitrite (as N)	0.015 0.01	<0.01 <0.01	<0.01 <0.01		<0.01 <0.01
Nitrite (as NO ₂)	0.05 0.04	<0.03 <0.03	<0.03 <0.03		<0.03 <0.03
Potassium	9 9.4 8.4 9	14 15 14 12	10 11 10 11		11 12 11 10
Selenium	0.038 0.039 <0.002 0.033 0.033 0.026 0.035 0.023 0.038 0.034	0.098 0.07 0.09 0.091 0.08 0.069 0.081 0.067 0.091 0.088	0.039 0.021 0.038 0.032 0.032 0.028 0.034 0.031 0.037 0.034		0.031 0.018 0.033 0.029 0.028 0.021 0.028 0.021 0.029 0.029

...continued

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992 (*continued*).

Parameters	Well				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
Selenium (continued)	0.035	0.03	0.011		0.009
	0.024	0.071	0.027		0.022
	0.015	0.073	0.012		0.015
	0.019	0.062	0.029		0.02
	0.006	0.049	0.016		0.014
	0.019	0.075	0.025		0.022
Silver	0.0005	0.0007	0.0005		0.0017
	15 n.d. at <0.0005	15 n.d. at <0.0005	15 n.d. at <0.0005		15 n.d. at <0.0005
Sodium	250	420	310		360
	270	450	330		350
	240	420	300		330
	280	380	310		330
Sulfate	110	390	220		260
	120	420	260		300
	120	410	250		290
	120	370	220		230
Thallium	3 n.d. at <0.2	3 n.d. at <0.2	3 n.d. at <0.2		3 n.d. at <0.2
	1 n.d. at <0.4	1 n.d. at <0.4	1 n.d. at <0.4		1 n.d. at <0.4
Total alkalinity (as CaCO ₃)	260	240	250		250
	260	240	250		250
	260	240	250		250
	250	240	250		250
Total dissolved solids (TDS)	810	1400	1100		1200
	830	1400	1100		1200
	860	1400	1100		1200
	830	1400	1100		1100
Total organic carbon (TOC)	1.1	0.94	1		1
	0.81	0.74	0.88		0.92
	1.2	0.7	1		1.1
	1.1	1	0.9		1.1
	0.92	1	0.78		0.81
	0.8	0.57	0.69		0.82
	1	0.7	0.9		0.9
	1.1	0.9	1.4		1.2
	0.86	0.81	0.79		0.84
	1.6	1.1	0.7		1.3
	4.2	0.8	0.9		1
	1.2	0.9	1.1		1
	1	0.73	0.89		0.97
	1.1	1.1	1		1.5
	1.4	1	1.4		1.2
	0.88	0.69	0.78		0.93
TOX, 1st replicate	0.03	0.03	0.12		0.03
	0.03	0.02	0.02		0.05

...continued

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992 (*continued*).

Parameters	Wells				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
TOX, 1st replicate	0.03	0.02	0.02		0.02
(continued)	0.025	13 n.d. at <0.02	0.04		0.021
	0.025		0.02		0.02
	0.03		0.02		0.02
	0.03		10 n.d. at <0.02		10 n.d. at <0.02
	0.03				
	0.03				
	0.02				
	0.03				
	0.02				
	4 n.d. at <0.02				
TOX, 2nd replicate	0.03	0.03	0.08		0.02
	0.03	0.02	0.02		0.03
	0.04	0.02	0.02		0.02
	0.023	13 n.d. at <0.02	0.03		0.02
	0.024		0.02		0.02
	0.02		0.02		11 n.d. at <0.02
	0.03		0.02		
	0.03		9 n.d. at <0.02		
	0.03				
	0.02				
	0.03				
	5 n.d. at <0.02				
Vanadium	0.15	0.15	0.14		0.13
	0.16	0.14	0.13		0.12
	0.14	0.12	0.12		<0.05
	0.16	0.16	0.13		0.13
Zinc	4 n.d. at <0.05	4 n.d. at <0.05	4 n.d. at <0.05		4 n.d. at <0.05
Specific conductance	1120	2010	1540		1660
(μmhos/cm)	1100	2080	1780		1720
	1270	2140	1630		1840
	1470	2350	2080		1880
	1200	2240	1580		1760
	1120	2010	1680		1730
	1050	1790	1560		1730
	1180	2110	1880		1870
	1080	2060	1740		1640
	1370	2060	1700		1700
	1230	1820	1430		1760
	1160	2030	1700		1860
	1080	2010	1740		1560
	1180	2020	1880		1680
	1150	2150	1610		1730
	1220	2310	1720		1870

