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Environmental Report for 1989

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PREFACE

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

The report has been divided into two major sections: one for the Livermore site, which is the main site of LLNL operations, and the other for Site 300, where high-explosives tests are conducted. Both of the major sections has been further divided into chapters. The primary focus of most of the chapters is a particular environmental media, e.g., air, water, or soil, that is being monitored. All of the information about that type of monitoring effort is presented in that chapter. The monitoring chapters are followed by summaries of environmental compliance and quality assurance activities for each site.

In addition, some background information about radiation dosimetry and risk assessment has been provided in this document. This information, which is provided for the general reader, is presented at the beginning of the chapters on these subjects. Also, the monitoring data is summarized following the DOE suggested format in the synopsis at the end of this document.

This report is the responsibility of the Regulatory Affairs Division of the Environmental Protection Department. Within this division, the Environmental Monitoring Group samples the environment, interprets the results, performs the impact analysis of radiological emissions from LLNL, and compiles the information presented here.

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ABSTRACT

This report documents the results of the Environmental Monitoring Program at the Lawrence Livermore National Laboratory (LLNL) and presents summary information about environmental compliance efforts for 1989. To enable evaluation of the effect of LLNL operations on the local environment, measurements were made at both the Livermore site and nearby Site 300 of direct radiation and a variety of radionuclides and chemical pollutants in ambient air, soil, sewage effluent, surface water, groundwater, vegetation, and foodstuff. This report was prepared to meet the requirements of Department of Energy Orders 5484.1 and 5400.1. Evaluations were made of LLNL's compliance with all applicable guides, standards, and limits for radiological and nonradiological emissions to the environment. The monitoring data demonstrate that LLNL was in compliance with environmental laws and regulations concerning emission and discharge of materials to the environment. In addition, the monitoring data demonstrate that the environmental impacts of LLNL are minimal and pose no threat to the public or the environment.

INTRODUCTION

LLNL has a substantial continuing commitment to environmental compliance and accountability. Each year, the Environmental Protection Department makes a significant effort toward monitoring the environment near the Livermore site and Site 300. In 1989, over 30 000 analyses of environmental samples were performed. This effort, which is conducted in accordance with DOE Orders 5400.1 and 5484.1, has three purposes: (1) to assess the effectiveness of effluent control programs, (2) to assess compliance with applicable environmental laws and regulations, and (3) to estimate the impact of operations on the environment. Data are produced from sampling of air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and environmental radiation; the type of samples collected at a specific location depends on the site and the potential pollutants to be monitored. Both monitoring and compliance activities are summarized in this document to provide a complete picture of the environmental program at LLNL.

LLNL—LIVERMORE SITE

Air Monitoring

Surveillance and effluent monitoring are conducted at the Livermore site and in the surrounding areas to determine if airborne radionuclides or hazardous materials are being released by operations. In 1989, all measurements of airborne radioactive pollutants at the Livermore-site perimeter and Livermore Valley sampling locations were well below the Derived Concentration Guides (DCGs) established by the DOE. DCGs are concentrations of radionuclides in air that could be continuously inhaled 365 days of the year and not exceed the DOE primary radiation protection standard to the public of 100 mrem/y effective dose equivalent. (DCGs are also calculated for concentrations of radionuclides in water. The Radiological Dose Assessment chapter provides an explanation of this and other units of dose.)

The highest concentration of plutonium detected was 4.14×10^{-17} $\mu\text{Ci/mL}$, which represents 0.21% of the DCG. No other statistically significant differences between

locations or samples were noted, and the overall levels determined were essentially the same as those reported in 1988. The measured concentrations of ^{238}U are less than 0.03% the DCG, and for ^{235}U , the concentrations are 0.001% of the DCG.

The highest concentration of tritium measured was 9.6×10^{-11} $\mu\text{Ci/mL}$ (0.1% of the DCG). The highest annual mean concentration of tritium at the Livermore-site perimeter was 3.2×10^{-11} $\mu\text{Ci/mL}$, or 0.03% of the DCG. The highest annual mean concentration of tritium for the Livermore Valley was 1.4×10^{-11} $\mu\text{Ci/mL}$ or 0.01% of the DCG. These values were generally lower than those reported for 1988. In 1989, a total of 2951.8 Ci of tritium were released to the atmosphere from operations at LLNL. Of the 2951.8 Ci, approximately 1554.4 Ci were released as tritiated water (HTO); the remaining tritium was elemental tritium gas (HT). Releases of the short-lived radionuclides ^{13}N and ^{15}O from Building 194 (the electron-positron linear accelerator) totalled 42 Ci.

The highest monthly average concentration of beryllium measured was

Summary

$<26 \times 10^{-5} \mu\text{g}/\text{m}^3$. This is the level of detection of the analysis method and represents $<2.6\%$ of the regulatory limit established by the Bay Area Air Quality Management District. These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium.

Gross radioactivity measurements (total alpha-emitting or beta-emitting radionuclides) are made for the purpose of screening and trending airborne radioactivity values. The gross alpha and gross beta values showed no significant trends in 1989. No gamma-emitting radionuclides were detected from air filter samples above background levels.

Accordingly, there were no airborne emissions from LLNL operations in 1989 that caused any significant impact on public health or the environment.

Sewage Monitoring

On a daily basis, LLNL discharges approximately 358 000 gallons of wastewater containing sanitary sewage and industrial effluent to the sewer system for eventual treatment at the Livermore Water Reclamation Plant (LWRP). Administrative and engineering controls prevent potentially contaminated wastewater from being directly discharged to the sewer. In addition, the outflow is continuously monitored and analyzed for compliance with permits and to assess the effectiveness of the control systems.

The concentrations of tritium (as tritiated water), ^{137}Cs , and ^{239}Pu were measured in the sanitary sewer effluent from LLNL and LWRP. During 1989, there were no inadvertent releases of radioactive materials to the sanitary sewer system that exceeded any discharge limits. The annual average concentration of tritium in LLNL sanitary sewer effluent was $3.5 \times 10^{-6} \mu\text{Ci}/\text{mL}$, about 0.04% of the DOE annualized discharge limit for application of best available technology (BAT) to a public sewer system. During 1989, a maximum of 1.6 Ci of tritiated water was discharged to the sanitary sewer. This is the combined release from the Livermore site and from Sandia National Laboratories, Livermore

(SNLL); SNLL records account for 0.298 Ci of this amount. This amount is well within the environmental protection standard of 5 Ci maximum yearly release established by the Nuclear Regulatory Commission (NRC) and adopted by DOE, and it is also within the range reported over the past 9 years.

The annual average ^{137}Cs concentration in sewer effluent of $4.9 \times 10^{-11} \mu\text{Ci}/\text{mL}$ is only 0.0003% of the DOE discharge limit. The concentrations of tritium and ^{137}Cs remain generally consistent with those observed during 1988. The annual average ^{239}Pu concentration was $9.7 \times 10^{-12} \mu\text{Ci}/\text{mL}$, which was 0.0001% of the DOE discharge limit for the application of BAT. The combined total release of ^{137}Cs and ^{239}Pu was 0.0029% of the 1 Ci/y NRC limit.

The Biological Oxygen Demand (BOD) and pH limits were the only parameters exceeded in the LLNL sanitary sewer effluent in 1989. The pH excursions were identified by the continuous on-line monitoring system, and the BOD value over the limit was noted during a routine 24-hour monitoring sample collected during the first quarter of the year. None of these releases resulted in any adverse impact on the operation of the LWRP.

Routine Water Monitoring

Surface water, drinking water, and stormwaters from the Livermore site and surrounding areas are monitored for the presence of radioactive constituents and nonradiological pollutants, including solvents, metals, and pesticides.

In 1989, the runoff from two rain storms was sampled. All measurements of alpha and beta radiation levels were low and were a small fraction of the maximum contaminant level (MCL) for water. For the first time, higher than usual tritium levels were observed at four of six monitoring locations during one of the rain storms. The highest value was $57.4 \times 10^{-6} \mu\text{Ci}/\text{mL}$. If this water were drinking water, it would have exceeded the limit established by the State of California of $20 \times 10^{-6} \mu\text{Ci}/\text{mL}$. Other samples taken during the same storm had

tritium levels at or below the State drinking water limit. These observations are presently under investigation.

The highest concentration of tritium measured in surface water, 19.3×10^{-7} $\mu\text{Ci/mL}$, occurred in the onsite swimming pool. If this water were drinking water, this concentration would represent 9.65% of the permissible concentration specified by the State of California.

Tritium data were also collected for wells in the vicinity of LWRP and for production wells used by local water-supply agencies. The wells in the vicinity of LWRP are used to monitor groundwater quality in that area; they are not used as drinking water sources. The highest tritium values appear in wells downgradient of LWRP. Tritium activities in other monitoring wells were at normal background levels, and all samples were well below the limits for water adopted by the State of California. The tritium levels in these wells are similar to those observed in the 1988 samples.

An estimate of the annual (effective) dose that may be delivered to an adult who consumes water containing these tritium concentrations can be made. These doses, which are all less than 6×10^{-2} mrem (the value estimated for the onsite swimming pool), are based on a water consumption of 2 L/day and DOE dose-conversion factors. The actual dose (if any) from the swimming pool and surface water sources would be considerably less because they are not used as drinking water sources. Methods used to calculate doses are presented in **Appendix A**.

Gross alpha and beta activities in the surface and domestic water samples collected in 1989 were below EPA and DHS MCLs. All gross alpha concentrations in stormwater runoff were below the detection limit. Gross beta concentrations in stormwater runoff did not differ significantly between the LLNL influent and effluent.

Data for physical and chemical parameters in stormwater are also collected. Most potential pollutants in the storm runoff were not present at detectable levels. For the first time, acetone was detected in one sample at the northwest corner of the

Livermore site at 140 $\mu\text{g/L}$. No other organic compounds were detected. Metals were not detected above normal background levels expected for water that has been in contact with soil.

Overall, the impact of LLNL operations on water in 1989 was minimal.

Soil Monitoring

Soil sediments are integrating media that can account for contaminants released to the atmosphere or through liquid effluents. Soil and arroyo sediments samples are analyzed annually to document any changes in environmental levels of both radioactive and nonradioactive contaminants that may have been the result of LLNL operations.

Elevated levels of ^{239}Pu , first observed in soils near the Livermore Water Reclamation Plant (LWRP) during the early 1970s, were again detected in 1989, although levels were well below those reported in 1988. The highest value of 59.9×10^{-9} $\mu\text{Ci/g}$ represents 0.5% of the proposed EPA soil standard for unrestricted use of 0.2 $\mu\text{Ci/m}^2$ (or 13×10^{-6} $\mu\text{Ci/g}$ based on average Livermore Valley soil densities). In addition, ^{241}Am was detected at LWRP in the same sampling areas exhibiting elevated plutonium levels; the ^{241}Am is probably due to natural decay of the trace ^{241}Pu that is present. The other radionuclides that were detected reflect worldwide fallout and naturally occurring concentrations of nuclides.

During 1989, sediment samples from the arroyos near the Livermore site were also collected. This was the second year that samples of this type were collected. The level of lead (Pb) in one sample (79 mg/L) was above CFLC limits (5 mg/L). Two samples showed detectable levels of the PCB Aroclor 1260 (0.07 mg/kg and 0.05 mg/kg). However, the levels detected were close to detection limits (0.03 mg/kg) and were below regulatory guidelines (50 ppm; 40 *Code of Federal Regulations* 761). None of the levels detected for other organic compounds were above regulatory standards. Many of these compounds are typical of fuel constituents and are expected in locations that

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concentrate stormwater runoff. Others are typical laboratory solvents that may indicate contamination of samples. Investigations have been initiated to determine the origin of these contaminants.

In general, the impact of LLNL operations on soils and arroyo sediments has not changed from previous years. Most analytes were detected at background concentrations, in trace amounts, or could not be measured above detection limits. Those compounds that have been detected are not at concentrations that warrant concern.

Vegetation and Foodstuff Monitoring

Sampling of vegetation can provide information about the buildup of radionuclides in the environment. In addition, the foodstuff pathway can be an important contributor to total dose. Therefore, vegetation and foodstuff analyses are performed throughout the year in the proximity of the Livermore site and also for areas beyond the influence of LLNL.

In general, LLNL impacts on vegetation and foodstuffs in the Livermore Valley in 1989 were minimal. Tritium levels found in the Livermore Valley vegetation were generally comparable to those observed in previous years. Based on the conservative assumption that an adult's diet includes vegetables with the highest observed average tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is approximately 6×10^{-2} mrem/y.

The highest concentration of tritium in goat milk was 4.9×10^{-7} $\mu\text{Ci/mL}$. Although there is no standard for the concentration of tritium in milk, this value is 2.5% of the California drinking water standard. The calculated annual radiation doses that could be received from consuming this milk, based on a milk intake of 310 L/y is 4.5×10^{-3} mrem/y.

The concentrations of tritium in honey produced in the Livermore Valley were slightly higher than those found in honey from neighboring areas, but within the range normally seen. Historically, the tritium content fluctuates significantly from year to year, and the average Livermore

Valley concentration is sometimes higher and sometimes lower than that of other Bay Area honeys. There are no safety standards for radionuclides in honey. However, none of the tritium levels observed would be of health concern even if the honey was consumed in the same quantities as drinking water, where safety standards do exist.

Samples of retail wines produced from grapes grown in the Livermore Valley, from grapes grown in other areas of California, and from grapes grown in Europe were analyzed. The mean Livermore Valley wine tritium content was greater than both the European and California means, but the means from all areas were unchanged since 1988. In fact, whether analyzed by sampling year or by vintage year, the Livermore Valley and California wines have each maintained essentially constant levels of tritium concentration since monitoring began. The European wines, which used to contain higher concentrations of tritium, have decreased to approximately the same levels as Livermore wines over the past 10 years.

There are no safety standards for radionuclides in wine. However, the highest tritium value for wine produced from grapes grown in the Livermore Valley and purchased in 1989 is 3% of the California drinking water standard. The most conservative dose calculation, based on the highest tritium value and the very conservative assumption that wine is consumed in the same volume as drinking water (2 L/day) resulted in an annual dose of 0.025 mrem. More realistic consumption models resulted in far lower doses. The potential dose from consuming wine from any region is, therefore, minute.

Environmental Radiation Monitoring

Penetrating radiation monitoring around the Livermore site and the surrounding Valley is performed using thermoluminescent dosimeters (TLDs). Both background and man-made radiation are measured. The average annual dose equivalent from external exposure to gamma radiation at the LLNL site

boundary (61 mrem) was statistically the same as the background external dose measured in the Livermore Valley (63 mrem). The dose is almost identical to that in 1987 (64 mrem) and 1988 (63 mrem). This demonstrates that there was no measurable dose due to direct radiation from LLNL operations at any point beyond the Livermore-site boundary.

The annual average neutron radiation dose at the Livermore-site perimeter in 1989 was 5.3 mrem, similar to the 1987 (5.0 mrem) and 1988 (4.2 mrem) values. The neutron doses were statistically the same at all perimeter monitoring locations. The neutron doses measured at the site boundary were consistent with that expected from natural background. These data indicate that no detectable contribution to external dose by direct penetrating radiation was made by LLNL operations.

Potential Radiological Dose from the Livermore Site

The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 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 definition of "effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway. (On December 15, 1989, this limit was changed to 10 mrem/y effective dose equivalent.)

The EPA standard is based on the AIRDOS-EPA Clean Air Act Code (CAAC) model code, while LLNL historically has used the Continuous-Point-Source Code (CPS Code) to determine compliance with DOE standards; this results in somewhat different calculated individual doses

because of the differences in model assumptions and calculations.

Small amounts of radioactive materials from operations at the Livermore site were discharged to the environment in air and sewer effluents. (The release of radioactivity to the sanitary sewer by LLNL and SNLL are discussed in the Sewage Monitoring section of this summary.) The total amount of tritium released to the atmosphere by LLNL in 1989 was 2951.8 Ci, approximately 1554.4 Ci in the form of tritiated water. An additional 834 Ci of tritium was released by SNLL, with approximately 656 Ci in the form of tritiated water. The total quantity of ^{13}N (half-life of 10 minutes) and ^{15}O (half-life of 2 minutes) released in 1989 was 42 Ci at the Livermore site. The amount of radioactivity released from LLNL during 1989 was lower than 1988 and well within the range of previous years.

The CAAC was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and dose at the maximum hypothetical offsite exposure location for each emission source. The CPS Code was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and maximum hypothetical offsite dose, as well as collective person-rem dose to the population residing within 80 km of the Livermore site. Both of these methods are based on conservative assumptions, and any actual dose received by an individual would be much less.

AIRDOS-EPA Clean Air Act Code (CAAC). The air pathway doses calculated using the CAAC included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The CAAC was run using specific meteorology for the Livermore site. The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Livermore-site operations in 1989 was 0.53 mrem; the dose to the nearest resident was 0.33 mrem; and the dose at the point of maximum hypothetical offsite exposure was 0.53 mrem. These doses represent only 2% or less of the 25-mrem/y EPA limit. Doses for

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emissions from specific facilities were also calculated.

Continuous-Point-Source Code (CPS Code). Air pathway doses were also calculated for each facility considered to have a measurable airborne discharge to the atmosphere using CPS Code. The maximum combined inhalation dose (i.e., the total from all facility discharges) from airborne emissions at the Livermore-site perimeter was 0.31 mrem. The maximum hypothetical combined inhalation dose from airborne emissions to the nearest resident was 0.21 mrem. The dose from tritium was entirely due to tritiated water (HTO). Elemental tritium (HT) did not present a measurable contribution to the dose.

The current DOE radiation protection limit for the public is 100 mrem during a one-year period. Prior to 1986, this limit was 500 mrem per year. The total offsite dose has decreased significantly over past years. Fluctuation in dose from year to year is due to changes in operations, operating schedules, and site meteorology. Since 1984, the offsite doses have remained very low, all less than 0.4% of the DOE limit.

The CPS Code was also used to calculate the dose to the maximally exposed individual, a hypothetical person who lives at a location and has a life style that results in receiving the maximum possible calculated radiation dose from Livermore-site operations. The calculated committed (50-y) effective dose equivalent to the hypothetical maximally exposed member of the public from all sources and pathways during 1989 was 0.43 mrem. For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation (including radon) during this same period.

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 0.64 person-rem during 1989. This dose is based on a population of

6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources, during the same period of time was estimated to be 1.9×10^6 person-rem.

Overall, all measured and calculated radiation doses were negligible: they were well below the applicable standards for radiation protection of the public and substantially less than the dose normally received from natural sources of background radiation.

Public Health Risk Assessments

LLNL conducted two public health risk assessments in 1989: one for emissions from the Building 624 incinerator and the other for volatile organic compounds (VOCs) in the groundwater near the Livermore site. For the incinerator, the assessment of chronic, noncarcinogenic effects indicated that daily exposure estimates for each compound emitted from the incinerator were below levels believed to produce any adverse effects, even for sensitive individuals such as the elderly or asthmatics. Similarly, the acute effects assessment indicated that maximum one-hour concentrations of emissions were also below levels that would cause adverse effects. In addition, the assessment of the increased risk of cancer from incinerator operations to the hypothetical maximally exposed individual was 9.1×10^{-7} , i.e., a nine-in-ten-million chance above that risk incurred by everyday living.

For groundwater contaminants, the highest predicted cancer risk associated with a 70-year-lifetime maximum exposure is 2×10^{-3} for exposure to contaminants in water from a potential monitoring well drilled 250 ft west of the Livermore site. Because no wells are likely to be drilled within this area, the risk based on the downtown-Livermore receptor sites was also calculated, resulting in a predicted risk of 1×10^{-3} . Moreover, these analyses of risk are based on the premise that no remediation of groundwater contamination will occur. In fact, LLNL will remediate these contaminants, and actual risks will be much lower. In addition, no

members of the public are currently exposed to VOCs derived from the use of wells near the LLNL site.

Summary of Environmental Compliance Activities

The activities undertaken at the Livermore site in response to legal requirements are described in the body of this report in the chapter "Summary of Environmental Compliance Activities."

Resource Conservation and Recovery Act (RCRA)—Hazardous Waste. In February 1989, LLNL submitted a reformatted RCRA Part B permit application for the storage, treatment, and incineration of hazardous waste and performed the second liquid waste trial burn. In September, the EPA proposed to deny the Part B permit for the Livermore site. In response to this notice, LLNL announced that the permit application would be withdrawn. In addition, LLNL completed physical upgrades to several hazardous and mixed waste management units, and completed the incinerator risk assessment.

The Part A and Part B permit applications were then significantly revised to describe more specifically the individual waste management units, to reflect physical or operational changes, to add mixed waste management units, and to address documentation issues. The revised permit application was submitted to the regulatory agencies in December 1989.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks. Personnel in the Tank Integrity Testing Program conducted tests of 30 underground diesel fuel and gasoline systems in 1989; all but one was leak tight, and it was removed from service. In addition, 33 underground wastewater retention systems were tested; 10 systems were identified that could not meet the minimum leak-rate criterion. Leak sites for two of these were identified and repaired. A program for necessary repairs or closure of the remaining eight systems is under way.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I.

The efforts of the Environmental Restoration Program are directed mainly toward the Ground Water Project, which addresses contamination at and near the Livermore site resulting from past releases of hazardous substances. Currently, efforts are ongoing to monitor the extent of VOCs and gasoline in soil and groundwater. Pilot remediation has been initiated in two areas. In addition, LLNL is working on various groundwater computer models as part of the EPA Remedial Investigation/Feasibility Study process.

In November 1989, a draft of the Remedial Investigation Report for the Livermore site was prepared for agency review. The objectives of the report were to characterize the site and lay a foundation for the development of remediation strategies. Screening of groundwater, surface water, soil, sediments, and air for toxic materials has led to the conclusion that the primary medium of concern is groundwater and that the principal compounds found to be of potential concern are VOCs and fuel hydrocarbons.

Superfund Amendments Reauthorization Act (SARA)—Title III. A physical inventory of all chemicals, subject to reporting under SARA Title III, was conducted in 1988. In early 1989, the data were entered into a computerized database system, and were used to generate reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site.

Toxic Substances Control Act. In 1989, LLNL removed and disposed of a large number of capacitors containing polychlorinated biphenyls (PCBs). These capacitors were associated with the Tandem Mirror Experiment (TMX). Until 1989, DOE had required LLNL to keep TMX in a moth-balled state so that it could be used again, if necessary. In 1989, DOE relaxed this requirement.

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National Environmental Policy Act (NEPA). In 1989, over forty projects were evaluated under the applicable policies and procedures for DOE compliance with NEPA. Two of these were determined by DOE to require an Environmental Assessment; four were the subjects of Action Description Memoranda.

National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements. LLNL holds permits for wastewater discharges to ground-water and surface water and to the sewer, and was the subject of compliance inspections in 1989.

Air Quality Management Activities. In 1989, the Bay Area Air Quality Management District issued 192 permits to LLNL for the Livermore site. No deficiencies were noted as a result of the annual inspection of permitted sources.

Pollution Abatement Projects. LLNL is involved in several projects to improve effluent monitoring and control systems. A system for control of tritium releases from the Tritium Facility is in the final construction phase, an additional monitoring system has been added to the Plutonium Facility, and improved monitoring and retention systems are being added to the sanitary sewer system.

Environmental Protection Department Internal Compliance Activities. The Environmental Operations Group is responsible for working closely with LLNL programs and departments in implementing environmental requirements so planned and current operations and experiments function in compliance with Federal, State, and local environmental regulations. In 1989, the group conducted 93 formal building inspections, responded to 6 spills, and conducted site evaluations for 27 construction projects.

Quality Assurance Activities

The Environmental Monitoring Group (EMG) conducted quality assurance activities to comply with DOE Order 5700.6B. A separate document prepared by EMG details all quality assurance activities in compliance with this order and with the

quality assurance standard, ANSI/ASME NAQ-1. Furthermore, all monitoring took place according to written, quality-assurance-approved procedures. Contract and onsite laboratories must comply with EMG quality assurance procedures and audits, and must participate in national cross-check programs.

Duplicate, blank, and spiked samples were analyzed as part of the Quality Assurance Program. In 1989, all laboratories participated in cross-check programs; duplicate sample data were comparable; and blank samples were, for the most part, adequate.

In 1989, over 95% of all expected data was captured.

LLNL—SITE 300

Air Monitoring

Surveillance monitoring is conducted at Site 300 to determine if airborne radionuclides or hazardous materials released by operations have an impact on the environment or public health. In 1989, all measurements of airborne radioactive pollutants at Site 300 were well below the DCGs established by DOE. The highest concentrations of plutonium detected were 0.088×10^{-17} $\mu\text{Ci/mL}$, which is about 0.005% of the DCG. The highest concentration of ^{238}U detected was observed in the February composite sample at a level of 18.9×10^{-5} $\mu\text{g/m}^3$ (6.3×10^{-17} $\mu\text{Ci/mL}$), or 0.06% of the DCG. The highest concentration of ^{235}U detected was also observed in the February composite sample at a level of 12.5×10^{-7} $\mu\text{g/m}^3$ (2.66×10^{-18} $\mu\text{Ci/mL}$), 0.003% of the DCG. No other significant differences between locations or samples were noted, and the overall levels were essentially the same as those reported in previous years.

The highest monthly average concentration of beryllium detected was a detection-limit value of $<26 \times 10^{-5}$ $\mu\text{g/m}^3$. This value is less than 3% of the regulatory limit established by the San Joaquin County Air Pollution Control District. These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium.

Routine Water Monitoring

Surface water, domestic water, and rain water at Site 300 and in nearby locations are monitored for the presence of radionuclides and other nonradioactive pollutants, such as metals, solvents, and pesticides. The only constituent of concern observed in the active water supply wells was a small amount of TCE sporadically detected in Well 19, which averaged approximately 3.3 $\mu\text{g/L}$ (below the California Department of Health Services maximum contaminant level (MCL) of 5 $\mu\text{g/L}$). Well 19 was only used as a back-up water supply and was taken out of service in the fourth quarter of 1989.

The highest concentration of tritium was 1.83×10^{-7} $\mu\text{Ci/mL}$. This represents 0.2% of the DCG and 1% of the permissible concentration specified by the State of California for drinking water. An estimate of the annual effective dose that may be delivered to an adult who consumes water containing this tritium concentration is less than 0.003 mrem, based on a water consumption of 2 L/day and the dose-conversion factors provided by DOE. The actual dose (if any) from these water sources would be considerably less because many of these sources are not used as drinking water sources.

The results from analyses of 10 groundwater sampling locations in the vicinity of Site 300 indicated no concentrations above background, with the exception of nitrate in one well that was above the MCL. This well, however, is not used for drinking water supplies.

Compliance Groundwater Monitoring

LLNL also routinely monitored the groundwater around landfills and wastewater surface impoundment units at Site 300. In 1989, very low concentrations of Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) continued to be observed in two wells at a maximum concentration of 5.8 $\mu\text{g/L}$ and 9.7 $\mu\text{g/L}$, respectively. Freon 113 was also detected in another well during the second quarter at a concentration of 0.9 $\mu\text{g/L}$. These levels are far below the State action level of 1200 $\mu\text{g/L}$.

Some groundwater monitoring wells near landfills at Site 300 continued to show sharply elevated concentrations of tritiated water. These elevated levels have been observed in this area since 1984. The highest value measured was 4.0×10^{-4} $\mu\text{Ci/mL}$. This value exceeds the MCL; however, it was found in an aquifer that is not used for onsite water supplies. Water movement analysis has shown that the tritium will decay to levels below drinking water limits before it reaches the site boundary. Traces of halogenated hydrocarbons were detected in wells downgradient of this area and in groundwater downgradient from another landfill at Site 300. As in 1988, the highest trichloroethylene value observed during routine monitoring in 1989 was from a well in the Building 817 area; this year the value was 81 $\mu\text{g/mL}$, in 1988 it was 98 $\mu\text{g/mL}$. This contamination is most likely due to past operations at Building 815. Nitrate levels in a number of monitoring wells were above the MCL. These levels are considered to be naturally occurring.

Soil Monitoring

Soil is an integrating medium that can account for contaminants released to the atmosphere or through liquid effluents. Soil samples are taken annually at Site 300 to document any changes in environmental radioactivity levels and to evaluate any increases that may have been the result of LLNL operations.

The soil samples show that greater-than-background concentrations of ^{238}U , including that from the new sampling location near Bunker 801, are limited to isolated regions near the firing tables. The highest value of 98.2 $\mu\text{g/g}$ (about 25 times greater than background) was observed in the vicinity of a now inactive firing table. In 1988, a value of 570 $\mu\text{g/g}$ was observed in this area. However, in 1988, the gravel from this firing table was removed to an onsite landfill after the sample yielding the 570 $\mu\text{g/g}$ value was taken. The 1989 value is probably an indication of residual material in this area. With the exception of the elevated ^{238}U observed near the bunker, the activities of all other samples

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were representative of background or naturally occurring radionuclides.

Vegetation Monitoring

Vegetation monitoring can provide information about the buildup or release of radionuclides in the environment. DOE orders require both sampling and pathway analysis for vegetation at and near DOE facilities. Quarterly vegetation samples were collected at and around Site 300 in 1989.

The levels of tritium detected in vegetation samples were mostly at detection limits, with the exception of samples from two locations, and were very similar to those reported in 1988. As was the case in 1988, vegetation samples from a landfill area contained the highest tritium values detected (up to 1.6×10^{-3} $\mu\text{Ci/mL}$ in recovered water). The 1989 maximum levels from these sampling locations are greater than those reported in previous years. Tritium has been observed in the vegetation of these areas since 1971, although tritium is not presently used at the site. These sampling locations are adjacent to landfills that include tritium-containing debris from firing tables. As a result of seasonal rains spreading tritium from this debris, the tritium is present in the soil and groundwater in the area where these samples are routinely collected. The landfill areas continue to be under investigation for soil and groundwater tritium contamination, as described in reports published by the Environmental Restoration Division of LLNL's Environmental Protection Department.

The calculated annual average dose from vegetation at the location with the highest detected tritium values is 7 mrem/y, using conservative pathway modeling assumptions (i.e., an adult's diet includes vegetables with the highest average tritium concentration, and includes meat and milk derived from livestock fed on grasses with the same concentration). In actuality, this dose would never be received because vegetation at Site 300 is neither consumed by people nor used for grazing livestock.

In general, LLNL impacts on vegetation at and near Site 300 were minimal in 1989. The levels detected at known sites of tritium contamination are not of concern because the contamination is localized and the affected vegetation is neither directly ingested by people nor consumed by livestock.

Environmental Radiation Monitoring

The average annual dose equivalent from external exposure to gamma radiation at the Site 300 boundary was 77 mrem (ranging from 69 to 89 mrem). The offsite measured doses are 76 mrem just west of Site 300 and 68 and 56 in the City of Tracy. The region around Site 300 has elevated levels of naturally occurring uranium and may be different than the San Joaquin Valley region. The differences observed between the two locations may account for the different measured external radiation doses. We are investigating these differences and will increase the offsite monitoring east of Site 300.

Potential Radiological Dose from Site 300

The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 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 definition of "effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway. (On December 15, 1989, this limit was changed to 10 mrem/y effective dose equivalent.)

The EPA standard is based on the AIRDOS-EPA Clean Air Act Code (CAAC) model code, while LLNL historically has

used the Continuous-Point-Source Code (CPS Code) to determine compliance with DOE standards; this results in somewhat different calculated individual doses because of the differences in model assumptions and calculations.

The total airborne discharge from the Advanced Test Accelerator in 1989 was 0.57 Ci of ^{13}N and 0.57 Ci of ^{15}O . These nuclides are air activation products generated during the interaction of the accelerator beam with air. Nitrogen-13 has a half-life of about 10 minutes, and ^{15}O has a half-life of about 2 minutes.

The CAAC was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and dose at the maximum hypothetical offsite exposure location for each emission source. The CPS Code was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and maximum hypothetical offsite dose as well as collective person-rem dose to the population residing within 80 km of LLNL. Both of these methods are based on conservative assumptions, and any actual dose received by an individual would be much less.

EPA Clean Air Act Code (CAAC). The air pathway doses calculated using the CAAC included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The CAAC was run using specific meteorology for Site 300. The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Site 300 operations in 1989 was 1.5×10^{-4} mrem; the dose to the nearest resident was 3.7×10^{-7} mrem; and the dose at the point of maximum hypothetical offsite exposure was 1.5×10^{-4} mrem. These doses represent only 0.006% or less of the EPA limit.

Continuous-Point-Source Code (CPS Code). Air pathway doses were also calculated using CPS Code. The maximum inhalation dose from airborne emissions at the Site 300 perimeter was 6.3×10^{-4} mrem. The maximum inhalation dose from airborne emissions to the nearest resident was 1.6×10^{-4} mrem.

The CPS Code was also used to calculate the dose to the maximally exposed individual, a hypothetical person who lives at a location and has a life style that results in receiving the maximum possible calculated radiation dose from Site 300 operations. The calculated committed (50-y) effective dose equivalent to the hypothetical maximally exposed member of the public from all sources and pathways during 1989 was 6.3×10^{-4} mrem. For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation (including radon) during this same period.

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 1.3×10^{-3} person-rem during 1989. This dose is based on a population of 6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources, during the same period of time was estimated to be 1.9×10^6 person-rem.

Noise Monitoring

LLNL conducted 55 high explosives tests at Site 300 during 1989. Microbarograph measurements in the vicinity of Site 300 and the City of Tracy demonstrated that the noise limit of 400 μbar was not exceeded, nor were there any complaints of noise or overpressure from residents in the vicinity of the test site. Furthermore, none of the 55 tests produced sound levels, at any of the 6 microbarograph stations, above 65 μbar .

Summary of Environmental Compliance Activities

The activities undertaken at Site 300 in response to legal requirements are described in the body of this report in the chapter "Summary of Environmental Compliance Activities."

Summary

Resource Conservation and Recovery Act (RCRA)—Hazardous Waste. Landfill Pits 1 and 7 were operated at Site 300 under provisions of the Interim Status Document CA 2890090002 and WDR Order 80-184 until November 1988 when their use ceased. They had been used for disposal of firing table gravel and debris. Plans for final closure of Pits 1 and 7 were submitted to DHS, EPA, and the Regional Water Quality Control Board. The RCRA Part A permit application was revised to show the change in landfill status. A RCRA Part B permit application was submitted to EPA and DHS in January 1989 for the hazardous waste container storage facility. The final Part B permits were issued by EPA and DHS in November 1989 for hazardous waste container storage.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks. Personnel in the Tank Integrity Testing Program conducted tests of two underground hazardous product retention systems; one system was identified that could not meet the minimum leak-rate criterion. The leak site was identified and repaired.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I. At Site 300, ongoing remedial investigations, feasibility studies, and remedial actions are being performed. Until recently, these investigations were being conducted under the California Clean Water Act, using CERCLA guidelines and procedures. In March 1989, LLNL received a proposed RCRA cleanup order from EPA. The terms of the cleanup order have not yet been negotiated with EPA.

Remedial Investigations/Feasibility Studies of TCE, tritium, and HE compounds in soil and groundwater continued during 1989. TCE contamination was investigated at the Building 834 complex, at Building 833, the General Services area, Landfill Pit 6, and the HE Process Area. A soil-vapor survey in the General Services area resulted in the detection of TCE in offsite soils east of the southeast corner of

Site 300. Subsequent installation of monitoring wells allowed identification of a plume of TCE (concentrations up to 58 ppb) in shallow groundwater extending about 4000 ft from the site boundary beneath private and State of California property. A groundwater treatment system has been designed to begin remediation of these low concentrations of TCE. By year end, the treatment unit was being constructed and applicable permits had been sought.

The investigation of tritium in groundwater at Landfill Pit 7 showed that groundwater in that area is moving at a maximum of about 15 m/y toward the northern site boundary. Given this flow rate and the radioactive decay half-life for tritium of 12.3 years, by the time the groundwater reaches the site boundary, its tritium concentration will be only slightly above background levels.

In 1989, LLNL continued its investigation of the extent of HE compounds and TCE in groundwater beneath the HE Process Area. Both plumes are small, with concentrations of HE compounds at 350 ppb or less and TCE at 280 ppb or less.

As part of LLNL's environmental remediation efforts, six inactive water-supply wells at Site 300 were sealed and abandoned. These older wells posed a potential threat of cross-contamination of water-bearing zones because of their long well screens or sand packs.

In addition during 1989, the Regional Water Quality Control Board approved LLNL's plan to close the nine decommissioned HE rinsewater lagoons in the HE Process Area. By October 1989, LLNL had filled the lagoons to grade level with native soils, placed a clay cover on each lagoon, and seeded them with native grasses. The lagoons have now been formally closed.

National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements. LLNL holds permits for cooling tower discharges, landfill sites, sewer lagoons, septic tanks, leachfields, and a high explosives rinsewater impoundment system. These permits were the subject of compliance inspections in 1989.

Air Quality Management Activities. The San Joaquin Air Pollution Control District issued nine permits to LLNL for Site 300 operations in 1989. No deficiencies were noted as a result of the annual inspection of permitted sources.

Endangered Species Act Activities. Staff from the California Department of Fish and Game and the U.S. Fish and Wildlife Service performed their annual inspection of the endangered wild flower, *Amsinckia grandiflora*, on March 30, 1989. A newly discovered second population located on Site 300 was also inspected.

Environmental Protection Department Internal Compliance Activities. The Environmental Operations Group is

responsible for working closely with LLNL programs and departments in implementing environmental requirements such that planned and current operations and experiments function in compliance with Federal, State, and local environmental regulations. In 1989, the group conducted 40 formal building inspections at Site 300.

Conclusion

In sum, the results of the Environmental Monitoring Program for 1989 demonstrate that the environmental impacts of LLNL are minimal and pose no threat to the public or the environment.

INTRODUCTION

LLNL is operated by the University of California for the United States Department of Energy (DOE). The Laboratory was established in 1952 to conduct research on nuclear weapons and magnetic fusion energy. Since then, other major programs have been added; these include laser fusion and laser isotope separation, biomedical and environmental sciences, and applied energy technology. These programs require research in such basic scientific disciplines as chemistry and materials science, computer science and technology, biological sciences, engineering, and physics. LLNL also carries out a variety of projects for other Federal agencies.

LLNL's Livermore site is located about 64 km (39 miles) east of San Francisco, California, in the Livermore Valley of eastern Alameda County, adjacent to the City of Livermore. Nearly 6 million people live within 80 km (50 miles) of the Livermore site (see Figure 1); of these, approximately 54 000 live in Livermore.

Much of LLNL's materials testing and high-explosives (HE) diagnostic work is conducted at Site 300, which is located in the sparsely populated hills of the Diablo Range, 24 km (15 miles) southeast of Livermore. **Figure 1** shows the location of the Livermore site with respect to its surrounding areas, including Site 300. In 1989, LLNL employed approximately 8200 people.

Operations at LLNL are subject to strict Federal, State, regional, and local environmental requirements, and a substantial commitment is made to meet these requirements. Strict effluent-control programs that emphasize controlling effluents at the source are in effect; these programs constrain potential hazardous emissions such as tritium, uranium, plutonium, metals, solvents, and common laboratory chemicals. The Environmental Monitoring Group (EMG) of the Regulatory Affairs Division of the Environmental Protection Department conducts an environmental monitoring program for three purposes: (1) to assess the effectiveness of these

control measures; (2) to assess compliance with applicable standards; and (3) to estimate the impact of these operations on the environment. A list of the potential environmental pollutants for which analyses are conducted is presented in **Table 1**. The monitoring program includes many different sampling and analytical techniques;

Figure 1. Estimated population distribution (in thousands) within 80 km of Livermore, by sectors.

Introduction

Figure 2. In 1989, the Environmental Monitoring Group conducted 31 485 routine monitoring analyses.

Figure 3. In 1989, the total number of monitoring analyses conducted by the Environmental Monitoring Group and the Environmental Restoration Division was 154 647.

these techniques permit detection of radioactive and nonradioactive pollutants at environmental background levels. The program includes the collection and analysis of air, soil, water, sewage effluent, vegetation, and foodstuffs. In addition, gamma and neutron dosimeters are used to measure environmental radiation levels at numerous locations in the vicinity of LLNL. In 1989, over 154 000 analyses were performed (see **Figures 2 and 3**).

This report is one of the documents written to comply with environmental regulations and to inform the public about emissions and impact of LLNL operations. It is prepared by EMG, with the assistance of other LLNL employees, in compliance with DOE Orders 5400.1 General Environmental Protection Program (U.S. Department of Energy 1988a) and 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements (U.S. Department of Energy 1981).

This report has been divided into two parts: Livermore site and Site 300. This was done to emphasize the difference in location and operation of the two sites, but has resulted in some duplication in information about monitoring methods. The topics in the major sections are organized by the aspect of the environment being monitored, e.g., air, water, or soil, rather than by the type of work performed by EMG. (An overview of this document is presented in the DOE suggested format in the synopsis at the end of this document.)

Environmental monitoring samples are analyzed by LLNL or commercial laboratories. When applicable, Environmental Protection Agency (EPA) standard methods are used to collect and analyze the samples. If EPA standard methods are not available, LLNL develops its own procedures, using radiochemical procedures derived from published techniques and modified to meet the specific analytical requirements of EMG.

While it is relatively easy to report the data that comprise the annual environmental report, it is much more difficult to place these data in context. In this report,

we present not only the data for environmental monitoring in 1989, but also information about what the data mean, including comparisons with data from past years, comparisons of these data with regulatory standards, and, for radiation, comparisons with natural sources. The assessment of potential impact to the public from emissions of materials is based on effluent discharges and measurements of environmental media. Radiation doses are calculated at the points of hypothetical maximum public exposure and to the total population residing within an 80-km (50-mile) radius of the Livermore site. This report does not contain detailed or historical information about compliance or cleanup activities; these activities are the subjects of many specific reports (see e.g., Thorpe et al. 1990; Taffet et al. 1989b). However, this report does present summary information about compliance activities conducted at LLNL in 1989.

Before progressing to the monitoring data, we present summary information about the organization and functions of the Environmental Protection Department.

ENVIRONMENTAL PROTECTION DEPARTMENT

The Environmental Protection Department ensures that LLNL can meet its environmental responsibilities as stipulated in environmental legislation, regulations, and DOE orders and collaborates with LLNL programs to maintain adequate protection of the environment. In 1989, the Department was reorganized into four divisions: Environmental Guidance Division, Environmental Restoration Division, Hazardous Waste Management Division, and Regulatory Affairs Division.

Environmental Guidance Division

The Environmental Guidance Division helps LLNL programs and organizations operate in an environmentally sound manner and meet compliance requirements. The Division staff advises and

trains program personnel on regulatory compliance, waste minimization, and pollution abatement. These consultations help identify and mitigate potential environmental contamination and compliance problems in the early stages of project planning. The Division staff conducts audits for compliance implementation. The Division staff also responds to emergencies and other urgent problems to advise on environmental cleanup standards, sampling, and possible regulatory reporting; implements regulatory requirements for tanks and wastewater systems, including record keeping and regulatory interface; and prepares risk assessments, reports, and documents, such as Environmental Impact Reports and Statements (EIRs and EISs), for compliance with the National Environmental Policy Act and the California Environmental Quality Act.

Environmental Restoration Division

The Environmental Restoration Division was established in response to past handling and disposal practices for hazardous materials, as well as leaks and spills, which resulted in environmental contamination at levels unacceptable by current standards. The staff of this Division plans, directs, and conducts assessments to determine the impact of such releases on the environment; the staff also conducts restorations to reduce contamination to levels acceptable to protect human health and the environment. Particularly, the Environmental Restoration Division staff investigates field sites to determine the existence and extent of contamination, manages corrections such as soil removal and groundwater and surface water treatment, and closes inactive facilities in a manner designed to prevent environmental contamination.

Hazardous Waste Management Division

The Hazardous Waste Management Division manages and processes all LLNL-generated hazardous wastes, radioactive wastes, and mixed wastes for the purpose

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of storage, treatment, and transportation for recycling or offsite disposal. The Division staff also manages the Waste Minimization Program. Specifically, the Hazardous Waste Management staff processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal or recycling; tracks and documents the movement of hazardous, mixed, and radioactive waste from waste accumulation areas to final disposal both on and off site; responds to emergencies; and participates in the cleanup of spills.

Regulatory Affairs Division

The Regulatory Affairs Division ensures that LLNL complies with environmental regulations through the regulatory permitting process for such environmental

matters as hazardous waste handling, air emissions sources, and water discharges. The Division also has the responsibility for monitoring the environment and preparing the numerous reports required by various environmental regulations and DOE Orders, including this report. Notably, the Regulatory Affairs Division staff monitors environmental media to verify compliance with established limits and to ensure there is no environmental degradation due to LLNL activities; works with regulatory agencies in the preparation of reports, permit applications, and other documents required to demonstrate compliance with environmental regulations; maintains knowledge of legislation as it may impact LLNL activities; and interacts with the community on environmental issues and the impact of LLNL operations.

Table 1. Potential environmental pollutants for which analyses are conducted.

Metals	Radioactivity	Organic compounds	
Antimony	Gross alpha	Acrolein	Ethylbenzene
Arsenic	Gross beta	Acrylonitrile	Freons
Beryllium	Gamma isotopes	Benzene	HMX
Cadmium	Plutonium isotopes	BHC, gamma isomer	Methoxychlor
Chromium	Potassium-40	(Lindane)	Methylene chloride
Cobalt	Radium isotopes	Bromodichloromethane	Polychlorinated
Copper	Thorium-232	Bromoform	biphenyls
Lead	Tritium	Bromomethane	RDX
Mercury	Uranium isotopes	Carbon tetrachloride	1,1,2,2-Tetrachloroethane
Molybdenum		Chlorobenzene	Tetrachloroethylene
Nickel		Chloroethane	TNT
Selenium		2-Chloroethylvinylether	Toluene
Silver		Chloroform	Toxaphene
Thallium		2,4-D	2,4,5-TP (Silvex)
Vanadium		Dibromochloromethane	trans-1,2-Dichloroethylene
Zinc		1,1-Dichloroethane	trans-1,3-Dichloropropene
		1,1-Dichloroethylene	1,1,1-Trichloroethane
		Dichloropropanes	1,1,2-Trichloroethane
		1,2-Dichloropropene	Trichlorofluoromethane
		1,3-Dichloropropene	Vinyl chloride
		Endrin	Xylene

Livermore Site
Aerial view
looking west

Introduction

The environmental effects of Livermore-site operations are governed by location, climate, and geology. For example, the dispersal of airborne emissions from the site are controlled by wind patterns and rainfall. Data on wind and rainfall are used to calculate the effects of emissions on nearby populations. Similarly, the dispersal of any groundwater contaminants are constrained by the particular geology of the site. This chapter is a brief overview of facts about Livermore-site surroundings that are used in determining environmental effects of various emissions.

Location

In 1952, when weapons research and development first took place at the Livermore site, the site was approximately one mile away from the city limits of the City of Livermore. However, during the last 30 years, the City has grown to the point where residential, industrial, and commercial development are occurring on parcels adjacent to the Livermore site. Recently, a vacant parcel located about 244 m (800 ft) west of the Livermore-site western boundary was annexed by the City of Livermore and rezoned to allow for low-density (3 units per acre), single-family residential development. Construction of residences on this property began in 1989.

Sandia National Laboratories, Livermore (SNLL) is located immediately to the south of the Livermore site. Operated by AT&T Technologies, Inc., SNLL is under DOE contract to provide research and development associated with nuclear weapons systems engineering and related national security tasks. Although their primary missions are similar, LLNL and SNLL are separate facilities, each having its own local management, and each reporting to a different DOE operations office.

Other property south of the site includes agricultural areas and low-density residential areas. Grazing is the primary activity, although orchards and vineyards may be found to the south; there is also a business park to the southwest of the Livermore

site. Farther to the south, property is primarily open space or rural ranchettes, with some agricultural use.

The property to the east of the site is agricultural land with low-density residential development. Farther east, foothills of the intercoastal range define the eastern margin of the Livermore Valley.

A business park is located directly north of the Livermore site, and a 287-acre parcel of open space and agricultural land northeast of the site has recently been rezoned to allow development of a center for heavy industry.

The developed portion of the Livermore site now occupies an area of 3.28 km² (1.3 miles²). Recently, DOE obtained additional land around the Livermore site to serve as a buffer zone. Additional land has also been acquired for security buffer zones on the east and west sides of the SNLL site.

Climate

The climate of the Livermore Valley is characterized by mild, rainy winters and warm, dry summers. The mean annual temperature is 12.5°C (59°F); the normal seasonal temperature range is defined by nighttime winter lows in the vicinity of 0°C (32°F) and summer daytime highs around 38°C (100°F). Annual wind data are given in **Fig. L-1** and **Table L-1**. Prevailing winds for approximately 45% of the year are from the west and southwest. During the remainder of the year, it is calm

Livermore Site Setting

(approximately one-third 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 707 mm (30.8 in.) and 138 mm (5.4 in.). Rainfall at the Livermore site for 1989 was 236 mm (9.29 in.).

Geology

Topography. The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast

Figure L-1. Wind rose showing the average annual wind speed frequency of occurrence and direction at the Livermore site for 1989.

Range Province. The Livermore Valley forms an irregularly shaped lowland area approximately 26 km (16 miles) long, east to west; the valley averages 11 km (7 miles) in width, north to south. The floor of the valley slopes to the west from an elevation of approximately 200 m (660 ft) at the eastern end to approximately 90 m (295 ft) at its drainage outlet, which is located near the southwestern corner.

Surface drainage is by westward-flowing intermittent streams (arroyos) that merge in the west end of the valley to form the southward-flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system. Winter flows that are not captured as groundwater recharge flow out the southwestern corner of the valley and eventually enter San Francisco Bay by way of Alameda Creek. Surface-water bodies near the Livermore site include the South Bay Aqueduct, which runs from northeast to southwest, 0.2 km (0.1 miles) to the southeast of the Livermore site; the treatment tanks and reservoir of the Patterson Pass water treatment facility, about 1.2 km (0.7 miles) east of the Livermore site; Frick Lake, an area of enclosed drainage 4 km (2.4 miles) north of the Livermore site, where winter storm flows accumulate in an intermittent pond; and the Springtown pond, an artificial decorative pond maintained in a community recreation area 2.6 km (1.6 miles) northwest of the Livermore site. Lake Del Valle, a water storage reservoir 8 km (4.9 miles) south of the Livermore site, provides aquatic recreation (swimming, boating, and fishing), as does the Shadow Cliffs Regional Park, 11 km (6.7 miles) to the west. Lake Isabel, 9 km (4.9 miles) to the southwest, is a fee-for-fishing area. San Antonio Reservoir, 13 km (8 mi) to the southwest, is used for water storage. Both Lake Isabel and the Shadow Cliffs facility are excavations produced by gravel quarry operations, which continue to develop additional pits in the same general area. The Livermore site normally receives its treated water supply from the Hetch Hetchy Aqueduct (which supplies San Francisco), located 11 km (6.7 miles) southwest of Livermore.

Table L-1. Average annual percent frequency of wind direction versus wind speed (m/s) for the Livermore site, 1989. Winds are based on one hour averages. (Row and column totals do not add up due to rounding of numbers.)

Direction	0.0-0.9 calm	1.0-2.9	3.0-4.9	5.0-6.9	≥7.0	Total
N	1.8	0.3	0.2	0.1	0.0	2.5
NNE	1.8	1.8	2.4	0.9	0.2	7.2
NE	1.8	2.2	3.1	0.4	0.1	7.6
ENE	1.8	1.2	0.1	0.0	0.0	3.2
E	1.8	0.5	0.0	0.0	0.0	2.3
ESE	1.8	0.5	0.0	0.0	0.0	2.4
SE	1.8	0.3	0.0	0.0	0.0	2.2
SSE	1.8	0.4	0.0	0.0	0.0	2.3
S	1.8	3.6	0.5	0.4	0.2	6.5
SSW	1.8	4.4	1.3	0.5	0.3	8.3
SW	1.8	4.5	5.2	3.3	1.3	16.1
WSW	1.8	5.2	4.8	2.5	0.6	15.0
W	1.8	3.7	5.6	3.8	0.6	15.6
WNW	1.8	1.0	0.5	0.3	0.1	3.8
NW	1.8	0.7	0.1	0.0	0.0	2.5
NNW	1.8	0.5	0.1	0.0	0.0	2.5
Total	29.6	30.9	23.9	12.2	3.4	100.0

Hydrogeology. The hydrogeology and groundwater occurrence and movement 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 subsection has been summarized from the reports of these investigations and from data supplied by Zone 7 of the Alameda County Flood Control and Water Conservation District, the agency responsible for groundwater management in the Livermore Valley basin.

The Livermore Valley is bordered in the east by the Altamont Hills, where Miocene-age Neroly and Cierbo Formations and rocks of the Late Cretaceous Great Valley sequence are exposed. Within the valley, lacustrine and fluvial valley fill deposits occur to depths in excess of 1 km. The oldest of these is the Lower Livermore Formation of late Tertiary age—a hard, locally lithified, predominantly fine-grained sedimentary sequence that is exposed in the

hills south of the Livermore Valley. This formation is encountered beneath the Livermore site at depths ranging from 7 m (23 ft) in the east to 119 m (389 ft) in the west. Above the Lower Livermore Formation are the heterogeneous, unconsolidated alluvial sediments of the Pleistocene-age Upper Livermore Formation, which consist of complexly interbedded layers of poorly sorted clay, silt, sand, and gravel. The late Pleistocene and Holocene-age alluvial deposits that form the uppermost sequence of valley sediments are virtually identical to the Upper Livermore Formation.

The Livermore Formation (and overlying alluvial deposits) contain the aquifers of the Livermore Valley groundwater basin. This is an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Zone 7 conducts artificial recharge as needed to maintain groundwater levels. This is done by releasing water from Lake Del Valle or the South Bay Aqueduct into arroyo channels in the eastern portion of the valley. Groundwater

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flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater flow in the basin is 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 water table varies from about 43 m (140 ft) to 8 m (25 ft). **Figure L-2** shows a contour map of water table elevations (feet above mean sea level) for September 1989. Although water-table elevations vary with seasonal and year-to-year variations in both natural and artificial recharge, the qualitative patterns shown in **Figure L-2** are generally maintained. At the eastern edge of the Livermore site, groundwater gradients (change in elevation per unit of horizontal distance) are quite steep, but

under most of the site and farther to the west, the contours flatten out to a gradient of approximately 0.003. Groundwater flow under the northern and western portions of the site is generally westward. Under the southeast corner of the site, there is an apparent groundwater depression, a phenomenon that has been further investigated; a detailed description of findings to date is provided in Dresen and Nichols (1986). 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 m/day (Weiss Associates 1985). This, in combination with the observed water-table gradients, yields groundwater velocity estimates of 5 to 90 m/y. The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

Figure L-2. Approximate groundwater surface elevations (feet above mean sea level, msl), Livermore site and vicinity.

Introduction

LLNL carries out surveillance and effluent air monitoring to determine if air-borne radionuclides or hazardous materials are being released by operations. Air monitoring involves measurement of particles collected on filters or of vapor chemically trapped in air samplers. Concentrations of various airborne radionuclides, including particulates and tritium water vapor, and beryllium are measured at the Livermore-site perimeter and at offsite locations near the Livermore site. Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters, and is discussed in a following chapter. These chemicals are also measured to comply with the Clean Air Act National Emissions Standards for Hazardous Pollutants.

Methods

LLNL maintains 6 continuously operating high-volume air-particulate (HIVOL) samplers on the Livermore-site perimeter, shown in **Figure L-3**, and 13 Livermore Valley HIVOL samplers, shown in **Figure L-4**. The samplers are positioned to reasonably ensure that any significant concentration of particulate effluents from LLNL operations will be detected, regardless of local meteorology.

The 6 HIVOL samplers on the Livermore-site perimeter and 7 of the off-site Livermore Valley samplers are equipped with $5.2 \times 10^{-2} \text{ m}^2$ Whatman 41 cellulose filters. These samplers are operated at average flow rates of 400 to 1000 L/min. These flow rates are verified at monthly intervals with a portable field-calibration unit. If a sampler fails, it is repaired and then calibrated with a spirometer that was itself calibrated using an immersion unit traceable to the National Institute for Standards and Technology (NIST), formerly known as the National Bureau of Standards. 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). The remaining off-site samplers use $8.11 \times 10^{-3} \text{ m}^2$ glass-fiber filters (Flanders F700) and are

Figure L-3. Air sampling locations, Livermore-site perimeter, 1989.

Livermore Site Air Monitoring

operated at a flow rate of 85 L/min; the flow-rate indicators are generally calibrated annually.

All air filters are changed weekly. Each filter is identified by its location, date on, date off, elapsed sampling time, and flow rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets and each filter sample is given a serial number that accompanies it throughout the analysis. After a 4-day delay for decay of the radon-thoron daughters, gross alpha and beta activities on the filters are determined with an automatic gas-flow proportional counter using 20-min counting periods. Normally, this counter is used only for environmental samples to avoid possible contamination. Separate ^{239}Pu and ^{90}Sr standards are used to determine alpha and beta counting efficiencies, respectively. These standards are traceable to NIST or equivalent certification sources. Counting-efficiency measurements are made with

each set of filters counted, and a background count is taken at the beginning of each run and between each set of 10 samples. Records are kept of background and counting-efficiency variations that occur in the counting equipment. Filters from Locations 5, 6, 7, 9, and 11 are analyzed for gross alpha and gross beta activities only. Filters from all other locations are analyzed for additional constituents, as described below.

Monthly composites of Livermore-site-perimeter samples (Locations 1, 2, 12, 13, 14, and 15) are sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the site-perimeter filters from individual locations are analyzed for the presence of ^{239}Pu , ^{235}U , and ^{238}U . Selected offsite samples from the Livermore Valley (Locations 3, 4, 8, 10, 16, and 17) are analyzed for ^{239}Pu . These 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 then separated by an ion-exchange process. Plutonium is further purified by ion exchange, electroplated onto a stainless steel disk, and submitted for alpha spectrometry. Uranium is further purified by ion exchange and submitted for analysis by mass spectrometry.

Replicate samples are taken to confirm the results obtained from the samplers. An additional air sampler is operated in parallel with the permanent sampler at one of the six Livermore-site-perimeter locations. This parallel operation is continued for one month; the filters are exchanged weekly, and both filters are submitted for analysis in the usual manner. Monthly rotation of the extra sampler among the six locations ensures that all perimeter samplers are checked annually. The replicate samples are then compared with respect to gross alpha and beta activities and to ^{239}Pu content.

Concentrations of airborne tritium are determined for each of the Livermore-site-perimeter air-sampling locations, offsite Locations S1 and S2, and four additional Livermore Valley locations (Locations 4, 7,

Figure L-4. Air sampling locations, Livermore Valley, 1989.

9, and 17). Water vapor is trapped on silica-gel samplers operated at a flow rate of about 0.7 L/min for a two-week period. The average flow rate is calculated from the initial and final flow rates, which are measured with a rotometer that is calibrated annually, and columns are exchanged biweekly. Each sample is identified by its location, date on, date off, elapsed sampling time, and flow rate. This information is transferred to log sheets at the Livermore site, and each sample is given a serial number that accompanies it throughout the analysis. A parallel air-tritium sampler is rotated among the perimeter locations at one-month intervals, as is done for the particulate parallel sampler. The collected water is recovered by freeze-drying, and the tritiated water is measured by liquid-scintillation counting.

For beryllium measurements, every month, half of the weekly air filters from the Livermore-site-perimeter samplers are composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% HNO_3 and 20% perchloric acid (HClO_4). The solutions are then evaporated to a few milliliters, and care is taken to prevent the samples from baking dry. After the samples are diluted with water, they are filtered, any residues are discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is done by atomic absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200 ng of beryllium, and several samples spiked with essentially carrier-free ^7Be . Standards of 1, 2, and 5 g/L are prepared by diluting an intermediate 1-ppm stock solution obtained from an NIST-traceable 1000-ppm stock dilution. The diluent in all cases is 1% HNO_3 in water.