...continued

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992 (*continued*).

Parameters	Well				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
pH	7.9	7.7	7.9		8
	7.9	8.1	8		8
	8.3	7.7	7.8		8.2
	8.1	8	8.1		8.2
	7.8	7.6	7.7		7.8
	8	7.8	7.9		7.9
	8.2	7.9	8		8.1
	8	7.8	7.9		8.1
	7.7	7.5	7.7		7.8
	8.1	7.7	7.9		8
	8	7.8	7.8		8
	7.9	8.4	7.8		8.4
	7.7	7.9	8		8
	8.1	7.9	8.1		7.8
	7.8	7.8	7.7		8.6
	8	7.8	7.9		8
Purgeable pollutants (EPA Method 601, µg/L)					
1,1,1-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,1,2,2-Tetrachloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,1,2-Trichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	0.65	5 n.d. at <0.5
	3 n.d. at <0.5				
1,1-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,1-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,2-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,2-Dichloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,2-Dichloroethene (total)	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	1.2	5 n.d. at <0.5
				2.8	
				2.6	
				0.9	
1,2-Dichloropropane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,3-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
1,4-Dichlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
2-Chloroethylvinylether	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Bromodichloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Bromoform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Bromomethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Carbon tetrachloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Chlorobenzene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Chloroethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Chloroform	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Chloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5

...continued

Appendix C. Ground Water Protection Tables

Table C-7. Parameters analyzed in the explosives rinse water surface impoundments area monitoring wells, Site 300, 1992 (*concluded*).

Parameters	Well				
	W-817-01	W-817-02	W-817-03	W-817-03A	W-817-04
cis-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	1.2 2.8 2.6 0.9	5 n.d. at <0.5
cis-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Dibromochloromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Dichlorodifluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Freon-113	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Methylene chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Tetrachloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
trans-1,2-Dichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
trans-1,3-Dichloropropene	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Trichloroethene	4 n.d. at <0.5	4 n.d. at <0.5	22 19 21 21	47 64 71 66	9.6 17 14 15 7.7
Trichlorofluoromethane	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Vinyl chloride	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	4 n.d. at <0.5	5 n.d. at <0.5
Explosive compounds (µg/L)					
HMX	16 n.d. at <20	16 n.d. at <20	17 n.d. at <20	3 n.d. at <20	17 n.d. at <20
RDX	107 200 72 109 116 74 94 92 76 163 74 189	16 n.d. at <30	17 n.d. at <30	3 n.d. at <30	17 n.d. at <30
TNT	4 n.d. at <30 16 n.d. at <30	16 n.d. at <30	17 n.d. at <30	3 n.d. at <30	17 n.d. at <30
Radiologicals (Bq/L)					
Tritium	-4.1 ± 3.1 3.2 ± 4.6 1.9 ± 2.5 -3.6 ± 3.0	-3.0 ± 3.2 -2.4 ± 4.4 0.1 ± 3.2 -3.0 ± 3.0	1.4 ± 3.4 1.5 ± 4.6 1.6 ± 3.3 1.5 ± 3.4	2.7 ± 3.5 -0.1 ± 4.5 -0.7 ± 3.2 -1.1 ± 3.2	-4.4 ± 3.2 -3.9 ± 4.4 -2.6 ± 3.2 -1.5 ± 3.2

Note: The abbreviation "n.d." stands for nondetection.