Results

Airborne Radioactivity. LLNL analyzes air filters for gross alpha and gross beta activity to ensure that releases of radionuclides other than those specifically analyzed for will be detected, and to identify trends in the LLNL environs. The values reported are similar to those observed

previously. Gross alpha and gross beta values 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 $<1 \times 10^{-15}$ $\mu\text{Ci/mL}$, and typical beta activity is 1×10^{-14} $\mu\text{Ci/mL}$. Most of the observed alpha and beta activity results from the naturally occurring radioisotopes of uranium and thorium and their decay products.

Table L-3 lists the activities of selected gamma-emitting radionuclides that normally contribute to the gross beta activity in the Livermore-site-perimeter samples. Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th are naturally occurring. The primary source of the ^{137}Cs and ^{22}Na is long-term global fallout and fallout resuspension. Other fission products are normally detectable only after such events as atmospheric nuclear tests by other nations or releases such as the Chernobyl accident. 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 the LLNL. The Derived Concentration Guides (DCGs) for these radionuclides are also presented in **Table L-3**. DCGs are concentrations of radionuclides in air (or water) that could be continuously inhaled (or consumed) 365 days of the year and not exceed the DOE primary radiation protection standard to the public of 100 mrem/y effective dose equivalent (U.S. Department of Energy 1990). (The Radiological Dose Assessment chapter provides an explanation of this and other units of dose.) Finally, the percentage of the DCGs are presented; these values demonstrate the low levels of gamma activity present at the Livermore-site perimeter.

Table L-4 shows the concentration of plutonium on air filter samples collected in the Livermore Valley. **Table L-5** shows the concentrations of airborne ^{239}Pu , ^{235}U , and ^{238}U (depleted uranium) in the Livermore-site perimeter. The Derived Concentration Guide (DCG) is based on

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the typical environmental oxide chemical form. Location 13 at the northwest perimeter of the Livermore site showed the highest concentrations of plutonium in air of the sampling locations. This sample was collected in June, when extensive airborne dust mass-loaded the high-volume air sampler filter. The dust was caused by dusty, earth-moving construction that occurred both in the immediate onsite area and also directly across the street and upwind in a housing tract construction area. The concentration measured for this sample, 4.14×10^{-17} $\mu\text{Ci/mL}$, represents 0.21% of the DCG. No other statistically significant differences between locations or samples were noted, and the overall levels determined were essentially the same as those reported in 1988. The measured concentrations of ^{238}U are less than 0.06% the derived concentration guides (U.S. Department of Energy 1990).

Table L-6 shows the average biweekly tritiated water-vapor concentrations observed at the Livermore-site-perimeter sampling locations. The highest annual mean concentrations were observed at Locations 1, 12, and 14; these concentrations were approximately 3.2×10^{-11}

$\mu\text{Ci/mL}$ or 0.03% of the DOE Derived Concentration Guide. **Table L-7** shows the average biweekly tritiated water-vapor concentrations for the Livermore Valley sampling locations. The highest annual average concentrations were observed at Locations 4 and S-2 (1.4×10^{-11} $\mu\text{Ci/mL}$); these concentrations are 0.01% of the DCG. The highest biweekly concentration was observed in August at location S-2. This concentration, 3.1×10^{-11} $\mu\text{Ci/mL}$, is 0.02% of the DCG. These values are generally lower than those reported last year.

Beryllium in Air. **Table L-8** shows average monthly concentrations of airborne beryllium for the Livermore-site-perimeter sampling locations. The concentrations, which are less than 2.6% of the monthly ambient concentration guide established by the Bay Area Air Quality Management District, can be attributed to suspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and Livermore's air typically contains 10 to 100 μg of particulates per cubic meter. By using a value of 50 $\mu\text{g}/\text{m}^3$ for an average dust load and 1 ppm for beryllium content of this dust, an airborne beryllium concentration of 5.0×10^{-5} $\mu\text{g}/\text{m}^3$ can be calculated. In view of the range of natural variation to be expected in these background values, this value is in excellent agreement with the data in **Table L-8**.

The monthly airborne beryllium concentrations for the Livermore site are plotted in **Figure L-5**. Values plotted for September through December represent the limit of detection for the contract laboratory, which modified its analytical procedures during those months. This procedure modification, which was instituted by the contract laboratory, raised the detection limit; consequently, very low values could not be determined. Although the detection limit of the new method still allows adequate analysis of data with respect to regulatory guidelines, we have requested that the previous analysis technique be reinstated. (The previous analysis technique was a graphite furnace beryllium analysis technique that has a lower limit of detection.)

Figure L-5. Monthly mean concentration of beryllium on air filters, Livermore-site perimeter, 1989.

Effluent Releases

Radioactive Effluents. In 1989, a total of 2951.8 Ci of tritium were released to the atmosphere from operations at LLNL. Of the 2951.8 Ci, approximately 1554.4 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 on the order of 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. Releases of the short-lived radionuclides ^{13}N and ^{15}O from Building 194 (the electron-positron linear accelerator) totalled 42 Ci. Comparative releases of radioactive effluents at LLNL during the 9-year period from 1981 through 1989 are shown in **Table L-9**. The radioactive emissions from LLNL operations during 1989 were within the range of previous years.

Of the 2951.8 Ci of tritium discharged to the atmosphere by LLNL in 1989, 2949.4 Ci came from the Tritium Facility (Building 331). The highest single weekly emission from the facility was 329 Ci of tritium gas during the week of August 22, 1989. Resulting doses from tritium were significantly below DOE guidelines. Nonetheless, because of LLNL and DOE policies to keep emissions as low as reasonably achievable (ALARA), the Tritium Facility received two major effluent-control upgrades in 1989. The Vacuum Effluent Recovery System (VERS) is designed to recover up to 90% of the present stack tritium emission. The Secondarily Contained Tritium System (SCOTS) is designed to

capture any accidental release involving large quantities of tritium.

Nonradioactive Effluents. During 1989 at the Livermore site, the total cumulative emissions from permitted equipment that evaporate organic nonprecursor compounds (chlorofluorocarbons, 1,1,1-trichloroethane, methylene chloride), were approximately 135 pounds per day. The estimated cumulative emissions from organic precursor compounds (all solvents except those listed above) were 35 pounds per day. Organic precursors are materials that change composition after being emitted into air and can contribute to the formation of smog. Abatement devices, which minimize air pollutants, are now installed on all units first operating in 1988 or later that emit nonprecursor solvents. These abatement devices meet Bay Area Air Quality Management District criteria for best available control technology.

Table L-2 lists the estimated release for organic precursor and nonprecursor compounds and other airborne emissions. The release of air pollutants at the Livermore site can be contrasted to the 1988 estimated daily release of air pollutants for the entire Bay Area. For example, the total organic precursor release of perchloroethylene from dry cleaning operations is estimated at 11 200 pounds per day versus LLNL's 35 pounds (0.3%) per day, which includes perchloroethylene. The evaporation of organic nonprecursor solvents (used in degreasers) is 8200 pounds, versus 135 pounds (1.6%) daily for LLNL. A summary of nonradioactive emissions in the San Francisco Bay Area is provided in **Table L-10**.

Table L-2. Nonradioactive airborne emissions, Livermore site.

Pollutant	Estimated release (tons/day)	Percent of total Bay Area emissions ^a
Particulates	0.0014	0.0002
Organic compounds	0.0852	0.0070
Oxides of sulfur	0.00033	0.0003
Oxides of nitrogen	0.0549	0.0118
Carbon monoxide	0.0110	0.0005
Chlorofluorocarbons	0.0705	0.0136

^aSee BAAQMD 1989.

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Table L-3. Gamma activity on air filters—Livermore-site perimeter, 1989.^a

	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na	²²⁶ Ra	²²⁸ Ra	²²⁸ Th	¹²⁵ Sb	¹⁰⁶ Ru	¹⁴⁴ Ce	⁶⁰ Co
Month	[10 ⁻¹³ μCi/mL ± 2σ (%)]			[10 ⁻¹⁶ μCi/mL ± 2σ (%)]							
Jan.	0.57 ± 2	<0.94	<0.03	<0.03	0.14 ± 98	<0.40	<0.08	<0.10	<0.26	<0.22	<0.034
Feb.	1.17 ± 2	3.46 ± 67	0.09 ± 70	<0.04	— ^b	— ^b	<0.10	<0.12	<0.29	<0.29	<0.018
Mar.	0.78 ± 2	2.92 ± 75	0.07 ± 68	<0.03	0.20 ± 74	0.72 ± 36	<0.08	<0.09	<0.24	<0.22	<0.030
Apr.	1.16 ± 2	5.54 ± 47	<0.04	0.11 ± 66	— ^b	0.67 ± 47	<0.11	<0.13	<0.36	<0.31	<0.043
May	0.86 ± 2	4.82 ± 47	<0.04	<0.10	— ^b	0.73 ± 48	<0.10	<0.12	<0.33	<0.28	<0.045
June	0.84 ± 2	5.72 ± 34	0.12 ± 63	0.16 ± 49	0.23 ± 53	0.72 ± 37	<0.09	<0.10	<0.27	<0.24	<0.037
July	0.70 ± 2	6.78 ± 26	<0.03	<0.03	0.28 ± 42	0.58 ± 37	<0.08	<0.09	<0.26	<0.19	0.091 ± 55
Aug.	0.70 ± 2	7.59 ± 25	<0.04	<0.04	0.42 ± 48	0.76 ± 37	<0.09	<0.11	<0.29	<0.22	0.151 ± 44
Sept.	1.03 ± 2	5.02 ± 51	0.16 ± 53	<0.04	0.28 ± 49	0.63 ± 45	<0.11	<0.12	<0.32	<0.30	<0.044
Oct.	1.50 ± 2	6.68 ± 53	<0.05	0.13 ± 69	0.70 ± 38	0.82 ± 58	<0.17	<0.16	<0.39	<1.07	<0.041
Nov.	1.21 ± 2	6.58 ± 36	0.11 ± 62	<0.04	— ^b	0.43 ± 64	4.31 ± 46	<0.11	<0.29	<0.29	<0.037
Dec.	0.73 ± 6	<0.81	<0.03	<0.04	— ^b	— ^b	2.71 ± 15	<0.12	<0.29	<0.27	<0.033
Mean	0.94	4.74	0.05 ^c	0.04 ^c	0.28 ^c	0.64	0.10 ^c	0.11 ^c	0.29 ^c	0.27 ^c	0.039 ^c
SDM (%)	29	48	33 ^d	14 ^d	30 ^d	21	18 ^d	11 ^d	10 ^d	12 ^d	14 ^d
DCG (μCi/mL)	4 × 10 ⁻⁸	9 × 10 ⁻¹⁰	4 × 10 ⁻¹⁰	1 × 10 ⁻⁹	1 × 10 ⁻¹²	3 × 10 ⁻¹²	4 × 10 ⁻¹⁴	6 × 10 ⁻⁹	3 × 10 ⁻¹¹	3 × 10 ⁻¹¹	8 × 10 ⁻¹¹
Percent of DCG	2 × 10 ⁻⁴	5 × 10 ⁻⁵	1 × 10 ⁻⁶	4 × 10 ⁻⁷	3 × 10 ⁻³	2 × 10 ⁻³	3 × 10 ⁻²	2 × 10 ⁻⁷	1 × 10 ⁻⁴	9 × 10 ⁻⁵	5 × 10 ⁻⁶

^a All Livermore-site perimeter samples composited.

^b No data reported by testing laboratory.

^c Median. See Quality Assurance chapter.

^d Median absolute deviation. See Quality Assurance chapter.

Table L-4. Plutonium-239 on air filters—Livermore Valley, 1989.

	Sampling location ^a						
	3	4	8	10	16	17	6
Month	[10 ⁻¹⁷ μCi/mL ± 2σ (%)]						
Jan.	0.011 ± 98	0.030 ± 50	<0.011	0.010 ± 98	0.146 ± 28	<0.005	0.033 ± 74
Feb.	0.025 ± 68	0.089 ± 3 ^c	0.011 ± 98	0.016 ± 68	0.049 ± 58	0.021 ± 78	0.026 ± 84
Mar.	0.024 ± 70	0.023 ± 72	0.013 ± 76	0.046 ± 54	0.030 ± 66	0.040 ± 58	0.020 ± 74
Apr.	0.027 ± 80	0.040 ± 58	0.032 ± 60	0.012 ± 88	0.029 ± 70	0.043 ± 54	0.021 ± 90
May	<0.010	0.058 ± 46	<0.017	0.022 ± 76	0.039 ± 60	0.039 ± 52	0.025 ± 70
June	<0.0005	— ^b	0.013 ± 82	0.024 ± 72	0.038 ± 60	0.039 ± 57	<0.012
July	<0.026	0.041 ± 55	0.021 ± 89	0.014 ± 87	0.058 ± 70	0.028 ± 70	0.017 ± 82
Aug.	<0.009	0.021 ± 76	0.021 ± 84	0.023 ± 66	0.047 ± 52	0.039 ± 60	0.019 ± 76
Sept.	0.028 ± 68	0.434 ± 52	0.040 ± 70	0.016 ± 92	0.020 ± 74	0.046 ± 57	0.022 ± 88
Oct.	0.019 ± 94	0.060 ± 50	0.029 ± 64	0.031 ± 68	0.100 ± 38	0.036 ± 48	0.023 ± 82
Nov.	0.063 ± 62	0.029 ± 66	0.054 ± 70	0.033 ± 62	0.051 ± 60	<0.009	<0.004
Dec.	<0.013	0.018 ± 84	0.019 ± 84	0.017 ± 90	0.033 ± 66	0.032 ± 60	0.030 ± 60
Mean	0.0215 ^d	0.077	0.023	0.022	0.053	0.031	0.021
SDM (%)	35 ^e	156	57	47	67	43	37
Percent of DCG ^c	0.001	0.004	0.001	0.001	0.003	0.002	0.001

^a See Fig. L-4 for sampling locations. Location 6 is in the City of Tracy.

^b No data available for this sample, see Quality Assurance chapter.

^c DCG for plutonium in air equals 4 × 10⁻¹⁴ μCi/mL or 4 × 10⁻² pCi/m³.

^d Median, see Quality Assurance chapter.

^e Median absolute deviation, see Quality Assurance chapter.

Table L-5. Plutonium and uranium on air filters—Livermore-site perimeter, 1989.

Month	Location ^a	²³⁹ Pu ^b [10 ⁻¹⁷ µCi/mL]	²³⁸ U [10 ⁻⁵ µg/m ³]	²³⁵ U [10 ⁻⁷ µg/m ³]	²³⁵ U/ ²³⁸ U [10 ⁻³]
Jan.	1	0.068 ± 38	2.10	1.48	7.05
	2	0.037 ± 57	1.98	1.40	7.07
	12	0.057 ± 44	3.08	2.15	6.98
	13	0.025 ± 67	1.51	1.05	6.95
	14	0.044 ± 47	1.50	1.07	7.13
	15	0.011 ± 98	2.79	1.97	7.06
Feb.	1	0.105 ± 31	4.03	3.26	8.09
	2	0.011 ± 99	7.90	3.03	3.84
	12	0.095 ± 39	13.9	5.96	4.29
	13	0.031 ± 73	13.5	4.63	3.43
	14	0.050 ± 57	6.33	2.39	3.79
	15	0.015 ± 77	10.2	4.97	4.87
Mar.	1	0.045 ± 43	1.77	1.24	7.01
	2	0.024 ± 61	1.97	1.38	7.01
	12	0.068 ± 38	4.86	3.45	7.10
	13	0.016 ± 78	2.11	1.49	7.06
	14	0.021 ± 71	1.50	1.01	6.73
	15	0.043 ± 49	5.91	4.27	7.24
Apr.	1	0.121 ± 37	2.96	2.09	7.06
	2	0.028 ± 90	3.03	2.14	7.06
	12	0.078 ± 51	6.01	4.28	7.12
	13	0.060 ± 66	7.44	5.36	7.20
	14	0.023 ± 95	2.59	1.86	7.18
	15	0.020 ± 98	5.90	4.21	7.14
May	1	0.274 ± 23	4.77	3.36	7.04
	2	0.046 ± 58	3.68	2.60	7.07
	12	0.069 ± 42	5.54	3.84	6.93
	13	0.043 ± 59	6.68	4.77	7.14
	14	0.039 ± 75	2.94	2.07	7.04
	15	0.042 ± 55	6.22	4.35	6.99
June	1	0.334 ± 29	7.83	5.43	6.93
	2	0.066 ± 61	5.81	4.11	7.07
	12	0.051 ± 59	7.52	5.26	6.99
	13	4.14 ± 8	11.5	8.21	7.14
	14	0.066 ± 53	4.07	2.87	7.05
	15	0.038 ± 63	7.34	5.17	7.04
July	1	0.121 ± 35	7.73	5.50	7.12
	2	0.413 ± 21	6.37	4.54	7.13
	12	0.083 ± 42	8.79	6.24	7.10
	13	0.051 ± 52	13.7	9.79	7.15
	14	0.069 ± 52	5.23	3.72	7.11
	15	0.036 ± 61	6.91	4.91	7.11
Aug.	1	0.137 ± 45	9.66	6.73	6.97
	2	0.291 ± 38	7.63	5.37	7.04
	12	0.096 ± 48	10.4	7.23	6.95
	13	0.054 ± 63	17.1	12.1	7.05
	14	0.092 ± 80	4.77	3.35	7.02
	15	0.064 ± 61	8.79	5.68	6.46

...continued

**Table L-5. Plutonium and uranium on air filters—Livermore-site perimeter, 1989
(concluded).**

Month	Location ^a	²³⁹ Pu ^b	²³⁸ U	²³⁵ U	²³⁵ U/ ²³⁸ U				
		[10 ⁻¹⁷ µCi/mL]	[10 ⁻⁵ µg/m ³]	[10 ⁻⁷ µg/m ³]	[10 ⁻³]				
Sept.	1	0.414 ± 25	9.48	6.67	7.04				
	2	0.140 ± 42	7.29	5.21	7.15				
	12	0.081 ± 52	7.47	5.26	7.04				
	13	0.039 ± 71	11.2	8.03	7.17				
	14	0.055 ± 54	4.70	3.36	7.15				
	15	0.026 ± 63	6.25	4.34	6.94				
Oct.	1	0.251 ± 26	6.35	4.46	7.02				
	2	0.277 ± 33	12.2	8.71	7.14				
	12	0.103 ± 45	7.27	5.08	6.99				
	13	0.049 ± 71	10.1	7.23	7.16				
	14	0.036 ± 90	4.69	3.33	7.10				
	15	0.030 ± 71	5.97	4.27	7.15				
Nov.	1	1.35 ± 12	9.74	6.93	7.12				
	2	0.164 ± 36	7.43	5.27	7.09				
	12	0.044 ± 76	8.25	5.79	7.02				
	13	0.077 ± 57	6.13	4.38	7.15				
	14	0.061 ± 76	3.50	2.53	7.23				
	15	0.068 ± 49	6.49	4.63	7.13				
Dec.	1	0.457 ± 17	5.98	4.21	7.04				
	2	0.004 ± 200	3.89	2.76	7.10				
	12	0.068 ± 41	3.79	2.70	7.12				
	13	0.034 ± 49	4.14	2.96	7.15				
	14	0.058 ± 50	3.50	2.46	7.03				
	15	0.040 ± 54	5.92	4.23	7.15				
Annual mean									
Location	²³⁹ Pu			²³⁸ U			²³⁵ U		
	10 ⁻¹⁷ µCi/mL	SDM (%)	% of DCG ^c	10 ⁻⁵ µg/m ³	SDM (%)	% of DCG ^d	10 ⁻⁷ µg/m ³	SDM (%)	% of DCG ^e
1	0.306	116	0.015	6.03	48	0.020	4.28	47	0.001
2	0.125	108	0.006	5.77	52	0.019	3.88	54	0.001
12	0.074	25	0.004	7.24	41	0.024	4.77	32	0.001
13	0.385	307	0.019	8.76	56	0.029	5.83	57	0.001
14	0.051	40	0.003	3.77	39	0.013	2.50	35	0.001
15	0.036	49	0.002	6.56	27	0.022	4.42	20	0.001

^a See Fig. L-3.

^b In all tables, activity listed as ²³⁹Pu includes activity due to ²⁴⁰Pu.

^c DCG = 2×10^{-14} µCi/mL for ²³⁹Pu activity in air.

^d DCG = $0.3 \mu\text{g}/\text{m}^3$ for ²³⁸U activity in air (1×10^{-13} µCi/mL).

^e DCG = $0.047 \mu\text{g}/\text{m}^3$ for ²³⁵U activity in air (1×10^{-13} µCi/mL).

Table L-6. Tritium in air—Livermore-site perimeter, 1989.

Month	Sampling location ^a					
	1	2	12	13	14	15
	[10 ⁻¹¹ μ Ci/mL $\pm$ 2 σ (%)]					
Jan.	2.4 $\pm$ 4	1.4 $\pm$ 7	3.3 $\pm$ 4	0.9 $\pm$ 12	2.1 $\pm$ 5	1.2 $\pm$ 9
	1.4 $\pm$ 6	1.3 $\pm$ 7	3.4 $\pm$ 3	0.7 $\pm$ 12	1.3 $\pm$ 6	1.0 $\pm$ 8
				0.6 $\pm$ 12		
				1.0 $\pm$ 8		
Feb.	2.8 $\pm$ 4	2.7 $\pm$ 4	3.3 $\pm$ 3	0.8 $\pm$ 7	2.2 $\pm$ 4	1.6 $\pm$ 6
	1.5 $\pm$ 5	1.2 $\pm$ 8	1.8 $\pm$ 5	1.1 $\pm$ 7	1.3 $\pm$ 7	1.4 $\pm$ 7
				0.3 $\pm$ 14		
				0.4 $\pm$ 16		
Mar.	4.1 $\pm$ 3	2.0 $\pm$ 6	3.5 $\pm$ 4	— ^b	2.3 $\pm$ 5	2.7 $\pm$ 5
	3.6 $\pm$ 5	2.1 $\pm$ 8	9.4 $\pm$ 3	0.7 $\pm$ 16	5.0 $\pm$ 4	4.0 $\pm$ 6
	2.7 $\pm$ 5	1.4 $\pm$ 10	2.9 $\pm$ 5	1.7 $\pm$ 8	3.5 $\pm$ 4	2.5 $\pm$ 5
				— ^b		2.3 $\pm$ 6
Apr.						— ^b
	3.3 $\pm$ 5	5.3 $\pm$ 3	4.8 $\pm$ 3	0.9 $\pm$ 12	2.1 $\pm$ 6	1.8 $\pm$ 7
	2.3 $\pm$ 6	0.9 $\pm$ 15	1.7 $\pm$ 8	0.2 $\pm$ 35	3.6 $\pm$ 4	1.5 $\pm$ 7
						1.1 $\pm$ 10
May						1.1 $\pm$ 10
	2.6 $\pm$ 5	2.5 $\pm$ 6	2.3 $\pm$ 6	0.6 $\pm$ 19	2.6 $\pm$ 5	1.6 $\pm$ 8
	2.5 $\pm$ 5	0.8 $\pm$ 14	1.0 $\pm$ 11	0.7 $\pm$ 15	2.6 $\pm$ 5	1.5 $\pm$ 8
						2.3 $\pm$ 6
June						1.7 $\pm$ 6
	2.5 $\pm$ 5	1.2 $\pm$ 10	2.3 $\pm$ 5	0.5 $\pm$ 17	2.9 $\pm$ 4	1.6 $\pm$ 7
	2.6 $\pm$ 4	1.5 $\pm$ 7	2.2 $\pm$ 5	0.6 $\pm$ 16	3.3 $\pm$ 4	1.3 $\pm$ 8
						1.4 $\pm$ 8
July						1.2 $\pm$ 8
	2.7 $\pm$ 4	— ^b	1.9 $\pm$ 6	0.6 $\pm$ 16	3.0 $\pm$ 4	1.1 $\pm$ 10
	4.1 $\pm$ 4	0.3 $\pm$ 30	1.4 $\pm$ 8	0.2 $\pm$ 64	2.9 $\pm$ 4	2.3 $\pm$ 6
					5.8 $\pm$ 3	
Aug.					6.0 $\pm$ 3	
	4.0 $\pm$ 4	1.1 $\pm$ 11	1.3 $\pm$ 9	0.5 $\pm$ 23	5.3 $\pm$ 3	2.7 $\pm$ 5
	9.6 $\pm$ 2	1.8 $\pm$ 5	2.6 $\pm$ 5	0.6 $\pm$ 14	5.6 $\pm$ 3	2.2 $\pm$ 5
	4.3 $\pm$ 4	1.3 $\pm$ 10	1.9 $\pm$ 7	0.5 $\pm$ 25	4.4 $\pm$ 3	2.4 $\pm$ 6
	4.7 $\pm$ 4				4.1 $\pm$ 3	
					3.4 $\pm$ 4	

...continued

Table L-6. Tritium in air—Livermore-site perimeter, 1989 (concluded).

Month	Sampling location ^a					
	1	2	12	13	14	15
	[10 ⁻¹¹ μ Ci/mL $\pm$ 2 σ (%)]					
Sept.	5.1 $\pm$ 3	2.7 $\pm$ 5	4.0 $\pm$ 3	0.5 $\pm$ 16	3.8 $\pm$ 3	2.2 $\pm$ 5
	5.6 $\pm$ 3	2.8 $\pm$ 6	4.0 $\pm$ 4	1.4 $\pm$ 11	3.3 $\pm$ 5	2.5 $\pm$ 6
	2.6 $\pm$ 5					
	3.6 $\pm$ 5					
Oct.	3.3 $\pm$ 4	6.8 $\pm$ 3	7.7 $\pm$ 2	0.7 $\pm$ 9	3.6 $\pm$ 4	1.8 $\pm$ 7
	3.5 $\pm$ 4	4.0 $\pm$ 4	3.7 $\pm$ 4	1.5 $\pm$ 10	3.8 $\pm$ 4	1.9 $\pm$ 8
	3.2 $\pm$ 5		4.0 $\pm$ 4			
Nov.	2.0 $\pm$ 5	4.3 $\pm$ 3	4.0 $\pm$ 3	1.1 $\pm$ 7	1.7 $\pm$ 6	1.3 $\pm$ 7
	1.0 $\pm$ 9	2.4 $\pm$ 5	4.2 $\pm$ 3	1.3 $\pm$ 8	1.0 $\pm$ 9	1.2 $\pm$ 8
			2.0 $\pm$ 5			
			2.0 $\pm$ 5			
Dec.	1.4 $\pm$ 7	1.8 $\pm$ 5	3.2 $\pm$ 3	1.4 $\pm$ 9	1.8 $\pm$ 7	1.1 $\pm$ 12
	2.0 $\pm$ 4	1.6 $\pm$ 5	2.3 $\pm$ 5	1.4 $\pm$ 6	1.8 $\pm$ 5	1.5 $\pm$ 6
		2.2 $\pm$ 7	— ^b			
Mean ^c	3.2	2.2	3.2	0.8	3.2	1.8
SDM (%)	51	67	57	50	43	37
Percent of DCG ^d	0.032	0.022	0.032	0.008	0.032	0.018
Dose (mrem) ^e	2.6 $\times$ 10 ⁻²	1.8 $\times$ 10 ⁻²	2.5 $\times$ 10 ⁻²	0.6 $\times$ 10 ⁻²	2.5 $\times$ 10 ⁻²	1.4 $\times$ 10 ⁻²

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

^b No data. See Quality Assurance chapter.

^c Livermore-site-perimeter overall average is 2.4 $\times$ 10⁻¹¹ μ Ci/mL.

^d DCG = 1 $\times$ 10⁻⁷ μ Ci/mL.

^e This dose is the effective dose equivalent. It was calculated from the annual average.

Table L-7. Tritium in air—Livermore Valley, 1989.

Month	Sampling location ^a					
	04	07	09	17	S-1	S-2
	[10 ⁻¹¹ μ Ci/mL $\pm$ 2 σ (%)]					
Jan.	0.9 $\pm$ 9	0.9 $\pm$ 11	0.2 $\pm$ 31	0.6 $\pm$ 15	0.9 $\pm$ 11	1.6 $\pm$ 6
	0.7 $\pm$ 11	0.4 $\pm$ 19	0.3 $\pm$ 23	0.6 $\pm$ 13	0.5 $\pm$ 15	1.3 $\pm$ 7
Feb.	1.2 $\pm$ 7	0.5 $\pm$ 14	0.8 $\pm$ 11	1.1 $\pm$ 9	1.2 $\pm$ 8	2.3 $\pm$ 5
	0.8 $\pm$ 9	0.5 $\pm$ 15	0.4 $\pm$ 20	0.6 $\pm$ 15	0.4 $\pm$ 17	2.0 $\pm$ 5
Mar.	1.5 $\pm$ 8	0.8 $\pm$ 14	0.4 $\pm$ 24	0.6 $\pm$ 16	0.8 $\pm$ 13	1.7 $\pm$ 7
	1.9 $\pm$ 8	1.3 $\pm$ 13	1.0 $\pm$ 13	1.4 $\pm$ 11	1.9 $\pm$ 8	2.0 $\pm$ 7
	1.6 $\pm$ 7	0.6 $\pm$ 18	0.6 $\pm$ 17	0.5 $\pm$ 21	0.9 $\pm$ 12	1.3 $\pm$ 10
Apr.	0.8 $\pm$ 11	0.4 $\pm$ 21	0.4 $\pm$ 21	1.3 $\pm$ 8	0.4 $\pm$ 21	2.3 $\pm$ 5
	— ^b	0.4 $\pm$ 29	0.1 $\pm$ 90	0.2 $\pm$ 67	0.5 $\pm$ 25	0.4 $\pm$ 31
May	1.1 $\pm$ 10	0.7 $\pm$ 17	0.2 $\pm$ 55	0.5 $\pm$ 21	0.5 $\pm$ 19	1.2 $\pm$ 10
	0.8 $\pm$ 11	0.6 $\pm$ 15	0.5 $\pm$ 20	0.4 $\pm$ 24	0.6 $\pm$ 16	0.6 $\pm$ 19
June	1.0 $\pm$ 10	0.3 $\pm$ 33	0.1 $\pm$ 100	0.5 $\pm$ 22	0.4 $\pm$ 19	0.9 $\pm$ 13
	1.4 $\pm$ 7	0.3 $\pm$ 26	0.2 $\pm$ 33	0.2 $\pm$ 30	0.7 $\pm$ 13	0.8 $\pm$ 10
July	1.1 $\pm$ 10	0.4 $\pm$ 26	0.2 $\pm$ 47	0.5 $\pm$ 16	0.7 $\pm$ 15	0.9 $\pm$ 12
	2.7 $\pm$ 5	0.3 $\pm$ 30	0.1 $\pm$ 100	0.1 $\pm$ 100	0.5 $\pm$ 17	0.3 $\pm$ 29
Aug.	2.3 $\pm$ 5	0.7 $\pm$ 17	0.1 $\pm$ 100	0.1 $\pm$ 100	0.6 $\pm$ 17	0.4 $\pm$ 29
	3.0 $\pm$ 4	0.5 $\pm$ 14	0.3 $\pm$ 26	0.4 $\pm$ 14	2.7 $\pm$ 5	1.5 $\pm$ 7
	1.9 $\pm$ 6	0.5 $\pm$ 19	0.2 $\pm$ 66	0.3 $\pm$ 26	0.7 $\pm$ 14	0.9 $\pm$ 13
Sept.	1.7 $\pm$ 7	0.6 $\pm$ 14	0.4 $\pm$ 24	0.8 $\pm$ 12	0.9 $\pm$ 11	1.9 $\pm$ 7
	1.9 $\pm$ 8	0.6 $\pm$ 21	0.4 $\pm$ 36	0.8 $\pm$ 20	0.9 $\pm$ 15	1.6 $\pm$ 10
Oct.	1.3 $\pm$ 9	0.6 $\pm$ 17	0.9 $\pm$ 11	1.7 $\pm$ 7	0.6 $\pm$ 8	3.1 $\pm$ 4
	1.8 $\pm$ 8	0.5 $\pm$ 26	0.5 $\pm$ 22	1.0 $\pm$ 15	0.7 $\pm$ 17	1.5 $\pm$ 9
Nov.	0.9 $\pm$ 10	0.4 $\pm$ 19	0.5 $\pm$ 13	1.4 $\pm$ 7	0.4 $\pm$ 17	2.5 $\pm$ 4
	0.7 $\pm$ 12	0.2 $\pm$ 27	0.5 $\pm$ 17	1.2 $\pm$ 12	0.4 $\pm$ 19	1.6 $\pm$ 7
Dec.	1.0 $\pm$ 12	0.5 $\pm$ 19	0.8 $\pm$ 13	0.9 $\pm$ 14	0.8 $\pm$ 13	1.3 $\pm$ 8
	0.9 $\pm$ 8	0.6 $\pm$ 12	0.5 $\pm$ 14	0.9 $\pm$ 9	1.1 $\pm$ 6	1.8 $\pm$ 5
Mean ^c	1.4	0.5	0.4	0.7	0.8	1.4
SDM (%)	45	41	62	61	64	48
Percent of DCG ^d	1 $\times$ 10 ⁻²	5 $\times$ 10 ⁻³	4 $\times$ 10 ⁻³	7 $\times$ 10 ⁻³	8 $\times$ 10 ⁻³	1 $\times$ 10 ⁻²
Dose (mrem) ^e	1.1 $\times$ 10 ⁻²	0.4 $\times$ 10 ⁻²	0.3 $\times$ 10 ⁻²	0.6 $\times$ 10 ⁻²	0.6 $\times$ 10 ⁻²	1.2 $\times$ 10 ⁻²

^a See Fig. L-4 for sampling locations.^b No data. See Quality Assurance chapter.^c Livermore Valley overall average = 0.9 $\times$ 10⁻¹¹ μ Ci/mL.^d DCG = 1 $\times$ 10⁻⁷ μ Ci/mL.^e This dose is the effective dose equivalent. It was calculated from the annual average.

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Table L-8. Beryllium on air filters—Livermore-site perimeter, 1989.

Beryllium concentration				Beryllium concentration			
Month	Location ^a	10 ⁻⁵ µg/m ³	Percent of BAAQMD monthly standard ^b	Month	Location ^a	10 ⁻⁵ µg/m ³	Percent of BAAQMD monthly standard ^b
Jan.	1	2.6	0.3	Aug.	1	2.3	0.2
	2	2.5	0.2		2	6.0	0.6
	12	3.1	0.3		12	7.5	0.7
	13	1.8	0.2		13	13.2	1.3
	14	1.3	0.1		14	3.8	0.4
	15	4.5	0.4		15	5.6	0.6
Feb.	1	2.0	0.2	Sept. ^d	1	<5.2	<0.5
	2	3.0	0.3		2	<5.7	<0.6
	12	6.3	0.6		12	<7.8	<0.8
	13	2.7	0.3		13	<4.8	<0.5
	14	1.3	0.1		14	<7.1	<0.7
	15	3.4	0.3		15	<2.9	<0.3
Mar.	1	5.4	0.5	Oct. ^d	1	<5.9	<0.6
	2	6.5	0.6		2	<8.9	<0.9
	12	4.7	0.5		12	<7.8	<0.8
	13	4.0	0.4		13	<8.4	<0.8
	14	7.4	0.7		14	<11.8	<1.2
	15	3.1	0.3		15	<4.8	<0.5
Apr.	1	1.0	0.1	Nov. ^d	1	<16	<1.6
	2	0.4	0.04		2	<23	<2.3
	12	0.9	0.09		12	<21	<2.1
	13	1.0	0.1		13	<16	<1.6
	14	1.9	0.2		14	<26	<2.6
	15	0.7	0.07		15	<26	<2.6
May	1	4.2	0.4	Dec. ^d	1	<5.5	<0.5
	2	1.2	0.1		2	<5.5	<0.5
	12	1.1	0.1		12	<5.5	<0.5
	13	1.0	0.1		13	<5.7	<0.6
	14	— ^c	— ^c		14	<5.5	<0.5
	15	0.4	0.04		15	<5.5	<0.5
June	1	4.5	0.4	Annual median			
	2	3.8	0.4	Location ^a	10 ⁻⁵ µg/m ³		MAD(%) ^e
	12	3.9	0.4				
	13	5.8	0.6				
	14	2.9	0.3				
	15	3.2	0.3				
July	1	2.1	0.2		1	4.4	
	2	3.0	0.3	2	4.7	38	
	12	1.3	0.1	12	5.2	47	
	13	2.6	0.3	13	4.4	50	
	14	1.9	0.2	14	3.8	66	
	15	2.6	0.3	15	3.3	41	

^a See Fig. L-3.

^b Ambient monthly concentration guide set by the Bay Area Air Quality Management District (BAAQMD) is 0.01 µg/m³ (1000 × 10⁻⁵ mg/m³).

^c Sample lost in analytical digestion process.

^d Beginning in September, the analytical laboratory changed analysis techniques.

^e Median absolute deviation. See Quality Assurance chapter.

Table L-9. Radioactive airborne effluent releases from the Livermore site, 1981-1989.

Year	Airborne effluents (Ci)	
	^3H	^{13}N and ^{15}O
1981	2619	344
1982	2014	584
1983	3245	855
1984	7354	81
1985	2204	520
1986	1254	113
1987	2751	62
1988	3983	30
1989	2952	42

Table L-10. Summary of nonradioactive emissions in the San Francisco Bay Area, total, and by industry category.^a

Emissions by source category (tons/day) — 1987 annual average ^b						
	Part ^c	TOG ^d	ROG ^e	NOX ^f	SO ₂	CO
Petroleum refining	4.2	45.4	37.2	43.8	51.4	7.3
Fuels — bulk loading	—	2.9	2.9	—	—	—
Fuels — filling stations	—	6.9	6.9	—	—	—
Structures coating	—	35.3	35.3	—	—	—
Other coating and printing	—	56.2	50.0	—	—	—
Solvent degreasing	—	11.5	7.4	—	—	—
Dry cleaners	—	5.7	5.6	—	—	—
Rubber, plastic products mfg.	—	3.2	3.2	—	—	—
Other solvent usage	—	9.2	8.8	—	—	—
Chemical mfg.	1.9	3.4	1.6	1.1	4.1	25.6
Metallurgical and mineral ind.	32.8	1.8	—	0.1	1.3	2.8
Construction and demolition	122	—	—	—	—	—
Gas distribution	—	159	16.6	—	—	—
Other industrial/commercial	31.4	12.1	7.3	2.8	3.3	—
Domestic fuel usage	25.9	11.6	9.8	21	0.8	125
Commercial fuel usage	0.2	0.5	0.3	6.3	0.7	1.1
Industrial fuel usage	1.1	3.2	1.8	39.8	4	13.9
Electrical generating plants	0.5	0.3	0.2	30.8	0.4	6.3
Waste burning and incineration	1.1	0.9	0.2	0.9	0.3	3.1
Domestic reciprocating engine	0.1	2.9	2.8	0.4	—	26.4
Other reciprocating engines	4.1	9.5	6.7	16.4	1	79.4
Farm and const. equipment	1.3	4.1	4	20	1.8	44.6
Ships	0.9	17.6	16.1	10	16.5	72
Locomotives	0.4	1.7	1.6	5	0.7	1.8
Sub-total (district jurisdiction)	228	405	226	198	86.5	409
Aircraft	2.5	19.7	18.1	16.6	1.6	84.4
Cars and light duty trucks	20.8	162	143	125	4	1190
Medium duty gas vehicles	5.9	43.6	40.6	43.6	1.8	353
Heavy duty gas vehicles	1.2	17.9	16.8	19.9	0.9	284
Diesel buses and trucks	12.3	11.7	11.1	60.8	12	30.9
Motorcycles	0.1	4.3	3.9	0.9	—	14.2
Sub-total (mobile sources)	42.8	260	233	267	20.3	1950
Accidental fires	7.5	3.4	3.1	0.5	—	30.8
Vegetation	—	— ^g	—	—	—	—
Paved and unpaved roads	509	—	—	—	—	—
Bio degradation	—	503	4	—	—	—
Consumer solvent usage	—	47.8	47.8	—	—	—
Pesticide usage	—	4.2	4.2	—	—	—
Sub-total (other sources)	517	558	59.1	0.5	—	30.8
Total emissions	787	1220	518	466	107	2390

^a Source: Bay Area Air Quality Management District Air Quality Handbook, 1989-1990.

^b Projections based on the 1983 Source Inventory.

^c Particulates.

^d Total organic compounds.

^e Reactive organic compounds.

^f Nitrogen oxides.

^g Vegetation emissions are about 320 tons/day (estimated by the Association of Bay Area Governments for BAAQMD).

Introduction

The Livermore site discharges approximately 358 000 gallons per day of wastewater to the City of Livermore sewer system; this constitutes about 10% of the total flow to the system. This volume is due to the discharges of both LLNL and SNLL. SNLL discharges to the LLNL collection system; the sewage 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 (from both LLNL and SNLL) 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 the San Francisco Bay. A small portion of the treated effluent from the LWRP is used for summer irrigation of the municipal golf course, which is adjacent to the LWRP. Sludge from the treatment process is disposed of in landfills.

Administrative and engineering controls at the Livermore site prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Wastewater is collected and monitored at several different points from its generation to its release to the municipal collection system. Moreover, personnel who generate waste receive training about the materials that are permitted to be released.

Potentially contaminated wastewater is collected in retention tanks at the facility where it is generated before the wastewater is released to the LLNL collection system. Then, the contents of the tanks are analyzed. The liquids are discharged to the sanitary sewer only if laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). If liquid effluents exceed permissible pollutant levels, they are treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or they are shipped to an offsite treatment or disposal facility. These sewer guidelines have been developed by LLNL for specific sources and operations to ensure that sewer effluent for the entire

site complies with LLNL's waste discharge permit. Radioactive materials in the waste are reduced to levels well below DOE (U.S. Department of Energy 1990) and LWRP discharge limits. (The discharge limits of LWRP, DOE, the Nuclear Regulatory Commission (NRC), and Title 17 of the *California Code of Regulations* are reproduced at the end of this chapter.)

In addition, the outflow to the municipal collection system is sampled continuously and analyzed for compliance with the discharge permit and for conditions that may upset the LWRP treatment process or impact public health. An on-line monitoring system that provides real-time information and a flow proportional sampler are located at the outfall from the Livermore site. The effluent is continuously monitored for pH, selected metals, and radioactivity. If warning levels are exceeded, an alarm is registered at the LLNL Fire Dispatchers Station, which is attended 24 hours a day. A sanitary sewer spill plan and a trained response team have been established to minimize effects of a spill, should one occur. The monitoring system provides a continuous

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check on sewage control and includes provisions for the timely notification of LWRP of any exceedance of regulatory standards.

LLNL has upgraded the existing liquid effluent outflow monitoring system. There are five goals for this upgrade: to improve the ability to identify specific metals and the sensitivity of metals detection, to provide on-line identification of radioisotopes detected at or below the DOE discharge limits, to reduce the number of false alarms, to reduce the instrument response time, and to improve the system reliability. The key to this new monitoring system is a computerized data-acquisition and analysis system. The data-acquisition system is connected to the radiation detector, three x-ray fluorescence systems, a pH meter, and a flow meter. The computer acquires and processes data from the radiation detectors and from pH and flow sensors, then analyzes the results to determine if alarm levels have been exceeded; it generates an alarm signal, if required, that is received by the LLNL Fire Dispatcher for immediate callout of a response team.

In addition, LLNL is implementing a system of satellite monitoring stations that operates in conjunction with the sewer monitoring system. The satellite monitoring stations are positioned at strategic locations in the main sewer system to help pinpoint the area at the Livermore site from which a spill originated. Each station consists of a pH recorder or data logger and an automatic sampler that collects samples on a time-proportional basis. In the event of a spill, these samples are analyzed. Currently, there are five satellite monitoring stations, and at least four more will be installed in 1990 to provide the capability to further pinpoint any area from which a spill may occur.

Furthermore, LLNL is designing a new diversion system to hold wastewater that is unacceptable for release to LWRP. At present, once an unacceptable discharge has been detected by the monitoring system, the only action LLNL can take is to notify the LWRP of the event and the possible need to divert sewage into the LWRP holding pond. To protect the LWRP and to minimize any cleanup that might become

necessary, LLNL has designed an onsite sewage diversion and retention system that is capable of containing approximately 200 000 gallons of potentially contaminated sewage until it can be analyzed and appropriate handling methods determined. Construction of the diversion system began in February 1990. The diversion system will help ensure that all but the first few minutes of wastewater flow that trigger the alarm are retained at LLNL for evaluation and disposal, if necessary.

Since February 1980, the LWRP has been connected to a pipeline constructed as part of the Livermore-Amador Valley Wastewater Management Program to transport wastewater out of the valley for discharge into the San Francisco Bay. Although some treated LWRP effluent is still used to irrigate municipal property during summer months, sewage is no longer discharged into Arroyo Las Positas. This has eliminated the primary means of pollutant migration to local and downstream groundwater from LWRP.

Methods

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for 4 seconds for every 1000 gallons of effluent. Aliquots of this composite are transferred to plastic bottles and submitted for analysis. Daily composites of treated effluent from LWRP are collected by LWRP employees. Aliquots of these composites are placed in 500-mL polyethylene bottles, which are retained for weekly collection by LLNL. Composite samples from the LWRP digesters are sampled and collected monthly. The composites consist of aliquots taken from the circulating sewage three times a week. As each sewage sample is collected in the field, it is labeled with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies it during analysis. One replicate sample of Livermore-site effluent and one replicate sample of LWRP effluent are taken every Wednesday. These samples are analyzed for gross alpha and gross beta activity, and tritium.

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the Livermore site and LWRP effluents are also analyzed for gamma-emitting radionuclides, ^{239}Pu , and heavy metals. Composite samples from the LWRP digesters are analyzed for gross radioactivity and heavy metals; they are also analyzed quarterly for plutonium content.

In addition, once each quarter, a 24-hour composite sample of the LLNL sewage effluent is subjected to an extensive set of analyses by an independent off-site laboratory. 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 are also collected at the point of discharge of specified metal finishing and electrical and electronic component categorical processes to ensure compliance with EPA discharge limits for those processes. LLNL reports the results of the analyses of the point source discharges semiannually to the LWRP, the agency delegated by EPA to implement those regulations.

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 (500 mL if a sample from on site; 100 mL if from LWRP), and the mixture is heated to dryness on a hotplate. 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.

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. Then 15 mL of Instagel is used to prepare a background for the sample, and both the sample and the background are placed in the refrigerated detection chamber of the scintillation counter for a 1-hour temperature

equilibration prior to counting. Each sample is counted for 100 min.

Plutonium is separated by co-precipitation with manganese dioxide (MnO_2). The manganese dioxide is then 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 spectrometry.

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

Monthly composites of Livermore-site sewage effluent are analyzed for cadmium, chromium, copper, iron, lead, nickel, silver, aluminum, beryllium, and zinc. The monthly composite samples are prepared by combining the 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 is 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 No. 40 Whatman 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 with an atomic-absorption spectrophotometer. The required standards are prepared by dilution of a 1000-ppm, NIST-traceable stock solution.

Results

Radioactivity in Sewage. The determination of the total radioactivity released as tritium, alpha emitters (calibrated with ^{239}Pu), and beta emitters (calibrated

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with ^{90}Sr) was based on either the measured radioactivity in the effluent or the limit of sensitivity, whichever was higher (see Table L-11). Figures L-6, L-7, and L-8 show the daily concentration of tritium, alpha radiation, and beta radiation for 1989. The concentrations of ^{239}Pu and tritium (as tritiated water) measured in the sanitary sewer effluent from LLNL and LWRP are presented in Table L-13. During 1989, there were no inadvertent releases of radioactive materials to the sanitary sewer

system that exceeded any discharge limits. The annual average concentration of ^{137}Cs was $4.9 \times 10^{-11} \mu\text{Ci/mL}$, only 0.0003% of the DOE annualized discharge limit for application of best available technology (BAT) to a public sewer system. This concentration was consistent with that observed during 1988. The annual average ^{239}Pu concentration was $9.7 \times 10^{-12} \mu\text{Ci/mL}$, which was 0.0001% of the DOE annualized discharge limit for application of BAT. The combined releases of ^{137}Cs and

Table L-11. Estimated total radioactivity (curies) in sewer effluents; LLNL, 1989.

Radioactive emitter	Estimate based on effluent concentration	Limit of sensitivity
Tritium	1.59 ^a	0.13
Alpha radiation	0.0007	0.0015 ^a
Beta radiation	0.0035 ^a	0.0019

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

Figure L-6. LLNL 1989 tritium effluent in sewage.

^{239}Pu were 0.0029% of the 1 Ci/y NRC limit.

Figure L-9 shows the average monthly plutonium concentrations in sewage since 1973.

The annual average concentration of tritium in LLNL sanitary sewer effluent was

$3.5 \times 10^{-6} \mu\text{Ci/mL}$, about 0.03% of the DOE annualized discharge limit for application of BAT. The daily concentration presented in **Figure L-6** was multiplied by the volume of sewage released on that day and

Figure L-7. LLNL 1989 alpha radiation effluent in sewage.

Figure L-8. LLNL 1989 beta radiation effluent in sewage.

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then summed to determine the total radiation released in the form of tritium, as given in **Table L-11**. Of the total estimate of 1.59 Ci, nearly 1.2 Ci was accumulated during the first three months of the year. For this period, poor agreement was seen between the daily effluent analysis results and releases reported by LLNL and SNLL; the reported releases totalled only 0.21 Ci. An analysis review revealed that nonradioactive constituents of the sewage could interfere with the determination of the tritium concentration. Beginning in May 1989, the analysis was changed to eliminate the interfering constituents. For the remainder of the year, the estimated daily tritium release agrees well with releases reported by LLNL and SNLL. Reanalysis of several anomalous samples archived during the first quarter confirmed the release statistics provided by LLNL and SNLL. The radiation total presented in **Table L-11**, based solely on the daily effluent analysis, is therefore a conservatively high estimate. It represents 26% of the NRC annual limit for tritium. An estimate based upon measurements made by LLNL and SNLL would be as low as 0.63 Ci, or 13% of the NRC limit.

Nonradioactive Pollutants in Sewage.

The monthly average metal concentrations in the LLNL sanitary sewer effluent are listed in **Table L-14**. All discharges of metals were below the discharge limits set by the City of Livermore. Chromium and zinc had the highest percentage of the discharge limits, 14.6% and 14.4%, respectively. The results of quarterly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table L-15**. These tables present the average concentration of various parameters and reflect LLNL's compliance with the City of Livermore sewer discharge ordinance.

The Biological Oxygen Demand (BOD) and pH limits were the only parameters exceeded in the LLNL sanitary sewer effluent in 1989. The pH excursions were identified by the continuous on-line moni-

toring system, and the BOD was noted during a routine 24-hour monitoring sample collected during the first quarter of the year. By agreement with the LWRP, momentary pH events were reported to the LWRP as part of a monthly status report of LLNL sewer monitoring data. Events generating an alarm were reported to the LWRP at the time of their occurrence. The BOD excursion was reported in the quarterly monitoring report.

Environmental Impact

Radioactivity in Sewage. Facility liquid effluents with potential for containing radioactive materials are routed to retention tanks; they are not discharged directly to the sanitary sewer system. These retention tanks function to 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 needed, the wastewater can be treated at LLNL's Hazardous Waste Management Facility to reduce 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.

Table L-16 summarizes the liquid releases over the past 9 years. During 1989, no more than 1.6 Ci of tritiated water was discharged to the sanitary sewer. This is the combined release from the Livermore site and from SNLL; SNLL records account for 0.298 Ci of this amount. This amount is well within environmental protection standards established by DOE, and it is also within the range reported in the past.

DOE requires that radiological releases to the sanitary sewer be consistent with NRC regulations (10 *Code of Federal Regulations* 20.303), and DOE has established criteria for the application of BAT to sewer effluent releases to adequately protect public health and minimize

degradation of the environment. The total activity of tritium discharged was 26% of the NRC limit and 0.03% of the limit for application of BAT. The combined ^{239}Pu and ^{137}Cs discharges were 0.0029% of the NRC limit of 1 Ci/y and 0.00015 and 0.0003% of the limit for the application of BAT.

A summary of the ^{239}Pu monitoring since 1973 (Figure L-9) demonstrates that the 1989 levels of ^{239}Pu are returning to the historical levels seen generally since 1981 (approximately $1 \times 10^{-11} \mu\text{Ci/mL}$), with the exception of a peak level seen in 1987. This peak was well below the applicable DOE annualized discharge limits for application of BAT, and, historically, levels are generally one-millionth (0.000001) of that limit.

Nonradioactive Liquid Effluents. The routine quarterly sewer monitoring sample

collected in February in compliance with LWRP monitoring requirements for LLNL showed high Biological Oxygen Demand (BOD). The 360 mg/L concentration exceeded the 300 mg/L limit. An investigation did not identify a reason for the increase. The discharge did not adversely impact the LWRP and subsequent BOD levels were within limits.

High- and low-pH discharges in the combined LLNL/SNLL sewer effluent generated nine alarms during 1989. High pH levels were detected three times and ranged from about 10 to 74 minutes in duration with the highest pH being about 11.4. Six low-pH-alarm events occurred, lasting from about 6 to 61 minutes and reaching a low of approximately 2.3. Most of the time during these events, the pH was not much less than 6.8 or much greater than 8.5 (the discharge limits for pH values

Figure L-9. LLNL monthly average plutonium concentration in sewage since 1973.

range from 6.8 to 8.5), with only a few minutes at the extremes. Additional momentary pH spikes occurred intermittently during the year, but were of too short a duration or in too close proximity to the discharge limits to generate an alarm.

In addition to the alarms, during May, June, and July a series of low-pH events occurred and were noted on the pH chart but did not generate alarms because the alarm system was disconnected while calibration and verification of system upgrades were in progress. A site-wide "Environmental Alert" memorandum was published in an effort to help locate and remedy the cause of the events, but the cause of the low-pH events remains unknown.

By agreement with the LWRP, excursions during the year that did not generate alarms were reported in the routine monthly report provided to the LWRP. Nonetheless, alarms were reported promptly both verbally and in writing. No specific source was identified for any of the events. None of these releases resulted in any adverse impact on the operation of the LWRP

Radiological Discharge Limits to the Sanitary Sewer System (NRC, DOE, and DHS)

LLNL discharges to the sanitary sewer are consistent with the requirements imposed by the Nuclear Regulatory Commission (NRC) (10 *Code of Federal Regulations* 20) as directed by DOE Order 5400.5, which was in effect during 1989. Subsection 20.303 of these regulations states the following:

No licensee shall discharge licensed material into a sanitary sewerage system unless;

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of paragraphs (b)(1) or (2) of this section.

(1) The quantity which, if diluted by the average daily quantity of sewage released

into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of the part; and

(d) The gross quantity of licensed and other radioactive material, excluding hydrogen-3 and carbon-14, released into the sewerage system by the licensee does not exceed one curie per year. The quantities of hydrogen-3 and carbon-14 released into the sanitary sewerage system may not exceed 5 curies per year for hydrogen-3 and 1 curie per year carbon-14. Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

DOE orders also require "best available technology" (BAT) as the level of treatment for liquid wastes released to the sanitary sewer when concentrations of radionuclides exceed five times the DCG reference value on an annual average basis.

Applying ALARA principals, LLNL restricts releases to the sanitary sewer as described in the Introduction of this section.

For the radionuclides of concern (^3H , ^{137}Cs , and ^{239}Pu), the release limits established by the NRC (10 *Code of Federal Regulations* Part 20) and the DOE guidance for applying BAT are presented in **Table L-12** based on an average discharge of 358 000 gallons per day. The State of California has adopted the NRC guidance except for the 5 Ci yearly limit for tritium and the 1 Ci yearly limit for carbon-14. The limit stated in 17 *California Code of Regulations* Section 30287(a)(4) is 1 Ci/y for the total quantity of radioactive material released to the sanitary sewer.

To provide a workable standard that can be applied on a daily basis, LLNL has chosen to apply the DOE annualized concentration guidance for application of BAT on a daily basis. These values are smaller

than the daily sewer effluent concentration limits established by the NRC.

Discharge Limits to the Sanitary Sewer System of the City of Livermore

Sections 13.32.06, 13.32.08, 13.32.09, 13.32.100, and 13.32.110 of the *City of Livermore Municipal Code* state the discharge limits for Livermore's sanitary sewer system. These sections are reprinted below.

Section 13.32.06 General Discharge Prohibitions

No person shall contribute or cause to be contributed, directly or indirectly, any pollutant or wastewater that will interfere with the operation or performance of the publicly-owned treatment works (POTW). These general prohibitions apply to all such users of the POTW whether or not the user is subject to national categorical pretreatment standards or any other national, state, or local pretreatment standards or requirements. A user may not contribute the following substances to the POTW:

(a) Any liquids, solids, or gases that by reason of their nature or quantity are, or

may be, sufficient either alone or by interaction with other substances to cause fire or explosion or be injurious in any other way to the POTW or to the operation of the POTW. At no time, shall two successive readings on an explosion hazard meter, at the point of discharge into the system (or at any point in the system) be more than five percent (5%) nor any single reading over ten percent (10%) of the lower explosive limit (LEL) of the meter. Prohibited materials include, but are not limited to, gasoline, kerosene, naphtha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides, and sulfides and any other substances that the city, the state, or the EPA has notified the user is a fire hazard or a hazard to the system.

(b) Solid or viscous substances that may cause obstruction to the flow in a sewer or other interference with the operation of the wastewater treatment facilities such as, but not limited to: grease, garbage with particles greater than one-half inch (1/2") in any dimension, animal guts or tissues,

Table L-12. Sewer discharge release limits for tritium (^3H), ^{137}Cs , and ^{239}Pu .

	^3H	^{137}Cs	^{239}Pu
NRC concentrations used to establish release limits	$1 \times 10^{-1} \mu\text{Ci/mL}$	$1 \times 10^{-3} \mu\text{Ci/mL}$	$8 \times 10^{-4} \mu\text{Ci/mL}$
NRC daily	5 Ci ^a	1 Ci ^b	1 Ci ^b
monthly	5 Ci ^c	1 Ci ^c	1 Ci ^c
yearly	5 Ci	1 Ci ^d	1 Ci ^d
DOE annualized discharge limit for application of BAT ^e	$1 \times 10^{-2} \mu\text{Ci/mL}$	$1.5 \times 10^{-5} \mu\text{Ci/mL}$	$1 \times 10^{-5} \mu\text{Ci/mL}$

^a A release of this magnitude would require that no other release of tritium occur during the reporting year. Also, a release of this magnitude would not be considered in accord with ALARA principals.

^b A release of this magnitude would require that no other release occur during the reporting year. NRC regulations impose a 1 Ci combined limit on ^{137}Cs and ^{239}Pu . Also, a release of this magnitude would not be considered in accord with ALARA principals.

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

^d NRC regulations impose a 1 Ci combined limit on these isotopes, i.e., the total release of all isotopes except ^3H and ^{14}C must not exceed 1 Ci. However, 1 Ci of either, but not both, isotopes could be released. Also, a release of this magnitude would not be considered in accord with ALARA principals.

^e The DOE annualized discharge limit for application of BAT is five times the DCC (ingested water) for each radionuclide released.

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paunch manure, bones, hair, hides or fleshings, entrails, whole blood, feathers, ashes, cinders, sand, spent lime, stone or marble dust, metal, glass, straw, shavings, grass clippings, rags, spent grains, spent hops, waste paper, wood, plastics, gas, tar, asphalt residues, residues from refining, or processing of fuel or lubricating oil, mud, or glass grinding or polishing wastes.

Specifically excluded from the sewers are waste products resulting from the handling, storage, and sale of fruits and vegetables from other than retail produce establishments, or other foods not intended primarily for immediate consumption.

(c) Any wastewater having a pH less than 6.8 or greater than 8.5, unless a city permit is obtained. Wastewater having any other corrosive property capable of causing damage or hazard to structures, equipment, and/or personnel of the POTW is also prohibited.

(d) Any wastewater containing toxic pollutants in sufficient quantity, either singly or by interaction with other pollutants, to injure or interfere with any wastewater treatment process, constitute a hazard to humans or animals, create a toxic effect in the receiving waters of the POTW, or to exceed the limitation set forth in the categorical pretreatment standard. A toxic pollutant shall include, but not be limited to any pollutant identified pursuant to Section 307(a) of the Act.