Appendix C. Ground Water Protection Tables

Table C-8. Parameters sampled in the Pit 9 Area monitoring wells, Site 300, 1992.

Parameters	Well			
	K9-01	K9-02	K9-03	K9-04
Physical and chemical (mg/L)				
Ammonia nitrogen (as N)	1.3	0.89	1.3	
Arsenic	0.003	0.036	0.012	<0.002
Barium	<0.05	<0.05	<0.05	<0.05
Beryllium	<0.0005	<0.0005	<0.0005	<0.0005
Bicarbonate alk (as CaCO ₃)	160	200	170	
Cadmium	<0.0005	<0.0005	<0.0005	<0.0005
Calcium	80	64	83	
Carbonate alk (as CaCO ₃)	<1	<1	<1	
Chloride	150	170	140	
Chromium	<0.005	<0.005	<0.005	<0.005
Copper	<0.05	<0.05	<0.05	
Fluoride	0.24	0.38	0.28	
Hydroxide alk (as CaCO ₃)	<1	<1	<1	
Iron	<0.1	<0.1	<0.1	0.54
Lead	<0.002	<0.002	0.003	0.003
Low level phenolics	<0.005	0.0084	<0.005	
Magnesium	37	35	39	
Manganese	0.1	0.061	0.069	0.15
Mercury	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	<0.005	<0.005	<0.005	<0.005
Nitrate nitrogen				
Nitrate (as N)	<0.1	<0.1	<0.1	
Nitrate (as NO ₃)	<0.4	<0.4	<0.4	
Nitrite (as N)	<0.01	<0.01	<0.01	
Nitrite (as NO ₂)	<0.03	<0.03	<0.03	
pH	7.6	7.8	7.8	
Potassium	8.4	10	9.2	
Selenium	<0.002	<0.002	<0.002	<0.002
Silver	0.0021	<0.0005	<0.0005	0.0005
Sodium	350	310	321	280
Specific conductance (µmhos/cm)	1820	1760	1880	
Sulfate	620	520	680	
Total alkalinity (as CaCO ₃)	160	200	170	
Total dissolved solids (TDS)	1300	1200	1300	
Total Kjeldahl nitrogen	<0.5	<0.5	<0.5	
Total organic carbon (TOC)	0.58	0.95	0.54	
Total suspended solids (TSS)	<1	<1	4	
TOX, 1st replicate	<0.02	<0.02	<0.02	
TOX, 2nd replicate	<0.02	<0.02	<0.02	
Vanadium	<0.05	<0.05	<0.05	<0.05
Zinc	<0.05	<0.05	<0.05	

...continued

Appendix C. Ground Water Protection Tables

Table C-8. Parameters sampled in the Pit 9 Area monitoring wells, Site 300, 1992 (*continued*).