(e) Any noxious or malodorous liquids, gases, or solids, which either singly or by interaction with other wastes are sufficient to create a public nuisance or hazard to life or are sufficient to prevent entry into the sewers for maintenance and repair.

(f) Any substance that may cause the POTW effluent or any other product of the POTW, such as residues, sludges, scums, or gases, to be unsuitable for reclamation and reuse or to interfere with the reclamation process. In no case, shall a substance discharged to the POTW cause the POTW to be in noncompliance with sludge use or disposal criteria, guidelines,

or regulations developed under Section 405 of the Act, any criteria, guidelines, or regulations affecting sludge use or disposal developed pursuant to the Solid Waste Disposal Act, the Clean Air Act, the Toxic Substances Control Act, or state criteria applicable to the sludge management method being used.

(g) Any waters or wastes that contain more than 100 mg/L of freon, extractable fat, oil, or grease.

(h) Any substance that will cause the POTW to violate its NPDES Permit or the receiving water quality standards.

(i) Any wastewater with objectionable color not removed in the treatment process, such as, but not limited to, dye wastes and vegetable tanning solutions.

(j) Any wastewater having a temperature that will inhibit biological activity in the POTW treatment plant resulting in interference, but in no case wastewater with a temperature at the introduction into the POTW which exceeds 40°C (104°F).

(k) Any pollutants, including oxygen-demanding pollutants (BOD, etc.) released at a flow rate and/or pollutant concentration that a user knows or has reason to know will cause interference to the POTW.

(l) Any wastewater containing any radioactive wastes or isotopes of such half-life or concentration as may exceed the limits established by the state or federal regulatory agency applicable to the POTW user.

(m) Any wastewater that causes a hazard to human life or creates a public nuisance.

(n) Any waters or wastes containing total dissolved solids increment greater than 325 mg/L, nor chloride increment greater than 75 mg/L increase during a single cycle use of the water supply, unless a city permit is obtained to exceed this limit.

(o) Any water or wastes having a BOD greater than 300 (the average BOD for residential users) unless a city permit is obtained.

(p) Any waters or wastes containing more than 300 mg/L of suspended solids (the average suspended solids for residential users) unless a city permit is obtained.

When the Superintendent determines that a user(s) is contributing to the POTW any of the above-enumerated substances in such amounts as to interfere with the operation of the POTW, the Superintendent shall (1) advise the user(s) of the impact of the contribution on the POTW, and (2) develop effluent limitations for such user(s) to correct the interference with the POTW.

Section 13.32.08. Federal Categorical Pretreatment Standards

Upon the promulgation of the Federal Categorical Pretreatment Standards for a particular industrial subcategory, the Federal Standard, if more stringent than limitations imposed under this article for sources in that subcategory, shall immediately supersede the limitations imposed under this article. The Superintendent shall notify all affected users of the applicable reporting requirements under 40 CFR Section 403.12.

Section 13.32.09. Modification of Federal Categorical Pretreatment Standards

Where the city's wastewater treatment system achieves consistent removal of pollutants limited by Federal Pretreatment Standards, the city may apply to the state/EPA for modification of specific limits in the Federal Pretreatment Standards. "Consistent Removal" shall mean reduction in the amount of pollutant or alteration of the nature of the pollutant, by the wastewater treatment system, to the

less toxic or harmless state, in the effluent that is achieved by the system in 95% of the samples taken when measured according to the procedures set forth in Section 403.7 (c) (2) of (Title 40 of the *Code of Federal Regulations*, Part 403), "General Pretreatment Regulations for Existing and New Sources of Pollution," promulgated pursuant to the Act. The city may then modify pollutant discharge limits in the Federal Pretreatment Standards if the requirements contained in 40 CFR, Part 403, Section 403.7, are fulfilled and prior approval from state/EPA is obtained.

Section 13.32.100. Specific Pollutant Limitations

No person shall discharge wastewater containing in excess of:

0.1	mg/L arsenic
0.2	mg/L cadmium
2.0	mg/L copper
1.0	mg/L cyanide
1.0	mg/L lead
0.01	mg/L mercury
1.0	mg/L nickel
0.2	mg/L silver
1.0	mg/L total chromium
3.0	mg/L zinc
0.02	mg/L total identifiable chlorinated hydrocarbons
1.0	mg/L phenolic compounds
0.01	mg/L polychlorinated biphenyls

Section 13.32.110 State Requirements

State requirements and limitations on discharges shall apply in any case where they are more stringent than Federal requirements and limitations or those in this article.

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Table L-13. Various radionuclides in sanitary sewer effluents—LLNL and Livermore Water Reclamation Plant (LWRP), 1989.

Month	³ H [10 ⁻⁶ μCi/mL ± 2σ (%)]		¹³⁷ Cs [10 ⁻¹¹ μCi/mL ± 2σ (%)]		²³⁹ Pu [10 ⁻¹² μCi/mL ± 2σ (%)]		²³⁹ Pu [10 ⁻⁸ μCi/g ± 2σ (%)]
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge
Jan.	0.5 ± 5	0.3 ± 7	6.6 ± 18	< 1.2	7.5 ± 16	< 0.20	
Feb.	22.4 ± 5	2.8 ± 5	5.9 ± 51	< 1.1	9.1 ± 12	0.26 ± 80	
Mar.	9.5 ± 4	0.5 ± 6	8.6 ± 38	< 1.5	18.2 ± 10	0.26 ± 74	8.2 ± 2.0
Apr.	1.2 ± 6	0.3 ± 7	4.5 ± 46	< 1.1	9.7 ± 12	0.47 ± 62	
May	0.7 ± 3	0.2 ± 7	2.9 ± 56	< 1.1	15.8 ± 10	< 0.11	
June	2.3 ± 6	0.3 ± 0	5.5 ± 37	< 1.1	7.2 ± 16	0.63 ± 48	2.8 ± 2.2
July	1.5 ± 6	0.3 ± 7	3.6 ± 61	< 1.0	6.4 ± 17	0.24 ± 89	
Aug.	0.9 ± 6	0.3 ± 7	3.5 ± 65	< 0.7	4.3 ± 21	0.31 ± 65	
Sept.	1.0 ± 6	0.5 ± 5	< 4.0	< 1.3	4.3 ± 21	0.28 ± 80	4.7 ± 3.3
Oct.	0.8 ± 5	0.5 ± 5	4.4 ± 34	< 1.2	7.4 ± 14	0.54 ± 46	
Nov.	0.5 ± 5	0.2 ± 4	5.0 ± 35	< 0.9	15.5 ± 10	0.35 ± 60	
Dec.	0.6 ± 5	0.2 ± 4	4.6 ± 60	< 1.5	10.6 ± 10	0.58 ± 60	2.2 ± 4.7
Mean	3.5	0.5	4.9	1.1 ^a	9.7	0.4	4.5
SDM (%)	184	135	32	9 ^b	47	47	60
Total release (Ci/y) ^c	1.3		24.4 × 10 ⁻⁶		4.8 × 10 ⁻⁶		
Percent of limit							
DOE ^d	0.04		0.0003		0.0001		
NRC ^e	26%		0.0029% of the combined limit for ¹³⁷ Cs and ²³⁹ Pu				

^a Median. See Quality Assurance chapter.

^b Median absolute deviation. See Quality Assurance chapter.

^c Total release was 1.6 Ci, 0.3 Ci released by SNLL and 1.3 Ci released by LLNL.

^d The DOE annualized limits for application of BAT are 1.00 × 10⁻² for tritium, 1.5 × 10⁻⁵ for ¹³⁷Cs and 1.5 × 10⁻⁵ for ²³⁹Pu.

^e NRC limit is 5 Ci/y for ³H and 1 Ci/y combined for all other radionuclides.

Table L-14. Metals discharged to Livermore-site sanitary sewer system: 1989 monthly summaries.

Month	Cd	Total Cr	Cu	Fe	Pb	Ni	Ag	Zn	Al	Be
	(mg/L)									
Jan.	0.002	0.089	0.382	0.62	0.016	0.020	0.010	0.516	0.39	0.0023
Feb.	0.002	0.053	0.466	0.86	0.005	0.031	0.004	0.493	0.37	0.0002
Mar.	0.002	0.086	0.329	0.81	0.041	0.029	0.015	0.587	0.64	0.0005
Apr.	0.002	0.070	0.271	0.74	0.017	0.013	0.014	0.336	0.27	0.0013
May	0.004	0.407	0.281	1.02	0.022	0.081	0.002	0.514	0.27	0.0010
June	0.003	0.129	0.303	0.74	0.023	0.037	0.001	0.474	0.44	0.0003
July	0.002	0.056	0.192	0.52	0.026	0.012	0.004	0.420	0.25	0.0003
Aug.	0.002	0.034	0.251	0.49	0.026	0.011	0.001	0.367	0.18	0.0003
Sept.	0.002	0.043	0.235	0.74	0.027	0.013	0.014	0.434	0.44	0.0003
Oct.	0.002	0.023	0.192	0.61	0.015	0.012	0.005	0.293	0.08	0.0002
Nov.	0.002	0.050	0.219	0.77	0.017	0.015	0.017	0.372	0.62	0.0002
Dec.	0.003	0.714	0.170	2.24	0.026	0.277	0.001	0.358	0.54	0.0005
Mean	0.002	0.146	0.274	0.85	0.022	0.046	0.007	0.430	0.37	0.0006
SDM (%)	28	141	31	55	41	164	85	20	46	103
Discharge limit ^a	0.2	1.0	2.0	— ^b	1.0	1.0	0.2	3.0	— ^b	— ^b
Percent of discharge limit	1.0	14.6	13.7	— ^b	2.2	4.6	3.5	14.4	— ^b	— ^b

^a Limits established in City of Livermore Municipal Code.

^b No established limit for analyte.

Table L-15. Positively detected parameters in LLNL sanitary sewer effluent, 1989.

Positively detected parameter ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Mean	SDM (%)
Physical and chemical (mg/L)						
Biological oxygen demand	360	84	<200	91	184	70
Chemical oxygen demand	450	290	230	130	275	49
Settleable solids (mL/L)	11	11	<0.1	1.5	5.9	100
Total dissolved solids	270	190	340	350	288	26
Total solids	380	300	280	250	303	18
Total suspended solids	130	80	25	55	73	61
Volatile solids (% total solids)	300	150	39	56	136	88
Ammonia nitrogen (as N)	34	34	34	33	34	1
Chloride	6	3	28	5	11	112
Cyanide	<0.02	<0.02	<0.02	<0.02	0.02 ^b	0 ^c
Nitrate nitrogen (as N)	0.8	<0.1	<0.1	<0.1	0.1 ^b	0 ^c
Nitrite nitrogen (as N)	<0.01	<0.01	<0.01	0.02	0.01 ^b	0 ^c
Sulfate	11	1	24	34	18	83
Total alkalinity (as CaCO ₃)	120	120	150	150	135	13
Total Kjeldahl nitrogen (as N)	43	44	39	38	41	7
Total phosphorous (as P)	4.7	4.9	3.6	4.2	4.4	13
Arsenic	<0.002	<0.002	<0.002	<0.002	0.002 ^b	0 ^c
Boron	0.3	0.3	<0.02	0.3	0.23	61
Cadmium	<0.01	<0.01	<0.01	<0.04	0.01 ^b	0 ^c
Calcium	10	13	12	9	11	17
Total chromium	<0.02	0.10	0.04	<0.05	0.05 ^b	33 ^c
Copper	0.57	0.46	0.25	0.30	0.40	37
Lead	0.012	0.022	0.055	<0.3	0.097	140
Magnesium	1.9	1.9	1.4	1.3	1.6	20
Mercury	0.0052	0.0030	0.0012	0.0028	0.0031	54
Nickel	<0.05	0.04	<0.05	<0.03	0.045 ^b	11 ^c
Potassium	20	15	15	20	17.5	16
Selenium	<0.001	<0.001	<0.002	<0.002	0.002 ^b	67 ^c
Silver	<0.01	<0.01	0.04	0.03	0.02 ^b	50 ^c
Sodium	35	39	29	31	34	13
Zinc	0.61	0.21	0.19	0.26	0.32	62
Organic compounds (mg/L)						
Oil and grease	12	13	7	9	10	27
Phenolics	0.018	0.015	0.015	<0.5	0.137	177
Total organic carbon	25	49	36	44	39	27

...continued

Table L-15. Positively detected parameters in LLNL sanitary sewer effluent, 1989 (concluded).

Positively detected parameter ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Mean	SDM (%)
Purgeable/extractable pollutants (EPA Methods 624/625, µg/L)						
Bis(2-ethylhexyl)phthalate	600	<100	<20	<40	70 ^b	43 ^c
Butylbenzylphthalate	14	<1	<10	<20	12 ^b	42 ^c
Dibutylphthalate	38	<1	<10	<20	15 ^b	63 ^c
Diethylphthalate	4	<1	<10	<20	7 ^b	64 ^c
Dimethylphthalate	4	<1	<10	<20	7 ^b	64 ^c
Chloroform	5	11	12	9	9	33
Acetone	160 ^d	750 ^d	170	<10	273	120
Benzoic acid	— ^e	100 ^d	<50	320	156	92
Benzyl alcohol	15 ^d	50 ^d	<10	320	99	150
TCE	<1	<1	<1	1	1 ^b	0 ^c
PCE	<1	<1	<1	1	1 ^b	0 ^c
Methylene chloride	<1	<1	<1	11	1 ^b	0 ^c

^a The sewer effluent samples were also analyzed for the following compounds. The concentrations of these compounds were below these detection limits.

Organochlorine pesticides	Detection limits µg/L	Organochlorine pesticides	Detection limits µg/L
Aldrin	0.05	DDE (mixed isomers)	0.05
Chlordane	0.3	DDD (mixed isomers)	0.05
Endrin	0.1	Heptachlor	0.05
Dieldrin	0.05	Heptachlor Epoxide	0.05
BHC (mixed isomers)	0.05	Methoxychlor	0.2
DDT (mixed isomers)	0.1	Polychlorinated biphenyls	0.3

^b Median. See Quality Assurance chapter.

^c Median absolute deviation. See Quality Assurance chapter.

^d Semi-quantified result.

^e No data reported by testing laboratory.

Table L-16. Radioactive liquid effluent releases from the Livermore site, 1981–1989.

Year	Liquid effluents (Ci)	
	^3H	^{239}Pu
1981	6.0	9.2×10^{-5}
1982	1.6	4.3×10^{-6}
1983	1.7	6.7×10^{-6}
1984	1.7	3.2×10^{-6}
1985	3.6	4.8×10^{-6}
1986	2.0	1.5×10^{-5}
1987	1.4	6.9×10^{-4}
1988	1.5	2.2×10^{-5}
1989	1.6	4.8×10^{-6}

ROUTINE WATER MONITORING

Introduction

LLNL performs surveillance monitoring of waters for the Livermore site and for surrounding regions of the Livermore Valley. The waters monitored in the Livermore Valley include lakes and aqueducts, tap water, stormwater runoff, and drinking-water supply wells. The samples are analyzed for gross alpha and beta radiation, tritium, and nonradioactive pollutants, including solvents, metals, and pesticides.

As noted in the Sewage Monitoring chapter, a small fraction of treated effluent from LWRP is used to irrigate nearby municipal property. This effluent contains low levels of tritium that come from natural sources, radioactive fallout, and normal LLNL and SNLL operational releases to the sanitary sewer system. As part of a study begun in 1977, tritium measurements are made annually on well-water samples collected from neighboring wells to determine the extent of tritium migration into the groundwater. Many of the wells are in the immediate vicinity of LWRP; however, additional samples are also collected from areas some distance away.

Beginning in 1975, LLNL's Environmental Monitoring Program was expanded to include surface runoff monitoring. The program was originally designed to detect the pesticides used at LLNL (which include herbicides, fungicides, and insecticides) in samples collected from the drainage ditch at the northwest corner of the Livermore site following the first major storm. Additional sampling points were subsequently added, and the samples were analyzed for metals, radioactivity, general water-quality parameters, and other priority pollutants, in addition to pesticides.

On the Livermore site, stormwater is channeled through storm sewers designed to accommodate a 10-y flow. Open ditches are used in undeveloped areas of the site. The Arroyo Las Positas flow is channeled north to the northeast corner of the site, then west along the north perimeter to an outlet at the northwest corner. This outlet, which also constitutes the main pathway for the site's surface drainage (storm and irrigation runoff), runs north to the Western Pacific railroad tracks, then west, where it joins the Arroyo Seco. The main channel of the Arroyo Seco crosses the center of the SNLL site from the

southeast to the southwest corner of the Livermore site.

Methods

Livermore Valley water-sampling locations for surface and domestic water in the vicinity of the Livermore site are shown in **Figure L-10**. Locations 11, 15, 16, 24, 26, and 29 are surface water sources (ponds, creeks, aqueducts, or reservoirs). Location 20 is the rainfall collection site for the Livermore site. Location 43 is the onsite swimming pool. The other locations are domestic water supply wells. Water samples from the Livermore Valley are taken quarterly and are analyzed for gross alpha, gross beta, and tritium activities. Because of the low tritium levels typically found, it is necessary to distill and enrich the samples before liquid-scintillation counting.

The locations of wells near LWRP that are sampled for tritium measurements to determine the extent of tritium migration into the groundwater are shown in **Figure L-11**. This figure also illustrates the locations of additional sampling sites some distance from LWRP.

Livermore Site Routine Water Monitoring

As presently designed, the runoff monitoring program calls for the sampling of 6 locations (Figure L-12) during the period of active surface water flow following the first major storm of the rain season. Location 1 is the influent to the east side of the Livermore site that feeds the Arroyo Las Positas flow; Location 2 is at the onsite drainage basin; and Location 3 is the effluent into the redirected Arroyo Las Positas channel at the northwest site boundary. Location 4 is in the Arroyo Seco channel influent to the SNLL site; Location 5 is the effluent to the Arroyo Seco channel of a culvert that collects surface drainage from the southeast area of the Livermore site; and Location 6 is the Arroyo Seco channel

effluent at the western boundary of the Livermore site (Vasco Road).

Grab samples are obtained from surface sources, such as ponds, creeks, and reservoirs, with a tethered plastic pail. A 500-mL sample is collected for tritium analysis in an argon-flushed glass container fitted with a ground-glass stopper. Samples for other radiological analyses are collected in 500-mL polyethylene bottles.

Groundwater monitoring wells are purged of stagnant water prior to sampling. In the case of wells with high water-production rates, this entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For wells with low water-production rates, the well is manually bailed to dryness. Sampling occurs when the well has produced sufficient water for the required samples. All sampling equipment is chosen so that it will not add compounds to the analysis sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

As samples are collected in the field, they are labeled with sampling location and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 10% of the water samples are duplicates.

For those samples that are analyzed for gross alpha and gross beta activity, a 100-mL sample or less, depending on the solid content, is digested with a mixture of 80% HNO₃ and 20% HClO₄ and dried. The residue is taken up with HNO₃ and a few milliliters of 5% hydrogen peroxide (H₂O₂). The solution is evaporated to about 5 mL and transferred to a 5-cm-diameter serrated, stainless steel planchet. After the planchet is dried and flamed, the sample is counted for 30 min in a proportional counter. A blank is processed with each set of samples, and ²³⁹Pu and ⁹⁰Sr standards are counted with every sample set. Background measurements are made between every 10 sample-counting measurements.

Samples analyzed for tritium are electrolytically enriched and then counted by

Figure L-10. Water sampling locations. Livermore Valley, 1989.

Figure L-11. Groundwater sampling locations, Livermore Valley, 1989.

Figure L-12. Stormwater runoff sampling locations, Livermore site, 1989.

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liquid-scintillation spectrometry. Each counting set includes a total of eight standards to establish quench corrections and eight blanks to determine background.

For beryllium analysis, a 100-mL sample is digested with HNO₃. The residue is diluted to 100 mL with deionized water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Table L-17 lists the standardized methods used in the analyses of groundwater and/or stormwater samples for nonradioactive contaminants.

Results

Radioactivity in Water. **Table L-18** shows the gross alpha activities in Livermore Valley water samples. Gross beta activities for Livermore Valley samples are

shown in **Table L-19**. Gross alpha and beta activities in these surface and domestic water samples collected in 1989 were below EPA and DHS maximum contaminant levels (MCLs; U.S. Environmental Protection Agency 1977; 22 *California Code of Regulations* Section 64443).

Table L-20 contains the data for radioactivity in stormwater runoff. The runoff from two rain storms (March 8 and December 31 storms) were sampled, and no sample could be collected at Locations 1 and 4 during either sampling. All measurements of gross alpha and gross beta radioactivity were a small fraction of the respective MCLs. The tritium concentration measured at the onsite Location 2 during the March 8 storm was 2.9 times the MCL of 20×10^{-6} $\mu\text{Ci/mL}$. Other concentrations were at the MCL (Location 5)

Table L-17. EPA groundwater standard methods.

Analyte	EPA method	Analyte	EPA method
Metals			
Antimony	204.1	Manganese	243.1
Arsenic	206.2	Mercury	245.1
Barium	208.1	Molybdenum	246.1
Beryllium	210.2	Nickel	249.1
Cadmium	213.1	Selenium	270.2
Chromium	218.1	Silver	272.1
Cobalt	219.1	Sodium	273.1
Copper	220.1	Thallium	279.1
Iron	236.1	Vanadium	286.1
Lead	239.2	Zinc	289.1
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)	350.2	Chloride	325.3
All alkalinities	310.2	Sulfate	375.3
Organic compounds			
Volatile organic compounds		Low level phenolic compounds	
Purgeable halocarbons	601	Total organic halide (TOX)	9020
Purgeable priority pollutants	624	Total organic carbon (TOC)	9060
Title 22 organic compounds	608	Oil and grease	413.1
Extractable priority pollutants	625	Chemical oxygen demand (COD)	410.1

or below the MCL (Locations 3, 5, and 6). This is the first observation of tritium concentrations above or near the MCL at more than one monitoring location during a sampling. These observations were investigated, but no unusual release of tritium from LLNL occurred that would explain these values. Review of the analyses resulting in these values does not reveal a reason to reject the data. To identify the source of the tritium, we are reviewing the possible environmental pathways for tritium migration to stormwater.

Table L-21 shows tritium data for Livermore Valley samples. The samples have concentrations that are well below recommended limits. The highest concentration of tritium in water, 19.3×10^{-7} $\mu\text{Ci/mL}$, occurred in the onsite swimming pool (Location 43) during the first quarter of sampling. This represents 1.54% of the DCG for drinking water and 9.65% of the DHS MCL for other waters. The averages and the percent of DCG for drinking water for the year are also presented in **Table L-21** for each location.

Table L-21 also includes an estimate of the annual (effective) dose that may be delivered to an adult who consumes water containing the listed tritium concentrations. These doses, which are all less than 6×10^{-2} mrem (the value estimated for Location 43), are based on a water consumption of 2 L/day and the dose-conversion factors contained in ICRP 30 provided by DOE (U.S. Department of Energy 1988b). The actual dose (if any) from the swimming pool and surface water sources would be considerably less because they are not used as drinking water sources. Methods used to calculate doses are presented in **Appendix A**.

The tritium data for production wells used by local water-supply agencies and

for wells in the vicinity of LWRP are shown in **Table L-22**. These wells are used to monitor groundwater quality in the vicinity of LWRP, and they are not used as drinking-water sources. The highest tritium values appear in monitor wells downgradient of LWRP. Tritium activities in the production wells were at background levels (approximately 0.5×10^{-7} $\mu\text{Ci/mL}$), and all samples were well below the limits for water adopted by the State of California (22 *California Code of Regulations* Section 64443). These tritium levels are similar to those observed in the 1988 samples.

Nonradioactive Pollutants in Water.

Table L-23 shows data for physical and chemical parameters in stormwater. Most potential pollutants in the storm runoff were not present at detectable levels. For the first time, acetone was detected at Location 6 at 140 $\mu\text{g/L}$. No other organic compounds were detected. Metals were not detected above normal background levels expected for water that has been in contact with soil. The data showed no significant impact of LLNL operations on other waters sampled.

Environmental Impact

The stormwater runoff showed acetone at the southwest corner of the Livermore site. At other locations, no detectable levels of specified hydrocarbons were found, and only a few other pollutants at detectable levels were seen. No nonradiological pollutants were seen in any stormwater samples above applicable regulatory limits. The impact of the radiological pollutants is minimal, with the only unusual occurrence being the observation of levels of tritium above the MCL in the runoff from a storm in March.

Table L-18. Gross alpha activity in water—Livermore Valley, 1989.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[10 ⁻⁹ μCi/mL ± 2σ (%)]			
11	4	12 ± 6	0 ± 2	5.8	107
15	4	<2	0 ± 1	1.0 ^b	100 ^c
16	4	5 ± 4	0 ± 2	1.9	62
19	4	<2	0 ± 1	0.5	173
20	1	0 ± 1	N/A ^d	N/A ^d	N/A ^d
24	4	6 ± 4	0 ± 1	1.5	173
26	3	1 ± 4	0 ± 2	0.3	143
29	4	<4	0 ± 2	1.5 ^b	67 ^c
30	1	<1	N/A ^d	N/A ^d	N/A ^d
31	4	<1	0 ± 1	0.3	172
34	4	3 ± 2	0 ± 2	0.5 ^b	100 ^c
37	4	<2	0 ± 1	1.5	112
43	8	<8	0 ± 2	0.5 ^b	100 ^c

^a See Fig. L-10 for sampling locations.

^b Median. See Quality Assurance chapter.

^c Median absolute deviation (%). See Quality Assurance chapter.

^d Not applicable.

Table L-19. Gross beta activity in water—Livermore Valley, 1989.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[10 ⁻⁹ µCi/mL ± 2σ (%)]			
11	4	14 ± 7	2 ± 3	7.8	59
15	4	5 ± 4	0 ± 4	2.8	65
16	4	<9	0 ± 7	4.8	67
19	4	<8	0 ± 1	2.0	173
20	1	0 ± 3	N/A ^b	N/A ^b	N/A ^b
24	4	210 ± 14	0 ± 2	57	156
26	3	18 ± 5	0 ± 4	7.8	89
29	4	<4	0 ± 3	1.8	102
30	1	1 ± 1	N/A ^b	N/A ^b	N/A ^b
31	4	<8	0 ± 3	2.5	131
34	4	9 ± 6	0 ± 3	2.5	151
37	4	8 ± 4	0 ± 4	4	73
43	8	24 ± 7	1 ± 3	6.9	99

^a See Fig. L-10 for sampling locations.

^b Not applicable.

Table L-20. Various radionuclides in stormwater runoff—Livermore site, 1989.

Location ^a	³ H [10 ⁻⁶ μCi/mL ± 2σ (%)]	Gross alpha [10 ⁻⁹ μCi/mL]	Gross beta [10 ⁻⁹ μCi/mL]
1	— ^b	— ^b	— ^b
	— ^b	— ^b	— ^b
2	57.3 ± 1	<2	9 ± 2
	57.4 ± 1	<1	6 ± 2
	0.98 ± 14	<1	<2
3	9.62 ± 2	3 ± 2	12 ± 3
	0.84 ± 16	<1	<2
4	— ^b	— ^b	— ^b
	— ^b	— ^b	— ^b
5	19.8 ± 2	<1	11 ± 3
	0.29 ± 46	<1	<2
6	14.9 ± 2	3 ± 2	11 ± 2
	<0.13	<2	<2
	0.16 ± 81	<1	3 ± 2

^a See Fig. L-12 for sampling locations.

^b No data. See the Quality Assurance chapter.

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Table L-21. Tritium in water—Livermore Valley, 1989.

	Sampling location ^a						
	11 ^b	15 ^b	16 ^b	19 ^c	20 ^d	24 ^b	26 ^b
	[10 ⁻⁷ μ Ci/mL $\pm$ 2 σ (%)]						
First quarter	0.62 $\pm$ 13	0.72 $\pm$ 9	2.48 $\pm$ 21	0.58 $\pm$ 14	2.39 $\pm$ 4	0.93 $\pm$ 10	1.93 $\pm$ 7
Second quarter	0.60 $\pm$ 12	0.35 $\pm$ 18	2.62 $\pm$ 4	0.63 $\pm$ 10	10.70 $\pm$ 2	0.69 $\pm$ 11	1.40 $\pm$ 7
Third quarter	0.59 $\pm$ 10	0.40 $\pm$ 14	1.06 $\pm$ 6	0.49 $\pm$ 16	6.46 $\pm$ 3	0.48 $\pm$ 13	1.39 $\pm$ 5
Fourth quarter	0.81 $\pm$ 9	0.32 $\pm$ 16	1.04 $\pm$ 7	0.51 $\pm$ 12	7.85 $\pm$ 17	0.38 $\pm$ 16	1.30 $\pm$ 6
Mean	0.65	0.44 $\pm$ 14	1.80	0.20 $\pm$ 29	6.85	0.62	1.42 $\pm$ 6
SDM (%)	16	0.45	48	0.48	50	39	17
Percent of DWS ^f	0.33	0.23	0.90	0.24	3.43	0.31	0.75
Effective dose (mrem)	3 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	1 $\times$ 10 ⁻²	2 $\times$ 10 ⁻³	3 $\times$ 10 ⁻²	3 $\times$ 10 ⁻³	7 $\times$ 10 ⁻³

	Sampling location ^a					
	29 ^b	30 ^g	31 ^c	34 ^h	37 ^c	43 ⁱ
	[10 ⁻⁷ μ Ci/mL $\pm$ 2 σ (%)]					
First quarter	0.57 $\pm$ 13	0.42 $\pm$ 16	0.69 $\pm$ 11	0.34 $\pm$ 16	0.66 $\pm$ 11	19.3 $\pm$ 8
Second quarter	0.43 $\pm$ 13	0.28 $\pm$ 18	0.51 $\pm$ 11	0.48 $\pm$ 13	0.44 $\pm$ 16	16.6 $\pm$ 9
Third quarter	0.38 $\pm$ 14	0.49 $\pm$ 13	0.39 $\pm$ 15	0.53 $\pm$ 11	0.34 $\pm$ 15	17.4 $\pm$ 8
Fourth quarter	0.47 $\pm$ 13	0.28 $\pm$ 24	0.38 $\pm$ 16	0.37 $\pm$ 16	0.32 $\pm$ 19	17.6 $\pm$ 8
Mean	0.46	0.28 $\pm$ 24	0.39 $\pm$ 14	0.37 $\pm$ 16	0.32 $\pm$ 19	4.9 $\pm$ 25
SDM (%)	17	0.28 $\pm$ 24	0.38 $\pm$ 16	0.37 $\pm$ 16	0.32 $\pm$ 19	5.8 $\pm$ 21
Percent of DWS ^f	0.23	0.19	0.23	0.22	0.22	9.2 $\pm$ 15
Effective dose (mrem) ^j	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	9.7 $\pm$ 14
						10.5 $\pm$ 14
Mean	0.46	0.37	0.47	0.43	0.44	12.3
SDM (%)	17	29	28	20	35	44
Percent of DWS ^f	0.23	0.19	0.23	0.22	0.22	6.15
Effective dose (mrem) ^j	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	6 $\times$ 10 ⁻²

^a See Fig. L-10 for sampling locations.

^b Surface water.

^c Tap water—Livermore locations.

^d Rain water.

^e No data. See Quality Assurance chapter.

^f DWS (State of California drinking water standard) = 2 $\times$ 10⁻⁵ μ Ci/mL.

^g Tap water—LLNL.

^h Well water.

ⁱ LLNL swimming pool.

^j Effective dose based on DOE standard of 4 mrem for drinking water.

Table L-22. Tritium in groundwater—Livermore Valley, 1989.

Well identification ^a	Activity [10 ⁻⁷ μ Ci/mL $\pm$ 2 σ %]	Percent of DWS ^b
1H3	0.19 $\pm$ 27	0.10
1P2	2.63 $\pm$ 4	1.32
1R2	1.14 $\pm$ 6	0.57
2R1	2.57 $\pm$ 4	1.29
9M3	0.64 $\pm$ 12	0.32
11B1	7.46 $\pm$ 3	3.73
12A2	1.34 $\pm$ 6	0.67
16L7	0.31 $\pm$ 16	0.16
17D2	0.28 $\pm$ 23	0.14
18A5	0.33 $\pm$ 16	0.17
7C2	1.34 $\pm$ 6	0.67
7P3	0.07 $\pm$ 75	0.04
8P1	0.75 $\pm$ 10	0.38

^a See Fig. L-11 for sampling locations.

^b DWS (State of California drinking water standard) = 200×10^{-7} μ Ci/mL

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Table L-23. Positively detected nonradioactive parameters in Livermore-site stormwater runoff, 1989.

Parameter ^b	Sampling location ^a					
	1	2	3	4	5	6
Physical/chemical						
Arsenic (mg/L)	— ^c	<0.002	0.003	— ^c	0.002	<0.002
Chemical oxygen demand (µg/L)	— ^c	38.4	45.8	— ^c	33.7	71.3
Fluoride (mg/L)	— ^c	0.10	0.10	— ^c	0.10	0.10
Lead (mg/L)	— ^c	<0.001	<0.001	— ^c	0.001	<0.001
Nitrate (as N) (mg/L)	— ^c	1.5	0.9	— ^c	1.5	0.9
Selenium (mg/L)	— ^c	<0.001	0.001	— ^c	0.001	<0.001
Organic compounds						
Acetone (µg/L)	— ^c	<10	<10	— ^c	<10	140
TOC (mg/L)	— ^c	8.8	8.5	— ^c	8.0	15

^a See Fig. L-12 for sampling locations.

^b The following parameters would have been reported had they appeared above the detection limits indicated below:

Metals (mg/L)	Detection limit
Mercury	0.0001
Silver	0.01
Barium	0.1
Beryllium	0.0001
Cadmium	0.01
Total chromium	0.02

Extractable priority pollutants (EPA 625)(µg/L)	Detection limit
2,4-Dinitrophenol	20
4-Nitrophenol	40
Benzidine	80
Bis(2-ethylhexyl)phthalate	200
All other analytes	2

Title 22 organic compounds (µg/L)	Detection limit
2,4,5-TP (Silvex)	1.0
2,4-D	10
Endrin	0.01
Lindane	0.4
Methoxychlor	10
Toxaphene	0.5
Oil and grease (mg/L)	5

Purgeable priority pollutants (EPA 624) (µg/L)	Detection limit
Acrolein	10
Acrylonitrile	10
Methyl ethyl ketone	20
All other analytes	1

^c No data. See Quality Assurance chapter.

Introduction

Soil is an integrating medium that can account for contaminants released to the atmosphere or through liquid effluents. Since 1972, annual soil sampling in the vicinity of the Livermore site has been part of the continuing LLNL monitoring program designed to document any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from Livermore-site operations. Prior to 1988, soil samples were collected at sites selected at random from Livermore Valley locations previously sampled in a 1971-1972 study; that study was conducted to determine the background concentrations of radionuclides in area soils. In 1988, sampling locations were chosen to coincide with air sampling locations or to give coverage of areas of known past contamination or concern. The 1988 sampling locations were resampled in 1989. The use of constant sampling locations allows for better trending of the data and closer monitoring of areas of concern.

In 1989, sediment samples from the arroyos near LLNL were collected, also continuing a monitoring effort begun in 1988. The sampling of sedimentary material from streams or ponds can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment. As a result of the accumulation of contaminants, sediment sampling is a more sensitive indicator of waterborne radionuclides than water sampling (U.S. Department of Energy 1988d). The sediments also have the potential to concentrate nonradioactive constituents present in stormwater runoff. Chemical and radiological analyses were used to determine if significant buildup of pollutants has occurred. The arroyo sediment sampling locations were chosen to coincide as closely as possible with the stormwater sampling locations.

Methods

Figure L-13 shows the soil-sampling locations in the Livermore Valley. Sampling activities followed standardized written procedures (Brekke et al. 1988). Samples are taken from reasonably level areas that represent undisturbed soil. A 2-m square is marked off in each area, and an 8.25-cm-

diameter coring tool, designed at LLNL, is used to collect 5-cm-deep subsamples at the corners and center of the square. All subsamples are collected to a depth of

Figure L-13. Soil sampling locations, Livermore Valley, 1989.

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5 cm because surface deposition from the air is the primary pathway for potential contamination. The five subsamples of soil collected from each 2-m square are combined into a single composite sample in a plastic bag. A label is affixed to the bag, and the sample is identified by number. This number is entered in a logbook, together with all pertinent sampling information and a description of the sample location. The number is used to identify the sample throughout the laboratory analyses and is used in this report.

After collection, the samples are dried, ground, and blended. Plutonium-239 content is determined in each sample following an acid-leaching procedure. The soil is leached by heating for 4 hours with a mixture of concentrated HNO_3 and HCl . The plutonium is then separated and purified by ion exchange and electroplating, and is submitted for alpha spectroscopy. The samples analyzed by gamma spectroscopy (for over 150 radionuclides) are first dried

at 110°C for a minimum of 2 days, pulverized, passed through a 32-mesh sieve, and blended. Approximately 300-g aliquots of the soils are sealed in 200- cm^3 thin-walled aluminum cans and are counted with a Ge(Li) detector.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, two adjacent cores, 5-cm deep, are taken from the corners and center of each 2-m square. Separate composites of the five cores are then made, and the composites are identified with unique sample numbers.

Figure L-14 shows the 6 arroyo sampling locations where samples are collected near the Livermore site. Standard written sampling procedures are followed (Brekke et al. 1988). At each location, a 30-foot transect is laid out (starting from a permanent marker), and 4 numbers between 1 and 30 are randomly generated. These numbers represent the distance (in feet) along the transect at

Figure L-14. LLNL arroyo sediment sampling locations, 1989.

which samples are taken. Samples are taken with a split-spoon sampler driven into the soil to a depth of two feet to allow for better characterization of volatile organic compounds. The bottom six inches are sealed in a stainless steel sampling tube and are submitted for organic-compounds and metals analyses. The next higher six inches are submitted for radiological analyses (tritium, gamma emitters, and plutonium). The location identification and sample number are written on the sample tube, on a label attached to the sample tube, and in a logbook. The location number, the sample number, and the date sampled are used to identify each sample throughout the sampling and analytical processes.

Gamma spectroscopy and plutonium analyses are conducted on arroyo sediments using the techniques outlined above for soil samples. Tritium analysis is performed by liquid-scintillation counting of water recovered through freeze-drying from the arroyo sediments. The arroyo samples are analyzed for metals by inductively coupled plasma emission spectroscopy (ICP) following extraction in water for comparison to Soluble Threshold Limit Concentrations (STLC). The arroyo samples are analyzed for organic compounds by standard EPA methods (method 8010 for halogenated volatile organic compounds; method 8020 for aromatic volatile organic compounds; and method 8080 for pesticides and PCBs).

Ten percent of the arroyo samples are collected in duplicate, in accordance with quality assurance protocols (Holland 1987). Duplicate samples are collected adjacent to sampling locations using identical procedures. The duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Results

Table L-24 presents data on the concentrations of ^{239}Pu , ^{40}K , ^{137}Cs , ^{232}Th , ^{238}U , and ^{241}Am in soils from the Livermore

Valley sampling locations, only positively detected parameters are shown. The rationale for including the naturally occurring nuclides (^{40}K , ^{232}Th , and ^{238}U) and the long-lived fission product (^{137}Cs) is to provide baseline data on global fallout and to allow monitoring of the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL. The concentrations and distributions of all observed nuclides in soil for 1989 are similar to or below the levels measured in 1988 and are within the ranges reported in previous years. Elevated levels of ^{239}Pu , first observed in soils near the Livermore Water Reclamation Plant (LWRP) during the early 1970s, were again detected at locations L-19, L-20, and L-24, although levels were below those reported in 1988. The highest value of $59.9 \times 10^{-9} \mu\text{Ci/g}$ represents 0.5% of the proposed EPA soil standard of $0.2 \mu\text{Ci/m}^2$ for unrestricted use of surface soil (or $13 \times 10^{-6} \mu\text{Ci/g}$ assuming average Livermore Valley soil densities). The remaining values reflect worldwide fallout and naturally occurring concentrations of nuclides. The ^{241}Am detected at LWRP in the same sampling areas exhibiting elevated plutonium levels is probably due to natural decay of the trace concentrations of ^{241}Pu that are also present.

Table L-25 presents data on radiological parameters in the arroyo sediment samples, again only positively detected parameters are shown. Plutonium-239 analytical techniques improved, so detection limits decreased in 1989. Therefore, actual concentrations are listed instead of the detection limits reported in 1988. Plutonium-239 levels are at background concentrations, reflective of worldwide fallout. All other radionuclides were detected at levels similar to or below levels reported in 1988. Cesium-137 is another fission product found at worldwide background concentrations. Potassium-40, ^{232}Th , and ^{238}U are naturally occurring radionuclides that were detected at background concentrations. Tritium concentrations are similar to those reported in 1988.

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Table L-26 presents data on metals of concern in the sediment samples. The level of lead (Pb) in one sample (79 mg/L) was above STLC limits; however, the other three samples from that location showed lead at the detection level. This finding is being investigated, and additional samples from this area will be taken in 1990. For the other metals, no concentrations above STLC limits or above levels normally encountered in sediments were detected.

Table L-27 presents data on organic parameters in the sediment samples, again, only positively detected parameters are shown. Analytical techniques for detection of organic compounds have improved over past years. Therefore, traces of a variety of compounds, many of which were undetected in previous years, were observed in all samples. Two samples show detectable levels of the PCB Aroclor 1260 (ALPW-3 at 0.07 mg/kg and ASN-2 at 0.05 mg/kg). However, the levels detected are close to detection limits (0.03 mg/kg) and are below regulatory guidelines (50 mg/kg, 40 *Code of Federal Regulations* Part 761). None of the levels detected for other organic compounds are

above regulatory standards. Many of these compounds are typical of fuel constituents and are expected in locations that concentrate stormwater runoff. Others (i.e., Freon 113, chloroform, methylene chloride, benzene, and toluene) are typical laboratory solvents that may indicate contamination of samples. Investigations have been initiated to determine the origin of these contaminants.

Environmental Impact

Soil and arroyo sediment sample analyses indicate that the impact of LLNL operations on these media in 1989 has not changed from previous years. Most analytes were detected at background concentrations, in trace amounts, or could not be measured above detection limits. While some contaminants have been detected, none of the measured levels are of a degree to warrant concern. Investigations into the source of detected contaminants are under way and will be continued. Sampling of soils and arroyo sediments will continue on an annual basis.

Table L-24. Positively detected radionuclides in soil---Livermore Valley, 1989
(sampling depth of 0 to 5 cm).

Location ^a	²³⁹ Pu	⁴⁰ K	¹³⁷ Cs	²⁴¹ Am	²³² Th	²³⁸ U
	[10 ⁻⁹ μ Ci/dry g $\pm$ 2 σ (%)]	[10 ⁻⁶ μ Ci/dry g $\pm$ 2 σ (%)]		[μ g/dry g $\pm$ 2 σ (%)]		
L-14	11.9 $\pm$ 6	11.4 $\pm$ 3	0.03 $\pm$ 16	<0.07	5.77 $\pm$ 6	2.81 $\pm$ 51
L-05	3.0 $\pm$ 11	12.0 $\pm$ 5	0.15 $\pm$ 8	<0.02	8.79 $\pm$ 3	2.64 $\pm$ 39
L-18	1.7 $\pm$ 11	12.5 $\pm$ 4	0.06 $\pm$ 13	<0.01	6.00 $\pm$ 3	2.43 $\pm$ 36
L-04	8.0 $\pm$ 8	13.4 $\pm$ 3	0.04 $\pm$ 14	<0.05	6.93 $\pm$ 3	2.53 $\pm$ 77
L-15	1.8 $\pm$ 12	14.5 $\pm$ 3	0.07 $\pm$ 11	<0.02	6.60 $\pm$ 3	2.51 $\pm$ 38
L-08	4.2 $\pm$ 14	11.8 $\pm$ 4	0.11 $\pm$ 8	<0.01	5.67 $\pm$ 4	1.01 $\pm$ 63
L-10	9.4 $\pm$ 6	13.9 $\pm$ 6	0.39 $\pm$ 3	<0.04	6.15 $\pm$ 4	<1.28
L-03	0.2 $\pm$ 28	11.8 $\pm$ 4	0.01 $\pm$ 54	<0.05	6.69 $\pm$ 3	0.89 $\pm$ 86
L-13	2.0 $\pm$ 13	16.4 $\pm$ 3	0.08 $\pm$ 10	<0.05	6.75 $\pm$ 3	2.80 $\pm$ 71
L-02	1.7 $\pm$ 15	15.6 $\pm$ 4	0.07 $\pm$ 8	<0.03	6.94 $\pm$ 3	<1.80
L-19	70.7 $\pm$ 5 ^b	9.5 $\pm$ 4	0.04 $\pm$ 18	0.04 $\pm$ 70	5.61 $\pm$ 3	1.95 $\pm$ 35
L-20	59.9 $\pm$ 6 ^b	12.1 $\pm$ 4	0.05 $\pm$ 12	0.04 $\pm$ 56	7.62 $\pm$ 3	2.36 $\pm$ 94
L-21	7.7 $\pm$ 8 ^b	12.7 $\pm$ 3	0.02 $\pm$ 21	<0.06	6.85 $\pm$ 4	3.22 $\pm$ 37
L-22	4.7 $\pm$ 9 ^b	10.4 $\pm$ 3	0.03 $\pm$ 12	<0.06	5.88 $\pm$ 5	1.95 $\pm$ 60
L-23	1.9 $\pm$ 13 ^b	10.1 $\pm$ 3	0.02 $\pm$ 19	<0.06	5.52 $\pm$ 5	2.17 $\pm$ 47
L-24	10.6 $\pm$ 7 ^b	10.2 $\pm$ 3	0.04 $\pm$ 18	<0.03	5.72 $\pm$ 4	3.21 $\pm$ 89
Mean	4.4 (11.2)	12.4	0.08	0.04 ^c	6.47	2.22
SDM(%)	90 (157)	16	121	38 ^d	13	32

^a See Fig. L-13 for sampling locations.^b Data from area of known contamination. Summary data with these data included in the calculations are in parentheses.^c Median value. See Quality Assurance chapter.^d Median absolute deviation (%). See Quality Assurance chapter.

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Table L-25. Positively detected radionuclides in arroyo sediments near the Livermore site, 1989.

Location ^a	²³⁹ Pu	³ H	⁴⁰ K	¹³⁷ Cs	²³² Th	²³⁸ U
	[10 ⁻⁹ µCi/dry g ± 2σ (%)]	[10 ⁻⁷ µCi/mL ^b ± 2σ (%)]	[10 ⁻⁶ µCi/dry g ± 2σ (%)]		[µg/dry g ± 2σ (%)]	
ALPE-1	0.3 ± 38	14.1 ± 10	12.5 ± 4	0.008 ± 45	7.2 ± 6	2.2 ± 74
ALPE-2	<0.1	12.7 ± 11	14.6 ± 4	<0.003	8.6 ± 3	<2.8
ALPE-3	1.0 ± 16	14.8 ± 9	9.0 ± 4	0.029 ± 17	4.5 ± 5	2.3 ± 86
ALPE-4	0.5 ± 26	12.8 ± 10	12.7 ± 3	0.010 ± 40	7.1 ± 4	2.1 ± 57
CDB-1	0.4 ± 38	38.9 ± 3	15.7 ± 3	<0.003	8.6 ± 3	<1.6
CDB-2	1.3 ± 16	21.3 ± 6	15.1 ± 3	<0.003	9.5 ± 3	<0.4
CDB-3	1.6 ± 16	21.1 ± 13	15.5 ± 3	<0.003	9.0 ± 3	1.4 ± 60
CDB-4	3.0 ± 10	19.0 ± 8	14.7 ± 4	<0.003	8.4 ± 4	2.8 ± 40
ALPW-1	1.6 ± 14	2.4 ± 35	11.1 ± 4	<0.003	6.8 ± 5	3.0 ± 43
ALPW-2	1.7 ± 16	3.3 ± 37	14.0 ± 3	0.016 ± 32	8.1 ± 3	2.1 ± 37
ALPW-3	7.6 ± 8	4.7 ± 18	12.1 ± 3	0.040 ± 21	8.0 ± 4	<0.6
ALPW-4	1.3 ± 16	2.2 ± 38	15.0 ± 3	0.012 ± 52	8.5 ± 3	2.5 ± 41
ASE-1	0.3 ± 20	33.9 ± 5	7.9 ± 3	0.010 ± 64	3.4 ± 9	1.2 ± 87
ASE-2	0.3 ± 26	35.3 ± 5	11.7 ± 4	0.019 ± 28	5.2 ± 4	1.5 ± 48
ASE-3	0.3 ± 20	39.7 ± 5	12.9 ± 6	0.015 ± 44	5.1 ± 9	<3.3
ASE-4	0.3 ± 18	43.2 ± 4	13.4 ± 4	0.018 ± 22	5.3 ± 4	<1.4
ASS-1	0.2 ± 54	7.2 ± 18	10.4 ± 3	<0.003	6.8 ± 7	<0.7
ASS-2	0.3 ± 20	5.1 ± 25	11.4 ± 4	0.017 ± 30	5.3 ± 3	2.1 ± 41
ASS-3	<0.03	9.2 ± 14	14.7 ± 4	<0.003	9.6 ± 3	<1.2
ASS-4	0.3 ± 24	7.5 ± 17	11.6 ± 3	0.010 ± 49	6.8 ± 3	3.0 ± 43
ASN-1	0.3 ± 25	7.9 ± 16	9.4 ± 6	0.010 ± 54	3.7 ± 6	1.9 ± 56
ASN-2	0.3 ± 24	9.3 ± 13	11.0 ± 4	0.014 ± 30	4.5 ± 3	<0.4
ASN-3	0.3 ± 21	7.9 ± 16	10.5 ± 3	0.016 ± 39	4.3 ± 3	<0.7
ASN-4	0.4 ± 20	9.2 ± 13	10.5 ± 5	0.018 ± 23	4.2 ± 4	1.1 ± 63
Mean	1.0	15.9	12.4	0.010 ^c	6.6	1.8 ^c
SDM (%)	160	81	18	70 ^d	30	36 ^d

^a See Fig. L-14 for sampling locations.

^b Activity in recovered water.

^c Median. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

Table L-26. Positively detected metals^a (in mg/L) in arroyo sediments near the Livermore site, 1989.

Location ^b	Ba	Cd	Co	Total Cr	Cu	Ni	Pb	V	Zn	As	Se	Hg
ALPE-1	8.9	< 0.04	0.40	0.07	0.15	0.83	1.3	0.28	0.67	0.04	< 0.02	< 0.001
ALPE-2	9.8	< 0.04	0.59	0.10	0.08	1.4	< 0.3	0.63	0.05	0.03	< 0.02	< 0.001
ALPE-3	8.8	< 0.04	0.71	< 0.05	< 0.08	1.2	< 0.3	0.67	0.07	0.02	< 0.02	< 0.001
ALPE-4	11.0	< 0.04	0.79	0.10	0.09	1.7	< 0.3	0.63	< 0.01	0.02	< 0.02	< 0.001
CDB-1	8.9	< 0.04	0.40	< 0.05	< 0.08	0.53	< 0.3	0.20	0.03	0.02	< 0.02	< 0.001
CDB-2	5.4	< 0.04	0.34	< 0.05	< 0.08	0.39	< 0.3	0.11	0.05	0.04	< 0.02	0.002
CDB-3	8.3	< 0.04	0.36	< 0.05	< 0.08	0.55	< 0.3	0.19	0.25	0.02	< 0.02	< 0.001
CDB-4	8.8	< 0.04	0.43	< 0.05	0.12	0.63	< 0.3	0.27	0.24	0.03	< 0.02	< 0.001
ALPW-1	6.1	< 0.04	0.28	0.09	2.2	0.44	< 0.3	< 0.03	0.68	0.06	< 0.02	< 0.001
ALPW-2	6.7	< 0.04	0.33	0.07	0.77	0.49	< 0.3	< 0.03	0.12	0.05	< 0.02	0.033
ALPW-3	4.1	< 0.04	0.25	< 0.05	0.26	0.40	< 0.3	< 0.03	1.50	0.07	0.02	< 0.001
ALPW-4	7.2	< 0.04	0.39	< 0.05	0.35	0.55	< 0.3	< 0.03	0.08	0.04	< 0.02	< 0.001
ASE-1	4.7	< 0.04	0.20	0.07	< 0.08	0.30	< 0.3	0.22	0.21	0.03	< 0.02	0.008
ASE-2	4.5	< 0.04	0.26	< 0.05	0.09	0.39	< 0.3	0.20	0.24	0.03	< 0.02	< 0.001
ASE-3	8.4	< 0.04	0.20	0.14	0.14	0.30	< 0.3	0.16	0.20	0.03	< 0.02	< 0.001
ASE-4	5.8	0.08	0.38	0.14	0.40	0.65	79.0	0.24	0.58	0.05	< 0.02	0.058
ASS-1	7.7	< 0.04	0.33	0.17	0.26	0.41	< 0.3	0.29	0.23	0.10	< 0.02	< 0.001
ASS-2	4.4	< 0.04	0.34	0.08	0.29	0.88	< 0.3	0.19	1.50	0.03	< 0.02	< 0.001
ASS-3	2.5	0.41	0.42	0.23	< 0.08	0.58	< 0.3	1.1	1.30	0.47	< 0.02	< 0.001
ASS-4	2.3	< 0.04	0.26	0.29	0.18	0.44	< 0.3	0.37	0.27	0.06	< 0.02	< 0.001
ASN-1	7.6	< 0.04	0.20	0.18	0.20	0.34	< 0.3	0.20	0.90	0.03	< 0.02	< 0.001
ASN-2	6.3	< 0.04	0.13	0.08	1.1	0.29	< 0.3	0.15	0.71	0.03	< 0.02	0.011
ASN-3	9.0	< 0.04	0.24	0.09	0.21	0.29	< 0.3	0.26	0.24	0.06	< 0.02	< 0.001
ASN-4	8.2	< 0.04	0.25	0.08	0.25	0.27	< 0.3	0.28	0.49	0.05	< 0.02	0.006
Mean	6.9	0.04 ^c	0.35	0.08 ^c	0.32	0.59	0.3 ^c	0.28	0.44	0.06	0.02 ^c	0.001 ^c
SDM (%)	33	0 ^d	45	38 ^d	147	62	0 ^d	88	103	153	0 ^d	0 ^d

^a Other metals for which analyses were performed include silver, beryllium, molybdenum, antimony, and thallium. However, all values for these metal analyses were below detection limits.

^b See Fig. L-14 for sampling locations.

^c Median value. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

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Table L-27. Positively detected organic compounds in arroyo sediments near the Livermore site, 1989
(in mg/kg).

Location	Aroclor 1260	1,1,1- TCA ^a	1,1- DCE ^b	1,1- DCA ^c	Chloro- form	Freon 113	Methylene chloride	Trichloro- TCE ^d	Trichloro- fluoro- methane	PCE ^e	Benzene	Ethyl- benzene	Toluene	Xylene isomers
ALPE-1	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0006	<0.0002	<0.0002	<0.0002	<0.001	<0.002	<0.002	<0.002
ALPE-2	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	0.001	<0.002	<0.002	<0.002
ALPE-3	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.002	<0.002	<0.002
ALPE-4	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.002	<0.002	<0.002
CDB-1	<0.03	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.059	<0.008
CDB-2	<0.03	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.020	<0.008
CDB-3	<0.03	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.090	<0.008
CDB-4	<0.03	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.071	<0.008
ALPW-1	<0.03	<0.0002	<0.0002	<0.0002	0.0009	0.0003	<0.0002	0.0003	<0.0002	0.0002	0.006	<0.001	0.004	<0.001
ALPW-2	<0.03	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	0.005	<0.001	<0.001	<0.001
ALPW-3	0.07	<0.0002	<0.0002	<0.0002	0.0019	0.0004	<0.0002	0.0014	<0.0002	0.0002	0.021	<0.001	<0.001	<0.001
ALPW-4	<0.03	<0.0002	<0.0002	<0.0002	0.0012	0.0002	<0.0002	0.0002	<0.0002	<0.0002	0.007	<0.001	0.004	<0.001
ASE-1	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	0.002	<0.002	0.003	<0.002
ASE-2	<0.03	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002	<0.002	<0.002	<0.002
ASE-3	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.001	<0.001
ASE-4	<0.03	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.002	<0.001	<0.001	<0.001
ASS-1	<0.03	<0.0002	0.0007	0.0002	0.0009	<0.0002	0.0003	0.0004	<0.0002	0.0002	0.003	<0.002	0.012	0.006
ASS-2	<0.03	<0.0002	<0.0002	<0.0002	0.0076	<0.0002	0.0009	<0.0002	0.0002	0.0019	0.015	<0.002	0.260	<0.002
ASS-3	<0.03	<0.0002	0.0027	<0.0002	0.0004	<0.0002	0.0006	0.0013	<0.0002	0.0003	0.005	0.006	0.130	0.035
ASS-4	<0.03	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002	<0.002	0.003	0.003
ASN-1	<0.03	0.0009	<0.0002	0.0005	0.0011	0.0003	<0.0002	0.0006	<0.0002	0.0029	0.003	<0.002	<0.002	<0.002
ASN-2	0.05	0.0021	<0.0002	0.0004	0.0019	0.0003	<0.0002	0.0013	<0.0002	0.0096	0.003	<0.002	<0.002	<0.002
ASN-3	<0.03	0.0010	0.0004	<0.0002	0.0019	0.0004	<0.0002	0.0008	0.0002	0.0030	0.002	<0.002	<0.002	<0.002
ASN-4	<0.03	<0.0002	<0.0002	0.0002	0.0005	0.0004	<0.0002	0.0003	0.0003	0.0013	0.001	<0.002	<0.002	<0.002
Median	0.03	0.0002	0.0002	0.0002	0.0007	0.0003	0.0002	0.0033	0.0002	0.0002	0.003	0.002	0.002	0.0002
MAD ^f (%)	0	0	0	0	71	20	0	33	0	0	67	0	50	50

^a 1,1,1-Trichloroethane.

^b 1,1-Dichloroethane.

^c 1,1-Dichloroethane.

^d Trichloroethylene.

^e Tetrachloroethylene, also called perchloroethylene.

VEGETATION AND FOODSTUFF MONITORING

Introduction

Sampling and measurement of native vegetation can provide information about the buildup of radionuclides in the environment. Native vegetation is specifically mentioned by DOE in its monitoring regulations as a medium that is appropriate for sampling and analysis (U.S. Department of Energy 1988d). The requirements also call for pathway analyses, and specifically mention analyses of milk and other representative samples of the pathway-significant agricultural products grown within 16 km of the site. LLNL collects and analyzes samples of vegetation, honey, goat's milk, and wine, and calculates any potential human dose from these substances.

Methods

Vegetation. At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley. **Figure L-15** shows the 1989 vegetation-sampling locations in the Livermore Valley. The sampling locations

are the same as those sampled in 1988. The use of constant sampling locations allows for better trending of the data and closer monitoring of areas of concern. Sampling activities follow standardized written procedures (Brekke et al. 1988). Grass samples are cut at ground level, and any soil or

Figure L-15. Vegetation sampling locations, Livermore Valley, 1989.

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dead tissues discarded. The bulk volume of the samples is between 0.5 and 1 L (approximately 1 kg). Each sample is collected, double-bagged in plastic, labeled according to sample type and location, and frozen in a dry-ice chest to minimize water loss on the bag's surface. A label is affixed to the bag, and the sample identified by number. This number is entered in a log-book, together with all pertinent sampling information and a description of the sample location. The number is used to identify the sample throughout the laboratory analyses and is used throughout this report. The samples are later transferred to a freezer in the laboratory. Two subsamples of vegetation are collected each quarter at each sampling location. One subsample is used for analysis and the other is preserved in the laboratory freezer in case the first sample is lost during analysis or in case the measurement result is in question and reanalysis of the sample is necessary for data verification.

Water from the vegetation samples is collected using freeze-drying techniques. The tritium content of the recovered water is determined by liquid-scintillation counting.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, a total of four subsamples of vegetation are collected using identical methodology from a sampling location. Two of the bags serve as the official sample, and the other two bags are considered the duplicate sample. The duplicate samples are preserved, stored, processed, and analyzed with methods identical to those employed for all other samples.