Parameters	Well			
	K9-01	K9-02	K9-03	K9-04
Purgeable pollutants (EPA Method 624, µg/L)				
1,1,1-Trichloroethane	<0.5	<0.5	<0.5	
1,1,2,2-Tetrachloroethane	<0.5	<0.5	<0.5	
1,1,2-Trichloroethane	<0.5	<0.5	<0.5	
1,1-Dichloroethane	<0.5	<0.5	<0.5	
1,1-Dichloroethene	<0.5	<0.5	<0.5	
1,2-Dichlorobenzene	<0.5	<0.5	<0.5	
1,2-Dichloroethane	<0.5	<0.5	<0.5	
1,2-Dichloroethene (total)	<0.5	<0.5	<0.5	
1,2-Dichloropropane	<0.5	<0.5	<0.5	
1,3-Dichlorobenzene	<0.5	<0.5	<0.5	
1,4-Dichlorobenzene	<0.5	<0.5	<0.5	
2-Chloroethylvinylether	<0.5	<0.5	<0.5	
2-Hexanone	<0.5	<0.5	<0.5	
4-Methyl-2-pentanone	<0.5	<0.5	<0.5	
Acetone	<5	<5	<5	
Acrolein	<5	<5	<5	
Acrylonitrile	<5	<5	<5	
Benzene	<0.5	<0.5	<0.5	
Bromodichloromethane	<0.5	<0.5	<0.5	
Bromoform	<0.5	<0.5	<0.5	
Bromomethane	<0.5	<0.5	<0.5	
Carbon disulfide	<0.5	<0.5	<0.5	
Carbon tetrachloride	<0.5	<0.5	<0.5	
Chlorobenzene	<0.5	<0.5	<0.5	
Chloroethane	<0.5	<0.5	<0.5	
Chloroform	<0.5	<0.5	<0.5	
Chloromethane	<0.5	<0.5	<0.5	
cis-1,2-Dichloroethene	<0.5	<0.5	<0.5	
cis-1,3-Dichloropropene	<0.5	<0.5	<0.5	
Dibromochloromethane	<0.5	<0.5	<0.5	
Ethylbenzene	<0.5	<0.5	<0.5	
Freon-113	<0.5	<0.5	<0.5	
Methyl ethyl ketone	<10	<10	<10	
Methylene chloride	<2	<2	<2	
Styrene	<0.5	<0.5	<0.5	
Tetrachloroethene	<0.5	<0.5	<0.5	
Toluene	<0.5	<0.5	<0.5	
Total xylene isomers	<0.5	<0.5	<0.5	
trans-1,2-Dichloroethene	<0.5	<0.5	<0.5	
trans-1,3-Dichloropropene	<0.5	<0.5	<0.5	

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Appendix C. Ground Water Protection Tables

Table C-8. Parameters sampled in the Pit 9 Area monitoring wells, Site 300, 1992 (concluded).

Parameters	Well			
	K9-01	K9-02	K9-03	K9-04
Trichloroethene	<0.5	<0.5	<0.5	
Trichlorofluoromethane	<0.5	<0.5	<0.5	— ^a
Vinyl acetate	<0.5	<0.5	<0.5	— ^a
Vinyl chloride	<0.5	<0.5	<0.5	— ^a
Title 22 herbicides (µg/L)				
2,4,5-TP (Silvex)	<1	<1	<1	— ^a
2,4-D	<5	<5	<5	— ^a
Title 22 pesticides (µg/L)				
BHC, gamma isomer (Lindane)	<0.03	<0.03	<0.03	— ^a
Endrin	<0.05	<0.05	<0.05	— ^a
Methoxychlor	<0.2	<0.2	<0.2	— ^a
Toxaphene	<1	<1	<1	— ^a
Explosive compounds (µg/L)				
HMX	<20	<20	<20	— ^a
RDX	<30	<30	<30	— ^a
TNT	<30	<30	<30	— ^a

Parameters	K9-01	K9-02	K9-03	K9-04
Radiological Data (Bq/L)^b				
Gross alpha	-0.13 ± 0.16	0.03 ± 0.20	0.01 ± 0.15	— ^a
Gross beta	0.29 ± 0.15	0.26 ± 0.13	0.24 ± 0.13	— ^a
Tritium	0.9 ± 3.5	-2.6 ± 3.4	-2.8 ± 3.0	— ^a
Uranium-234	0.012 ± 0.004	0.040 ± 0.008	0.044 ± 0.007	0.029 ± 0.007
Uranium-235	-0.000 ± 0.001	-0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.002
Uranium-238	0.000 ± 0.000	0.006 ± 0.003	0.007 ± 0.003	0.003 ± 0.003
Radium-226	0.005 ± 0.021	0.003 ± 0.011	0.014 ± 0.015	— ^a

^a No sample; see Quality Assurance chapter.

^b Radionuclide results are reported ±2σ; see Quality Assurance chapter.

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