Wine. As in past years, three types of retail wine samples were collected and analyzed: wines 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. California and Europe were divided into 10 and 12 wine producing regions, respectively. Thirteen wines that were produced in eight of the California regions and eight wines that were produced in six of the

European regions were purchased as representative samples of these regions. Seven estate-bottled Livermore wines completed the sampling for 1989.

Approximately 10% of the total complement of wines were sampled in duplicate to comply with quality assurance protocols (Holland 1987).

This year's sampling plan continued the practice of determining the tritium content of wines purchased from retail outlets.

The wines were selected based on general availability to provide data on the potential tritium exposure from wine consumption. Thus, the wines were selected from different vintages (i.e., from wines produced in different years). Consequently, the tritium values are not indicative of how the year's operations at the Livermore site affected grapes and wines produced in 1989, but they do serve as an index of potential exposure. In addition, wine sample data can be decay-corrected to its initial tritium concentration given the number of months that have elapsed between production and analysis. The decay-corrected data can be used to determine trends and may help determine the impact of vintage-year operations.

The wine samples are purchased at local retailers and are submitted unopened to the Nuclear Chemistry Division for tritium analyses. The wine samples are oxidized in a Peterson furnace, gas-converted, and analyzed for tritium content by gas-proportional counting. It should be noted that the analysis methods used are highly sensitive. Only by using such techniques could differences in the tritium content of retail wines be determined. If less-sensitive methods, such as those employed by commercial analytical laboratories were used, the tritium content of all samples would be at or below detection limits for those methods and no differences would be apparent.

Honey. Samples of honey available for purchase in 1989 from a variety of flower sources both inside and outside the Livermore Valley were also analyzed for tritium content. As was the case with the wine samples, the tritium values are not indicative of the year's emissions of tritium, but they do serve as an index of

potential exposure. This is because honey purchased in 1989 may not have been produced during 1989. Following oxidation of the samples in a Parr oxygen bomb, the tritium content of the water produced was determined by gas proportional counting. Honey-sample submittals complied with quality assurance protocols (Holland 1987).

Milk. During 1989, goat-milk samples were obtained monthly from four farms within about 5 km of the Livermore site. Production from the farms was variable, so samples were obtained as available. (See the Quality Assurance chapter for a discussion of deviations from the sampling program.)

A portion of each milk sample was freeze-dried, and the collected water was analyzed for tritium activity by liquid-scintillation counting. Another portion of each milk sample was preserved with formalin, and was analyzed for gamma-emitting isotopes by counting a 1-L aliquot in a Marinelli beaker using Ge(Li) spectrometers. At least one milk source was sampled in duplicate each month to comply with quality assurance protocols (Holland 1987). Canned goat's milk, presumably produced outside of the Livermore Valley, was analyzed each month as a measure of background concentrations.

Results

Vegetation. Table L-28 shows tritium data for vegetation collected in the Livermore Valley. The values are somewhat greater than those reported in 1988, but are within the range of tritium values normally reported for vegetation in the area. An analysis of variance (ANOVA) indicated that there is no statistically significant difference in the tritium content of the vegetation among any of the sampling locations.

Wine. The results from the 1989 wine tritium analyses are shown in Table L-29. The data for the 1989 sampling year were analyzed using analysis of variance (ANOVA). The statistical analysis showed that the mean of the Livermore wines sampled was statistically greater than both the European and California wines sampled.

The mean tritium content of the European wines was also statistically greater than that of the California wines. Multiple comparison tests indicated that the means of the 1989 sampling year data from each area were not statistically different than those reported for the 1988 sampling year. **Figure L-16** shows the results of the wine analyses by sampling year since monitoring began.

Regression analysis and ANOVA of the wine data when decay-corrected and grouped by vintage year showed no statistically significant trends in the tritium content of Livermore or California wines since monitoring began. The tritium content of European wines has significantly decreased since monitoring began, but has not decreased significantly since 1980. Over the past 10 vintage years, the tritium content of wines from all areas have remained essentially constant, with some variation from year to year (**Figure L-17**). During that period, European and Livermore wines have exhibited comparable tritium concentrations, with Livermore wines having higher concentrations some years, and European wines

Figure L-16. Tritium in retail wines (error bars are ± 1 standard error).

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having higher concentrations in other years. Wines from both Livermore and Europe have consistently contained statistically higher tritium concentrations than wines from California during the same period.

Figure L-17. Mean tritium in retail wines, 1980–1989, decay-corrected and plotted by vintage year (error bars are ± 1 standard error).

Figure L-18. Tritium concentration in honey (error bars are ± 1 standard error).

Honey. Table L-30 shows tritium data for honey collected from producers in the Livermore Valley and from other Bay Area producers. The concentration values for the Livermore Valley samples are statistically higher than those seen from producers outside the valley. However, an additional analysis of variance showed that the 1989 Livermore honey tritium values are not significantly different than the 1988 tritium values reported for honey for the other areas of California. **Figure L-18** shows the average values for Livermore Valley honey collected from 1979 to 1989, and other California honeys collected in 1980–1989. The graph shows that the tritium content of honey fluctuates significantly from year to year, and that the average Livermore Valley concentration is sometimes higher and sometimes lower than that of other California honeys. There are no health or environmental standards for radionuclides in honey. However, none of the tritium levels observed would be of health concern even if the honey were consumed in the same quantities as drinking water, for which safety standards do exist (the EPA drinking-water standard is $200 \times 10^{-7} \mu\text{Ci/mL}$).

Milk. The activities of ^{137}Cs , ^{40}K , and ^3H in goat-milk samples collected this year are shown in Tables L-31 to L-33. No other nuclides were present at detectable levels; ^{137}Cs and ^{40}K were only detected at background levels. Tritium levels in milk are comparable to those reported in previous years. The highest concentration of tritium in milk is $4.9 \times 10^{-7} \mu\text{Ci/mL}$. An analysis of variance showed that tritium values for Livermore milk, as a whole, are not significantly different (95% confidence) than background. The value for one individual location was significantly different than background, but it was still only at a concentration of 1 to 2% of the EPA drinking water standard. Also shown are the calculated annual radiation doses that could be received from consuming this milk. These calculations are based on a milk intake of 310 L/y and on models described in Appendix A. The dose resulting from tritium (Table L-31) was calculated using dose factors provided by

DOE (U.S. Department of Energy 1988b). The maximum dose received from ingestion of milk, based on this model, was 4.5×10^{-3} mrem/y.

Environmental Impact

In general, LLNL impacts on vegetation in the Livermore Valley in 1989 were minimal. Tritium levels found in the Livermore Valley vegetation were generally comparable to those observed in previous years. The effective dose equivalents shown in **Table L-28** were derived using the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b) 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 average tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is approximately 6×10^{-2} mrem/y.

The results of this year's monitoring of tritium in wine, as in past years, indicate that all the tritium concentrations detected were low and were at or near the concentrations measured in tap water (**Table L-21**). There are no health standards for radionuclides in wine. However, all the wine tritium data were far below drinking water standards. In fact, even the highest detected

value (5.5×10^{-7} $\mu\text{Ci/mL}$) was only 3% of the California drinking water standard (200×10^{-7} $\mu\text{Ci/mL}$). Doses from wine consumption can be calculated according to methods for water-ingestion detailed in **Appendix A**. The corresponding annual dose of the highest detected tritium value (5.5×10^{-7} $\mu\text{Ci/mL}$), based on the very conservative assumption that wine is consumed in the same quantities as water (730 L/year, or 2 L/day), is 0.025 mrem. Using a more realistic wine consumption factor (52 L/year, or 1 L/week of wine from a single area), and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.000011 mrem, from European wine would be 0.000006 mrem, and from California wine would be 0.000003 mrem. Compared with an annual background dose of 300 mrem (including radon) and a 10 mrem dose from a typical chest x-ray (Shleien and Terpilak 1984), it is easily seen that 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.

Honey and milk produced in the Livermore Valley contained tritium levels slightly higher than those found in honey and milk from other areas, but within the range normally seen.

Table L-28. Tritium in vegetation—Livermore Valley, 1989.

	Sampling location ^a							
	4	15	20	23	29	31	32	33
	[10 ⁻⁷ μCi/mL of moisture content ± 2σ (%)]							
First quarter	14 ± 10	— ^b	15 ± 9	71 ± 3	11 ± 13	21 ± 7	36 ± 5	2.6 ± 50
Second quarter	2.5 ± 49	13 ± 10	2.9 ± 43	19 ± 8	8.4 ± 16	27 ± 6	19 ± 8	2.4 ± 51
Third quarter	14 ± 10	9.2 ± 14	4.0 ± 31	18 ± 8	2.2 ± 55	13 ± 11	8.2 ± 16	<1.2
Fourth quarter	3.2 ± 39	27 ± 6	24 ± 6	31 ± 5	39 ± 4	6.0 ± 22	8.0 ± 17	2.3 ± 54
Mean	8.4	16	11	35	15	17	18	2.1
SDM (%)	77	59	91	71	108	55	74	30
Effective dose (mrem) ^c	1.5 × 10 ⁻²	2.8 × 10 ⁻²	2.0 × 10 ⁻²	6.2 × 10 ⁻²	2.7 × 10 ⁻²	3.0 × 10 ⁻²	3.2 × 10 ⁻²	3.7 × 10 ⁻³

^a See Fig. L-15 for sampling locations.

^b No data. See Quality Assurance chapter.

^c This dose represents the total effective dose from the forage-cow-milk pathway.

Table L-29. Tritium in retail wines, 1989.

Sample	Area of Production		
	Livermore Valley	California (Non-Livermore Valley) [10 ⁻⁷ μCi/mL ± 2σ (%)]	Europe
1	3.5 ± 6	0.5 ± 46	1.9 ± 10
2	4.6 ± 13	1.6 ± 20	3.4 ± 8
3	5.5 ± 6	0.4 ± 95	2.1 ± 26
4	2.3 ± 16	0.4 ± 58	3.5 ± 8
5	4.6 ± 13	0.5 ± 25	1.3 ± 24
6	2.7 ± 7	1.1 ± 24	1.1 ± 24
7	1.2 ± 23	0.8 ± 60	0.8 ± 32
8		0.4 ± 42	<0.4
9		0.4 ± 51	
10		0.4 ± 54	
11		2.5 ± 20	
12		0.7 ± 32	
13		<0.4	
Mean	3.5	0.8	1.8
SDM (%)	44	81	63

Table L-30. Tritium in honey, 1989.

Sample ^a	Sampling location [10 ⁻⁷ μ Ci/mL (in water recovered $\pm$ 2 σ (%))]	
	Livermore	California
1	2.06 $\pm$ 18	2.22 $\pm$ 23
2	2.69 $\pm$ 11	1.53 $\pm$ 33
3	2.20 $\pm$ 11	1.18 $\pm$ 37
4		1.56 $\pm$ 16
5		1.48 $\pm$ 14
Mean	2.32	1.59
SDM (%)	14	24

^a Three samples were obtained for the Livermore area, and five samples were obtained for California.

Table L-31. Tritium in milk—Livermore Valley, 1989.

	Sampling location				Canned goat's milk
	5	7	12	13	
	[10 ⁻⁷ μ Ci/mL $\pm$ 2 σ (%)]				
Jan.	— ^a	— ^a	— ^a	— ^a	— ^a
Feb.	— ^a	2.8 $\pm$ 46	<1.2	— ^a	1.8 $\pm$ 69
Mar.	4.9 $\pm$ 34	1.7 $\pm$ 73	2.0 $\pm$ 62	— ^a	<1.2
Apr.	2.6 $\pm$ 48	<1.2	1.3 $\pm$ 91	— ^a	<1.2
May	<1.2	<1.2	2.1 $\pm$ 59	2.3 $\pm$ 54	<1.2
June	1.8 $\pm$ 68	<1.2	<1.2	<1.2	<1.2
July	<1.2	<1.2	1.6 $\pm$ 79	2.1 $\pm$ 58	<1.2
Aug.	1.9 $\pm$ 62	<1.2	<1.2	2.3 $\pm$ 53	<1.2
Sept.	3.6 $\pm$ 36	1.6 $\pm$ 80	— ^a	2.9 $\pm$ 44	<1.2
Oct.	1.9 $\pm$ 66	<1.2	— ^a	1.6 $\pm$ 81	<1.2
Nov.	1.8 $\pm$ 75	— ^a	— ^a	1.5 $\pm$ 90	— ^a
Dec.	— ^a	— ^a	— ^a	— ^a	— ^a
Mean	2.3	1.2 ^b	1.3 ^b	2.0	1.2 ^b
SDM (%)	56	0 ^c	8 ^c	29	1 ^c
Effective dose (mrem)	4.5 $\times$ 10 ⁻³	2.3 $\times$ 10 ⁻³	2.5 $\times$ 10 ⁻³	3.9 $\times$ 10 ⁻³	2.3 $\times$ 10 ⁻³

^a No data. See Quality Assurance chapter.

^b Median value. See Quality Assurance chapter.

^c Median absolute deviation (%). See Quality Assurance chapter.

Table L-32. Potassium-40 in milk—Livermore Valley, 1989.^a

	Sampling location			
	5	7	12	13
	[10 ⁻⁶ μ Ci/mL $\pm$ 2 σ (%)]			
Jan.	— ^b	— ^b	— ^b	— ^b
Feb.	— ^b	1.7 $\pm$ 3	1.8 $\pm$ 3	— ^b
Mar.	2.0 $\pm$ 3	1.7 $\pm$ 2	1.9 $\pm$ 3	— ^b
Apr.	1.6 $\pm$ 3	1.8 $\pm$ 3	1.9 $\pm$ 2	— ^b
May	1.7 $\pm$ 3	1.9 $\pm$ 3	1.9 $\pm$ 3	1.7 $\pm$ 3
June	2.0 $\pm$ 4	1.9 $\pm$ 3	2.0 $\pm$ 4	1.7 $\pm$ 3
July	2.0 $\pm$ 3	1.9 $\pm$ 3	2.0 $\pm$ 3	1.9 $\pm$ 3
Aug.	2.0 $\pm$ 3	1.9 $\pm$ 3	1.8 $\pm$ 3	1.7 $\pm$ 4
Sept.	1.9 $\pm$ 3	1.6 $\pm$ 3	— ^b	1.8 $\pm$ 3
Oct.	1.9 $\pm$ 3	1.6 $\pm$ 3	— ^b	1.8 $\pm$ 3
Nov.	0.5 $\pm$ 7	— ^b	— ^b	1.8 $\pm$ 3
Dec.	— ^b	— ^b	— ^b	— ^b
Mean	1.7	1.8	1.9	1.8
SDM (%)	28	7	4	4

^a Potassium-40 is a naturally occurring radionuclide and is not an emission from LLNL.

^b No data. See Quality Assurance chapter.

Table L-33. Cesium-137 in milk—Livermore Valley, 1989.

	Sampling location			
	5	7	12	13
	[10 ⁻⁹ μ Ci/mL $\pm$ 2 σ (%)]			
Jan.	— ^a	— ^a	— ^a	— ^a
Feb.	— ^a	<0.17	<0.17	— ^a
Mar.	1.19 $\pm$ 91	<0.14	<0.18	— ^a
Apr.	<0.17	1.46 $\pm$ 81	<0.14	— ^a
May	<0.20	<0.16	<0.14	<0.16
June	<0.17	<0.16	<0.19	<0.13
July	0.94 $\pm$ 98	4.89 $\pm$ 41	<0.16	0.58 $\pm$ 19
Aug.	<0.17	<1.61	<0.16	1.57 $\pm$ 77
Sept.	<0.17	<0.18	— ^a	<0.18
Oct.	<0.16	<0.16	— ^a	<0.18
Nov.	<0.67	— ^a	— ^a	<0.16
Dec.	— ^a	— ^a	— ^a	— ^a
Median	0.17	0.17	0.16	0.18
MAD ^b (%)	6	6	13	11

^a No data. See Quality Assurance chapter.

^b Median absolute deviation (%). See Quality Assurance chapter.

ENVIRONMENTAL RADIATION MONITORING

Introduction

Penetrating radiation, which cannot be measured by collection of material on filters nor chemically trapped, is measured using dosimeters. The dosimeters provide a measure of the total amount of radiation, both background radiation and any radiation that has man-made origins, at a particular location. Penetrating radiation primarily includes gamma rays, but also includes neutron radiation.

Methods

External doses from gamma radiation are measured at 22 Livermore-site perimeter locations (**Figure L-19**) and 55 offsite locations (**Figure L-20**). Thermoluminescence dosimeters (TLDs) are used to measure external gamma radiation doses. The dosimeters are mounted in the field on existing structures (such as fence lines) at approximately 1 m above ground level. The dosimeters are exchanged, analyzed, and dose rates are calculated quarterly.

The dosimeters contain three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Each dosimeter is heat-sealed in a 3-1/2 in. $\times$ 2-1/4 in., 4.5-mm-thick foil pouch for protection against light and moisture. The TLDs measure gamma radiation exposure from all sources of radiation. These include natural sources, fallout from past nuclear weapons testing, and any contribution from LLNL. Offsite dosimeters are located in areas surrounding the Livermore site and nearby residential areas. These areas are considered background, and they are used for comparison with the perimeter dosimeters. When a TLD is missing, the annual dose is calculated as four times the average quarterly dose determined from available data.

The TLDs measure environmental gamma radiation exposure in milliroentgens (mR). The measured exposure is converted to dose by calibrating the dosimeters to read out in absorbed dose and applying a quality factor for a

Figure L-19. Locations of Livermore-site gamma and neutron dosimeters, 1989.

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beta/gamma radiation field. The resulting dose equivalents (mrem) are compared to radiation protection standards. The dose at the Livermore-site boundary also is compared to background measurements to determine the contribution, if any, from LLNL operations.

Environmental neutron dose measurements using ^{235}U track-etch detectors are also made at eight locations on the Livermore-site perimeter. A detailed description of the detector and the spark-counting procedure used may be found in Fisher (1976). Neutron-monitoring locations are shown in **Figure L-19**.

Results

Table L-34 shows the quarterly and annual TLD gamma radiation dose-equivalents for perimeter locations, and **Table L-35** presents data for offsite

locations. The average annual dose equivalent from external exposure at the LLNL site boundary (61 mrem) is statistically the same as the background external dose measured in the Livermore Valley (63 mrem) as determined by analysis of variance. **Figure L-21** presents the 1989 frequency distribution of environmental gamma doses measured at the 55 offsite locations. The annual total dose is almost identical to that in 1987 (64 mrem) and 1988 (63 mrem). This demonstrates that there is no measurable dose due to direct radiation from LLNL operations at any point beyond the Livermore-site boundary.

Table L-36 presents the data for neutron monitoring at the Livermore-site perimeter. The annual average neutron radiation dose at the Livermore-site perimeter for 1989 is 5.3 mrem, similar to the 1987

Figure L-20. Locations of Livermore Valley gamma dosimeters, 1989.

(5.0 mrem) and 1988 (4.2 mrem) values. The neutron doses measured at the site boundary are consistent with those expected from natural background radiation.

Environmental Impact

Based on past measurements (Lindeken et al. 1973), environmental terrestrial exposure rates in the Livermore Valley vary from 30 to 60 mR/y. Cosmic radiation is about 35 mR/y [calculated from local elevation and geomagnetic latitude

according to the data of Lowder and Beck (1966)]. This results in a total typical exposure rate of 65 to 95 mR/y. Exposures measured at the LLNL perimeter fall within these predicted values. In addition, the external dose measured at the LLNL perimeter is identical to the offsite dose, which is considered natural background. This indicates that there is no contribution to the external dose at or beyond the Livermore-site fence line from LLNL operations.

Figure L-21. Offsite gamma radiation background dose frequency distribution, Livermore, 1989.

Table L-34. Environmental radiation measurements (TLD)—Livermore-site perimeter, 1989.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual Total
	(mrem)				
1	16	17	16	18	67
2	14	15	16	15	60
3 ^b	16	18	17	18	69
4 ^b	16	17	18	24	75
5 ^b	15	17	17	18	67
6 ^b	15	16	17	24	72
7	15	17	17	17	66
8	16	17	17	16	66
9	16	17	17	17	67
10	14	15	16	16	61
11	11	12	13	13	49
12	13	13	14	14	54
13	15	15	— ^c	— ^c	60
42	14	15	15	16	60
47	15	15	17	16	63
48	14	16	16	16	62
49	14	14	16	16	60
50	14	— ^c	15	15	59
52	15	15	16	16	62
53	16	16	16	17	65
54	15	16	16	16	63
56	14	14	15	15	58
Mean	15 (15) ^d	15 (16) ^d	16 (16) ^d	16 (17) ^d	61 (63) ^d
SDM (%)	9 (8) ^d	9 (10) ^d	7 (7) ^d	7 (16) ^d	7 (9) ^d

^a See Fig. L-19.

^b Due to recent land acquisition, the Livermore-site perimeter has been extended. Locations 3, 4, 5 and 6 are no longer at the perimeter, but now are located onsite.

^c Dosimeter missing; see Quality Assurance chapter.

^d Averages calculated including onsite locations 3, 4, 5 and 6 are presented in parentheses.

Table L-35. Environmental radiation measurements (TLD)—Livermore Valley, 1989.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual	Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual
	(mrem)				Total		(mrem)				Total
14	14	10	15	15	54	44	15	14	18	18	65
15	15	17	17	17	66	45	13	15	15	15	58
16	15	16	17	17	65	46	14	15	— ^b	15	59
17	16	— ^b	15	16	63	51	13	17	16	17	63
18	14	15	16	16	61	55	14	16	18	15	63
19	14	14	15	15	58	57	15	16	17	18	66
20	14	14	15	— ^b	57	58	14	16	16	16	62
21	14	14	14	14	56	59	16	16	16	17	65
22	15	16	.8	18	67	60	15	15	16	15	61
23	15	16	— ^b	16	63	61	13	13	14	14	54
24	— ^b	18	18	17	71	62	— ^b	25	14	14	71
25	— ^b	17	18	19	72	63	14	16	16	16	62
26	— ^b	17	23	18	77	64	14	16	17	17	64
27	15	— ^b	18	17	67	65	14	17	— ^b	16	63
28	17	18	18	18	71	66	15	16	16	16	63
29	15	17	17	17	66	67	15	16	17	16	64
30	14	15	16	18	63	68	15	16	16	16	63
31	14	14	15	15	58	69	14	— ^b	— ^b	16	60
32	14	16	17	16	63	70	15	16	16	16	63
33	15	17	17	— ^b	65	71	16	17	18	19	70
34	16	— ^b	19	18	71	72	16	18	18	17	69
35	15	16	17	16	64	73	15	16	16	16	63
36	15	— ^b	17	16	64	74	14	14	15	15	58
37	15	15	16	16	62	75	12	13	13	14	52
38	15	16	17	18	66	76	17	11	11	12	51
39	15	17	17	17	66	77	14	14	15	14	57
40	15	17	19	16	67	Mean	15	16	16	16	63
41	15	15	15	17	62	SDM (%)	13	27	22	17	16
43	14	15	15	17	61						

^a See Fig. L-20.

^b No data available; dosimeter was missing, see Quality Assurance chapter.

Table L-36. Environmental neutron monitoring—Livermore-site perimeter, 1989.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual
	(mrem)				Total
1	1.1	1.1	1.2	1.6	5.0
2	1.1	1.4	1.6	1.6	5.7
3	0.9	1.1	1.9	1.7	5.6
4	0.8	1.3	1.4	1.1	4.6
5	1.3	1.2	1.6	1.0	5.1
6	0.6	0.8	1.4	1.2	4.0
7	1.1	1.1	2.1	1.9	6.2
8	1.4	1.4	1.6	1.5	5.9
Mean	1.0	1.2	1.6	1.5	5.3
SDM (%)	25	17	18	22	14

^a See Fig. L-19.

RADIOLOGICAL DOSE ASSESSMENT

Introduction

Because of the broad distribution of this report outside the scientific community, we present here a short, general discussion of radiation before we discuss the Livermore site radiological dose assessment. Many of the terms used in this report, such as "rad" and "rem," have no counterparts in everyday English. Our purpose in presenting this discussion is to enable the general reader to better understand the radiological dose assessment information contained in this report. [The interested reader is referred to *Radiation: Doses, Effects, Risks* (U.N. Environment Programme 1985), from which some of this discussion was excerpted.]

Natural and Man-made Radiation

Atoms are made up of three types of particles: protons, electrons, and neutrons. Atoms of the same element have the same number of protons; however, atoms of the same element can have differing numbers of neutrons in their nucleus. Those atoms of elements that have differing numbers of neutrons, but the same number of protons, belong to different varieties or "isotopes" of the element. Isotopes are distinguished by the total number of protons and neutrons in their nuclei. For example, uranium-238 has 92 protons and 146 neutrons, whereas uranium-235 has 92 protons and 143 neutrons. Generically, species of atoms that are so characterized are called "nuclides."

Many nuclides are unstable because the particles in the nucleus cannot remain tightly clustered together. Eventually some of the particles will break away. For example, two protons and two neutrons will eventually break away from the nucleus of uranium-238, resulting in the creation of thorium-234 with 90 protons and 144 neutrons. However, thorium-234 is also unstable, and becomes protactinium-234, with 91 protons and 143 neutrons. Protactinium-234 is extremely unstable and continues to lose particles until it finally ends up as lead.

This transformation process is called "radioactivity," and the unstable nuclides are called "radionuclides." As each change takes place, energy is released and is

transmitted as radiation. Loosely speaking, the emission of protons and neutrons, as from uranium-238, is "alpha" radiation; and the emission of an electron is "beta" radiation. Frequently, the unstable nuclide will be so excited that the emission of particles is not sufficient to reach a more stable state; it then gives off a burst of electromagnetic energy called "gamma" radiation. Gamma radiation does not involve the emission of particles.

The different forms of radiation are emitted with different energies and penetrating power—and so have different effects on living things. Alpha radiation, with its relatively heavy neutrons and protons, is halted by a sheet of paper, and can scarcely penetrate the dead outer layers of skin. It is not dangerous unless substances emitting it get into the body through an open wound or are eaten or breathed in, when it becomes especially damaging. Beta radiation is more penetrating. It will go through a centimeter or two of living tissue. Gamma radiation is extremely penetrating and will go through anything short of a thick slab of lead or concrete.

Measurement of Radioactivity and Dose.

The radioactivity of a nuclide is measured by the number of transformations that take place each second. It is measured in units called curies (abbreviated Ci); each curie equals 3.7×10^{10} transformations per second.

However, the number of transformations, the radioactivity, is not a measurement of the effect of the nuclide on living tissue. It is the energy of radiation which does the damage, and the amount of energy deposited in living tissue is called the "dose." The dose may come from any radionuclide, or number of radionuclides, whether they remain outside the body or irradiate it from inside after being inhaled in air or swallowed in food or water. Doses are expressed in different ways depending on how much of the body and what parts of it are irradiated, whether one individual or many people are exposed, and the period during which the exposure takes place.

The amount of radiation energy that is absorbed per gram of tissue is called the absorbed dose and is measured in units called rads. However, the same absorbed dose of alpha radiation is much more damaging than one of beta or gamma radiation. Consequently, the dose needs to be weighted for its potential to do damage, with alpha radiation given 20 times the weight of the others. This weighted dose is known as the "dose equivalent," and it is measured in units called rem.

Just as one type of radiation can be more damaging than the others, so can some parts of the body be more vulnerable than others. For example, a given dose equivalent of radiation is more likely to cause fatal cancer in the lung than in the thyroid, and the reproductive organs are of particular concern because of the risk of genetic damage. The different parts of the body are, therefore, also given weightings. Once it has been weighted appropriately, the dose equivalent becomes the "effective dose equivalent," also expressed in rem.

The effective dose equivalent describes only doses to individuals. When all the individual effective dose equivalents received by a group of people are added up, the result is called "the collective effective dose equivalent," and this is expressed as person-rem.

There is one further definition to be introduced. Because many radionuclides decay so slowly that they are radioactive far into the future, there is a collective effective dose equivalent that will be delivered to generations of people over time. This is called the "collective effective dose equivalent commitment."

This hierarchy of concepts is illustrated in **Figure L-22**. Most of the discussion in this report will address absorbed dose and effective dose equivalent. However, the other terms will be used as required to ensure accuracy and eliminate ambiguity.

Natural Sources of Radioactivity. By far the greatest part of radiation received by the world's population comes from natural sources, such as cosmic radiation, radiation from radioactive materials in rocks, and radon gas released from deep in the earth. Human exposure to natural radiation can be external, from substances that may remain outside the body, or internal, from substances inhaled in air or swallowed in food and water. Individual exposures vary with location; the approximate average radiation exposure from natural sources including radon in the general Livermore area is 318 mrem.

Approximately 40 mrem of the exposure to external natural radiation comes from cosmic rays. Most of these rays originate deep in interstellar space, although some are released from the sun during solar flares. They irradiate the earth directly, and interact with the atmosphere to produce further types of radiation and different radioactive materials. The poles receive more cosmic radiation than the equatorial regions because the earth's magnetic field diverts the radiation. More significantly, the level of radiation increases with altitude because there is less air overhead to act as a shield.

Another major source of external radiation is radioactive materials in rocks; this accounts for approximately 50 mrem of exposure in the general Livermore area. The main radioactive materials in rocks are potassium-40, rubidium-87, and two series of radioactive elements arising from

the decay of uranium-238 and thorium-232. The levels of terrestrial radiation differ from place to place around the United States and around the world.

Much of the internal dose to humans from natural sources of radioactivity is derived from terrestrial sources. Inhalation exposure is dominated by the short-lived decay products of radon, resulting in a dose of approximately 200 mrem/y, depending on the geographical location, or 63% of natural exposure. Radon seeps out of the earth all over the world, but levels in outside air vary markedly from place to place. Radon in water and natural gas provide further, but less important, sources of radon in homes. Consumption of water high in radon is not the main problem, for heating the water releases the gas. The greater exposure arises from radon in water vapor in showers. Ingestion of radionuclides is another source of internal exposure. The foods we eat also contain natural

radioactivity, which results in approximately a 28 mrem dose, depending on the soil type and other factors at the location where the food is grown.

Man-Made Sources of Radioactivity.

Man-made radionuclides have been used in medicine, consumer products, the production of energy, and the production of nuclear weapons. Generally, exposure to man-made sources can be more readily controlled than exposure to most natural sources; although exposure to external irradiation due to fallout from past nuclear explosions is virtually inescapable.

At present, medicine is the greatest source of human exposure from man-made radiation. Individual doses vary enormously—from zero for someone who has not had an x-ray examination to many thousand times the annual average dose from natural radiation for some patients undergoing treatment for cancer. Another source of human exposure to man-made radiation is consumer products, including

Radioactivity	Term	Units of measure
Absorbed dose: Energy imparted by radiation per gram of tissue.	rad
Dose equivalent: Absorbed dose weighted for the potential of different radiations to do damage.	rem
Effective dose equivalent: Dose equivalent weighted for susceptibility to harm different tissues.	rem
Collective effective dose equivalent: Effective dose equivalent to a group of people from a source of radiation.	person-rem
Collective effective dose equivalent commitment: Collective effective dose equivalent delivered over time to generations of people.	person-rem

Figure L-22. Radiation dose terminology and corresponding units of measure (adapted from U.N. Environment Programme 1985).

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luminous-dial watches, smoke detectors, airport x-ray baggage-inspection systems, optical lenses, false teeth, and tobacco products. On the average, medical and consumer-product sources of radiation result in a dose of approximately 90 mrem/y.

Radiation Protection Standards

The DOE environmental radiation protection standards are provided in DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (U.S. Department of Energy 1990). The order incorporates a new system for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 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 definition of "effective dose equivalent" is somewhat different than the definition provided above; the term is defined as the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards, which apply to air emissions, are contained in 40 *Code of Federal Regulations* Part 61, Subpart H of the Clean Air Act and are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway. (On December 15, 1989, the standard was changed to 10 mrem/y effective dose equivalent; this value will be reflected in the report for 1990.)

The DOE and EPA standards are different. Each uses different criteria for determining the standard. The EPA standard is based on the AIRDOS-EPA-Clean Air Act Code (CAAC) model code, while LLNL, to fulfill the DOE requirement, historically has used the Continuous-Point-Source Code (CPS Code); this results in somewhat different calculated individual doses because of the differences in model assumptions and calculations. In recent years, LLNL has run both model codes and presented the results of each. Both model codes were run again in 1989, and the results are summarized in **Tables L-37 to L-40**.

Potential Radiological Dose from the Livermore Site

Small amounts of radioactive materials from operations at the Livermore site were discharged to the environment in air and sewer effluents during 1989. The total amount of tritium released to the atmosphere by LLNL in 1989 was 2951.8 Ci, of that, 1556.8 Ci in the form of tritiated water. An additional 834 Ci of tritium was released by Sandia National Laboratories, Livermore (SNLL), with approximately 656 Ci in the form of tritiated water. The total quantity of ^{13}N (half-life of 10 minutes) and ^{15}O (half-life of 2 minutes) released in 1989 was 42 Ci at the Livermore site. The amount of radioactivity released from LLNL during 1989 was lower than 1988 and well within the range of previous years (see **Table L-8** in the Air Monitoring chapter).

In accordance with DOE environmental protection orders and other Federal and State requirements, the EMG assessed the radiological impact from operations at LLNL during 1989. Potential radiation doses to the public that were calculated from radionuclide concentrations in environmental media (determined by surveillance sampling) are presented with the data in the various chapters; doses calculated from emissions of radioactive materials to the atmosphere are presented here.

Radiation doses based on emissions were calculated by two methods: the EPA Clean Air Act Code (CAAC) (40 *Code of Federal Regulations* Part 61, Subpart H), which contains the AIRDOS-EPA and RADRISK models, and the Continuous-Point-Source (CPS) Code (Peterson et al. 1976). EPA mandates use of the CAAC AIRDOS-RADRISK model. Both model codes are run because LLNL used the CPS Code prior to the EPA requirement for the use of the CAAC AIRDOS-RADRISK model, and the results from the CPS Code can be compared to results from previous years.

The CAAC Code is used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and dose at the maximum offsite exposure location for each emission source. The CPS Code is used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and maximum offsite dose as well as collective person-rem dose to the population residing within 80 km of the Livermore site. Both of these methods are based on conservative assumptions, and any actual dose received by an individual would be much less. **Appendix A** contains definitions of the doses discussed in this subsection and the mathematical equations used to perform this assessment.

These codes were used to determine the doses due to releases of tritium, ^{13}N , and ^{15}O . There was no evidence of gamma or neutron exposure in excess of background values. The 1989 average external gamma-radiation (fence-line) doses measured at the Livermore-site boundary and Livermore Valley locations were 61 mrem and 63 mrem, respectively (see Environmental Radiation chapter). Consequently, there were no doses due to penetrating radiation above background.

EPA Clean Air Act Code. This year, as for 1988, the air pathway doses calculated using the Clean Air Act Code included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The Clean Air Act Code was run using specific meteorology for the

Livermore site. The air pathway dose calculated is expressed as dose equivalents.

The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Livermore-site operations in 1989 was 0.53 mrem; the dose to the nearest resident was 0.33 mrem; and the dose at the point of maximum offsite exposure was 0.53 mrem. These doses represent 2% or less of the 1989 EPA limit. Doses for emissions from specific facilities were also calculated, see **Table L-37**.

Continuous-Point-Source Code. Air pathway doses are also calculated for each facility considered to have a measurable airborne discharge to the atmosphere using CPS Code (**Table L-38**). The maximum combined inhalation dose (i.e., the total from all facility discharges) from airborne emissions at the Livermore-site perimeter was 0.31 mrem. The maximum combined inhalation dose from airborne emissions to the nearest resident was 0.21 mrem.

Figure L-23 presents a comparison of the calculated radiological dose at the site perimeter from airborne emissions in 1989 with similar air pathway doses for the previous 11 years. This figure also shows the contribution of each radionuclide to the total dose. (There have been no ^{41}Ar emissions since the LLNL research reactor was shut down in 1981.) The dose from tritium was entirely due to tritiated water (HTO). Elemental tritium (HT) dose was evaluated but did not present a measurable contribution to the dose; therefore, it was not included in the graph.

Figure L-24 presents the dose at the site perimeter since 1973. The current DOE radiation protection limit for the public is 100 mrem during a 1-y period. Prior to 1986, this limit was 500 mrem/y. As illustrated in **Figure L-24**, the total offsite dose has decreased significantly over past years. Fluctuation in dose from year to year is due to changes in operations and operating schedules. Since 1984, the offsite doses have remained very low, all less than 0.2% of the DOE limit. The calculated doses by

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year from 1984 to 1989 were 0.09 mrem, 0.22 mrem, 0.16 mrem, 0.18 mrem, 0.11 mrem, and 0.31, respectively.

Table L-39 is a summary of the radiological dose to the maximally exposed individual in the public; this is a hypothetical person who lives at a location and has a lifestyle that results in receipt of the maximum possible calculated radiation dose from Livermore-site operations. This dose includes all significant exposure pathways, not just the air pathway, and is derived using the most conservative, but realistic, exposure data and assumptions. The inhalation submersion pathways are calculated using the CPS Code. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1989 was 0.43 mrem. The DOE radiation protection limit to the public is 100 mrem/y. For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation, including the dose from radon, during this same period. (A dose value for

radon of 200 mrem/y has been determined specifically for the Livermore area. The dose from radon is included because, at 200 mrem, it represents the largest single source of radiation exposure for Livermore-area residents.)

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 0.64 person-rem during 1989. This dose is based on a population of 6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources, during the same period of time was estimated to be 1.9×10^6 person-rem.

Table L-40 compares the dose to the public resulting from Livermore-site operations with the dose to the public from natural and other background sources of radiation. The dose resulting from Livermore-site operations is negligible.

Figure L-23. Calculated radiological dose by radionuclide to the hypothetical maximally exposed individual from the air pathway, Livermore site, 1978-1989.

Figure L-24. Maximum air pathway dose at the Livermore-site perimeter, 1973-1989.

Summary

Overall, all measured and calculated radiation doses were well below the applicable standards for radiation protection of the public. Moreover, the potential radiological doses from Livermore-site operations were substantially less than the doses normally received from natural sources of background radiation.

A committee of the National Academy of Sciences has suggested that the average risk factor for total body exposure to ionizing radiation is on the order of 120 fatal cancers for each 1 000 000 person-rem of exposure (NAS 1980). From **Table 39**, the total body dose to the maximally exposed person is 0.43 mrem, from all LLNL operations and all exposure pathways; thus, the risk to the hypothetical maximally exposed individual of developing a fatal cancer is less than 1 in 20 million. Moreover, it should be noted that the annual average total body dose to individuals in the United States from natural sources, including radon, is approximately 200 mrem, and approximately 100 mrem from man-made sources, such as medical procedures, consumer products, weapons fallout, and airline travel.

The risk of developing cancer from radon can be used as a basis of risk comparison. Radon is a radioactive gas in our environment that results from the decay of naturally occurring uranium in the earth's crust. Radon gas is ubiquitous and is a source of radiation dose to everyone. Radon gas in water and air results in both whole-body and lung radiation doses. The lung dose from environmental radon air concentrations, particularly in our homes, is a public health concern. The EPA estimates that up to 20 000 lung cancer deaths per year may be due to radon exposure (U.S. EPA 1986). For the U.S. population of 240 million, the estimated risk of death from lung cancer is approximately 1 in 12 000.

The doses presented above for Livermore-site operations were calculated using conservative assumptions; they are not the doses actually received by anyone. Any dose actually received by an individual would be considerably less. Thus, these maximum credible doses show that Livermore-site operations had no significant impact on public health during 1989.

Table L-37. Radiation dose from the air pathway, all Livermore-site facilities, during 1989 (Clean Air Act Code).^a

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Tritium facility	³ H/2949.4 ^c	0.52	0.32	0.52
Insulating core accelerator	0	0	0	0
Rotating target neutron source	³ H/2.18 ^d	0.0019	0.0007	0.0019
Incinerator	0	0	0	0
Laser complex	³ H/0.25 ^e	0.0002	0.00008	0.0002
Linear accelerator	¹³ N/21 ¹⁵ O/21	0.0094	0.0044	0.0094
Total	2993.8	0.53	0.33	0.53
Percent of Federal Emission Standard^f		2%	1%	2%

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations Part 61, Subpart H*.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose. The doses are calculated using the most conservative exposure assumption and are not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^c Doses are based on 1554.4 Ci of HTO and 1395.0 HT released by LLNL.

^d Doses are based on 2.18 Ci of HTO.

^e Doses are based on 0.25 Ci of HTO.

^f The Federal Emission Standards for radionuclides (contained in 40 *Code of Federal Regulations 61, Subpart H*) limit doses to the public to 25 mrem/y to the whole body and 75 mrem/y to any critical organ. On December 15, 1989, a new standard of 10 mrem/y effective dose equivalent took effect; the percentages of this new standard for dose at site perimeter, dose to nearest resident, and dose at maximum offsite exposure are 5.3%, 3.8%, and 5.3%, respectively.

Table L-38. Estimated radiation dose to the public from Livermore-site airborne effluents during 1989 (Continuous-Point-Source Code).

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Tritium facility	³ H/2949.4 ^b	0.26	0.18	0.26	0.64
Insulating core accelerator	0	0	0	0	0
Rotating target neutron source	³ H/2.18 ^c	0.0006	0.0004	0.0006	0.071
Incinerator	0	0	0	0	0
Laser complex	³ H/0.25 ^d	0.00007	0.00004	0.00007	0.00012
Linear accelerator	¹³ N/21 ¹⁵ O/21	0.05 ^e	0.03 ^e	0.05 ^e	0.00001 ^e
Total (Livermore site)	2993.8	0.31	0.21	0.31	0.64

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b Doses are based on 1554.4 Ci of HTO and 1395.0 HT released by LLNL.

^c Doses are based on 2.18 Ci of HTO.

^d Doses are based on 0.25 Ci of HTO.

^e Submersion dose. The short half-life of ¹³N and ¹⁵O preclude calculation of air inhalation dose.

Table L-39. Summary of radiological dose assessment for 1989 for the Livermore site.

Effective dose equivalent to the maximally exposed individual in the public						
Nuclide	Pathways			Total		Percent of DOE primary radiation protection standard for the public ^b
	Inhalation/ submersion ^a (mrem)	Ingestion- foodstuffs (mrem)	Ingestion- water (mrem)	(mrem)	(mSv)	
³ H	0.25	0.07	0.06	0.38	0.0038	0.38
¹³ N, ¹⁵ O	0.05	N/A ^c	N/A ^c	0.05	0.0005	0.05
Livermore-site Total ^d				0.43	0.0043	0.43

^a The inhalation/submersion dose was derived using the Continuous-Point-Source code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c There is no ingestion dose from short half-life air activation products.

^d This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table L-40. Comparison of radiation doses—Livermore site, 1989.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
LLNL Sources		
Atmospheric emissions	0.43 ^b	0.64
Liquid emissions	0 ^b	0 ^c
Other Sources		
Natural radioactivity ^d		
Cosmic radiation	40	240 000
Terrestrial radiation	50	300 000
Internal (food consumption)	28	168 000
Radon	200	1 200 000
Medical radiation ^{e,f} (Diagnostic procedures)	55	330 000
Weapons test fallout ^{e,g}	5	550 000
Nuclear power production ^{e,g}	5.5	33 000

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of the Livermore site (approximately 6 000 000).

^b These doses represent the maximum committed effective dose equivalent from all LLNL emissions. It is calculated using the most conservative exposure assumptions and is not a dose actually received by any member of the public. Therefore, it is not used to calculate LLNL population dose.

^c Populations dose from Livermore-site emissions.

^d These values vary with location and represent approximate averages in the vicinity of LLNL.

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

^f From Mettler et al. (1990).

^g From Glasstone and Jordan (1980).

PUBLIC HEALTH RISK ASSESSMENTS FOR THE LIVERMORE SITE

Introduction

In 1989, two public health risk assessments were conducted for the Livermore site: one for the emissions from the Building 624 incinerator (Radian Corporation 1989), and the other for exposures from contaminants in groundwater (Layton 1990). Brief summaries of these assessments, preceded by a brief discussion of risk assessment, are presented below. The general discussion of risk assessment and risk management was excerpted from Environ Corporation (1988); the discussions of the specific risk assessments were excerpted from the summaries in the respective risk assessment documents. The reader interested in further general information about risk assessment is directed to Environ Corporation (1988), National Academy of Sciences (NAS 1983), and Moghissi (1984).

Risk Assessment and Risk Management

Risk is the probability of injury, disease, or death under certain circumstances. Regulatory actions are based on two distinct processes, risk assessment and risk management. According to the definitions developed by the National Academy of Sciences (NAS 1983), risk assessment is the characterization of the probability of potentially adverse health effects from human exposures to environmental hazards. Risk management is the process of evaluating alternative regulatory actions and selecting among them. The latter process is guided by risk assessment information and other considerations.

Risk Assessment. The National Academy Sciences has defined four steps in the risk assessment process. These steps are hazard assessment, dose-response assessment, exposure assessment, and risk characterization.

Hazard assessment involves gathering and evaluating toxicity data on the types of health injury or disease that may be produced and on the conditions of exposure under which injury or disease may be produced. Risk is not assessed at this stage. Hazard identification is conducted to determine whether and to what degree it is scientifically correct to infer that toxic effects observed in one setting will occur in other settings (e.g., are chemicals found

to be carcinogenic or teratogenic in experimental animals also likely to be so in exposed humans?).

Dose-response assessment involves describing the quantitative relationship between the amount of exposure to a chemical and the extent of toxic injury or disease. Data are usually derived from animal studies; less frequently, data are derived from studies in exposed human populations.

Exposure assessment involves describing the nature and size of the various exposed populations and the magnitude and duration of their exposures. Exposure, in this context, means the contact between the person and the environmental media (air, diet, water, soil) containing the chemical of interest.

Risk characterization involves integrating the data and analyses involved in the other three steps of risk assessment. The object of this analysis is to determine the likelihood that the human population of interest will experience any of the various forms of toxicity associated with a chemical under its known or anticipated conditions of exposure.

In almost all risk assessments, the assessors must go beyond the available data and make inferences about risks expected for the conditions of exposure under which direct evidence of risk cannot now be collected. In fact, a major conclusion of

the NAS (1983) report on risk assessment was that "the basic problem in risk assessment is the sparseness and uncertainty of the scientific knowledge."

In the absence of information that indicates a "best" or "most correct" assumption about the risk associated with exposure to a chemical, assessors generally choose the most plausible assumption that will not cause the risks to be underestimated; i.e., the most "conservative" choice is made.

Risk Management. The results of risk assessment are but one consideration in most environmental decision making. Risk management is the catch-all phrase that encompasses all of those activities necessary to reach decisions about whether an assessed risk requires reduction and the degree of reduction necessary. The other factors considered by regulatory risk managers, such as costs, benefits, and technical feasibility, depend upon the requirements of applicable statutes and the policy precedents established within the responsible regulatory agencies; however, agencies generally emphasize protection of the public health as a primary goal.

Building 624 Incinerator

Risk Management. In 1989, LLNL pursued a RCRA Part B permit for the Building 624 incinerator and its associated waste-feed tank. As part of this permitting process, DHS and EPA requested that a public health risk assessment be conducted for the emissions. In November 1989, LLNL withdrew its Part B application for the incinerator after EPA found that the trial burn results did not conclusively show that the incinerator met the required 99.99% destruction and removal efficiency. Nonetheless, LLNL submitted the Health Risk Assessment to the regulatory agencies to complete the record and to fulfill its commitment to the public that this report would be made available within the public-comment period for the application.

Hazard Assessment. The types of wastes generated at LLNL and the compounds present in those wastes were identified through a review of waste-treatment records and the LLNL waste-tracking

database. The results of this evaluation were used to identify the types and quantities of compounds to be incinerated.

After the wastes were characterized, potential emissions of toxic substances were determined. Organic emissions from the incinerator were estimated from waste-composition data and the total quantity of waste feed to the incineration based on a 99.99% destruction and removal efficiency. (EPA regulations, 40 *Code of Federal Regulations* 264.343 require a minimum 99.99% destruction and removal efficiency for the operation of a hazardous waste incinerator.) Metal emissions were determined from the waste-composition data and a conservative assumption that all metals present in the waste feed would be emitted from the stack. Emissions from the waste-feed tank were estimated using published EPA factors (U.S. EPA 1988a). Radionuclide emissions were based on LLNL administrative limits restricting the quantity of radionuclides that can be fed to the incinerator (Radian Corporation 1989). It was assumed that all radionuclides would be emitted from the stack. In actuality, however, some of the radionuclides and metals will be present in the incinerator ash and would not be released into the environment.

Toxicity (Dose-Response) Evaluation. Based on the waste characterization and the emissions estimates, a hazard identification process was conducted to focus the risk assessment on those pollutants that could pose a health risk and exclude those with no significant potential for adverse health effects. Relative toxicity and emissions rates were the determining factors for excluding pollutants from further evaluation.

All compounds determined to be carcinogens by the EPA Carcinogenic Assessment Group or by the DHS were included regardless of their emission rates. Additionally, metals, undestroyed principal organic hazardous constituents, and products of incomplete combustion were included, regardless of their emission rates.

Commonly used compounds, such as acetic acid (vinegar), bleach, and sodium chloride (table salt), were omitted. Threshold Limit Values (TLVs) were used

as indicators of relative toxicity when screening the noncarcinogenic compounds. A TLV is an 8-hour time-weighted-average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect (ACGIH 1989). Compounds with TLVs of 100 ppm or greater were omitted from the risk assessment. In this case, TLVs did not serve as indicators of toxicity but suggest relative magnitudes of potential hazards from different emissions. A minimum emission rate of one pound per year was used as a screening criteria for the remainder of the nonradioactive, noncarcinogenic compounds whose TLVs were below 100 ppm. Materials included in the risk assessment are listed in **Table L-41**.

Exposure Assessment. Because weather and wind patterns play an important role in how emitted substances move through the environment, three years of hourly weather data for a monitoring station at LLNL, supplemented by upper air data from the Oakland Airport, were obtained (Radian Corporation 1989). These data were used with two computer models, Industrial Source Complex Short Term (ISCST) and SHORTZ, to simulate the movement of nonradioactive emissions and to estimate air concentrations and deposition rates at offsite locations (Radian Corporation 1989). A different model, the EPA AIRDOS-DARTAB model (U.S. EPA 1979), was used with the LLNL weather data to simulate the movement of radionuclides.

Human exposure to nonradioactive emissions from LLNL was estimated for

Table L-41. Materials included in the Building 624 incinerator risk assessment.

Materials	
Barium	Ethylenedichloride ^a
Benzene ^a	Ethylene glycol
Beryllium ^a	Hexachlorobenzene ^a
Bis(2-ethylhexyl)phthalate) ^a	Lead
Bromodichloromethane ^a	Mercury
Bromoform	Methylene bromide
Butylbenzylphthalate	Methylene chloride ^a
Carbon tetrachloride ^a	Naphthalene
Chlorobenzene	Nickel ^a
Chloroform ^a	Nitrobenzene
Cadmium ^a	Nitrophenol
Chromium ^a	Paraformaldehyde ^a
Copper	Phenol
Diethylphthalate	Silver
meta-Dichlorobenzene	2,3,7,8-Tetrachlorodibenzo-p-dioxin ^a
ortho-Dichlorobenzene	1,1,2,2-Tetrachloroethane ^a
para-Dichlorobenzene ^a	Tetrachloroethylene ^a
Dimethylphenol	Trichloroethylene ^a
Dioxane ^a	Trichlorobenzene

^a Carcinogen.

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both a hypothetical maximally exposed individual (MEI) and individuals at approximately 200 additional locations within a 5-km radius of the Livermore site. The MEI is assumed to be born, reside, and work for a 70-y lifetime at the location of greatest offsite exposure. This approach does not account for differences resulting from population mobility (time spent at work, time spent indoors, and time spent traveling out of the area). The MEI will, consequently, have an exposure greater than the other individuals at the other locations in the Livermore-site area.

Three primary-exposure routes were considered in quantifying the exposure to emissions from the incinerator: inhalation, ingestion, and dermal contact. The EPA AIRDOS-DARTAB model (U.S. EPA 1979) was used to carry out the calculations of radionuclide exposure. The methods for quantifying exposure to emissions of the nonradioactive chemicals are presented in the *RCRA Part B Health Risk Assessment Phase 1. Existing Hazardous Waste Management Incinerator* (Radian Corporation 1989).

Risk Characterization. Finally, the lifetime risk of developing cancer and the potential for both acute and chronic non-carcinogenic effects were evaluated. A plausible case and a worst case are presented to account for the uncertainty in

the health risk assessment process and to provide a range of values for "theoretical" cancer risks. The worst-case analysis includes two separate scenarios—one based on DHS-prescribed potencies (CAPCOA 1987) and the other based on EPA-prescribed potencies (U.S. EPA 1988b, 1989a); in many cases, the potencies prescribed by DHS and EPA are equivalent. The plausible case was evaluated based solely on EPA cancer potency factors. Several compounds, which were identified in small quantities in the incinerator waste stream, could not be evaluated in this risk assessment. The available toxicology data for these compounds were not sufficient to support a calculation of cancer risk. Accordingly, their contribution to the estimated cancer from the incinerator could not be determined.

Noncarcinogenic effects were evaluated by comparing exposure rates to pollutant-specific, health-based criteria (e.g., reference dose or TLVs). An estimate of the increased number of additional cancer cases in the exposed population (referred to as cancer burden) from a 70-y exposure to emissions from the existing incinerator was also included in this risk assessment.

For those compounds fully evaluated in this risk assessment, the worst-case "theoretical" lifetime risk of excess cancer for the MEI was estimated to be nine in ten

Table L-42. Summary of excess cancer risk from exposure to emissions from the Building 624 incinerator.

Scenario	Risk		
	Nonradioactive emissions	Radionuclide emissions	Total emissions ^a
Worst case			
DHS potencies ^b	3.7×10^{-7}	5.4×10^{-7}	9.1×10^{-7}
EPA potencies ^c	1.2×10^{-7}	5.4×10^{-7}	6.6×10^{-7}
Plausible case ^d	6.2×10^{-7}	5.4×10^{-7}	5.5×10^{-7}

^a Values represent the maximum exposed individual's lifetime excess risk of developing some form of cancer due to incinerator emissions.

^b Excess cancer risk values based on DHS-prescribed potency values and worst-case exposure assumptions.

^c Excess cancer risk values based on EPA cancer potency factors and worst-case exposure assumptions.

^d Excess cancer risk values based on EPA cancer potency factors only and the plausible exposure assumptions.

million (9×10^{-7}). This means an individual residing for 70 y at the point of highest concentration of emissions, approximately 300 m east of the incinerator location, has a nine-in-ten-million chance above that risk already incurred by everyday living of developing some form of cancer. This risk estimate is based on cancer potency factors recommended by DHS (CAPCOA 1987). When EPA-recommended potencies (U.S. EPA 1988b, 1989a) are used, the worst-case risk was estimated to be slightly lower, seven in ten million (7×10^{-7}). The excess cancer risk for the MEI in the plausible case was estimated to be six in ten million (6×10^{-7}). The risks for all scenarios are summarized in **Table L-42**. The risk estimates in **Table L-42** represent a conservative estimate of potential risk for the compounds evaluated; the actual risk is likely to be lower and could be as low as zero.

The worst-case "theoretical" number of cancer cases that could develop in the exposed population (cancer burden) was estimated to be 0.0001. This means that 0.0001 (or significantly less than one) case of cancer would be expected in the exposed population of 436 persons over a 70-y period of exposure to the incinerator emissions. The 436 exposed persons are the Livermore valley residents that reside within the area defined by the one-in-ten-million isopleth (Radian Corporation 1989). The one-in-ten-million isopleth, shown in **Figure L-25**, defines the area in which increased risk of one in ten million or greater may occur. Individuals residing outside this oval-shaped area would have excess risks below one in ten million (1×10^{-7}). For one additional cancer case to develop, the exposed population within the area defined by the isopleth would have to increase from 436 people to 10 000 people.

The chronic, noncarcinogenic effects assessment indicated that daily exposure estimates for each compound emitted from the incinerator were below levels believed to produce any adverse effects, even for sensitive individuals such as the elderly or asthmatics. Similarly, the acute effects assessment indicated that maximum one-hour concentrations of

emissions were also below levels that would cause adverse effects.

Groundwater Risk Assessment

Hazard Assessment. A screening analysis was conducted to determine which substances and exposure pathways are potentially important from the perspective of adverse health effects for the public. Thousands of water samples from monitoring wells and data from a number of different soil/sediment and stormwater runoff sampling studies were analyzed.

The first part of the screening focused on the volatile organic compounds (VOCs) in groundwater. The VOCs are dominated by trichloroethylene (TCE), tetrachloroethylene also termed perchloroethylene, (PCE), and chloroform, which account for an estimated 91% of

Figure L-25. The risk isopleth defining an area in which residents have at least a one-in-ten million increased risk of cancer from incinerator operations (from Radian Corporation 1989).

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the total amount of VOCs dissolved in groundwater under the Livermore site. Based on the results of previous chronic animal bioassays, lifetime exposure to TCE, PCE, and chloroform may pose a cancer risk. The remaining 9% of the VOCs in groundwater is composed of a variety of different organic compounds, over half of which is 1,1-DCE. However, from a health-risk perspective (as agreed by DHS), the most hazardous is carbon tetrachloride, which was used to represent the adverse effects of the remaining 9% of the VOCs. Nonetheless, 1,1-DCE was also assessed because it also poses a cancer risk.

The second part of the screening examined other contaminants in groundwater, including benzene from a gasoline spill from an underground storage tank in 1979 and radioactive tritium. The very slow groundwater movement in the locale of the onsite gasoline spill in combination with benzene's fairly rapid biodegradation rate virtually assures that benzene will never reach detectable concentrations beyond DOE property. Consequently, benzene does not constitute a public-health threat. Tritium exceeds the California drinking water standard of 20 000 pCi/L (22 *California Code of Regulations* Section 64443) in one well (25 000 pCi/L). Levels have declined significantly over the period of LLNL's sampling due to radioactive decay and will be reduced further with time to levels well below the State standard. Consequently, tritium will be below regulatory limits prior to offsite migration in groundwaters.

The final part of the screening analysis examined the nature and extent of soil contamination. Principal findings of that analysis are that (1) no contaminated soils have been found off site; (2) the only potential soil-based exposure pathway for the public to soil on site is through the inhalation of volatilized VOCs migrating off site, a pathway that was found to be insignificant; (3) for persons on site, there is a potential for exposure in certain areas to soils contaminated with VOCs, PCBs,

and inorganic substances, but the potential hazard is too low to require a quantitative risk assessment, moreover, access to these areas is minimal and cleanup is already in progress; and (4) there is no evidence to suggest that soil concentrations of radioactive substances present a public health hazard.

To assess the potential future health risks of the known contaminants in groundwater, the movement of VOCs was modeled. We calculated 70-y average concentrations at both existing and potential wells off site using the PLUME model of contaminant transport and fate in the groundwater system (In-Situ, Inc. 1986). The model accounts for the physical and chemical processes that affect the movement and distribution of contaminants.

The physical parameters describing these processes depend on the hydrogeology and environmental chemistry of the chemicals identified as being of concern, and therefore may vary over the complete groundwater flow path. The path, in turn, is determined by the direction of groundwater flow and the locations of potential receptor points, either existing water-supply wells, or hypothetical monitoring wells. Despite comprehensive characterization of the groundwater, there remains some uncertainty about the total mass of contaminants now trapped in unsaturated sediments that could later reach groundwater.

These uncertainties are treated by defining two scenarios: (1) a "best estimate" case, consisting of private and municipal supply wells as receptors and the most probable hydrogeologic, chemical, and source parameters; and (2) a "health conservative" case that considers hypothetical receptors very near the LLNL site (i.e., potential monitoring wells), the highest possible source contamination, and hydrogeologic parameters that would produce the highest offsite concentrations. For the health-conservative case, we assume there is no natural degradation of the compounds, no dilution with clean water at a receptor, and the fastest plausible transport rate. In both cases, we assume all the

groundwater moves westward toward the receptors, when in fact, much of the groundwater flows toward more distant potential receptors to the northwest.

Table L-43 lists the maximum lifetime concentrations of total VOCs at a receptor for the two scenarios. To demonstrate the extremely slow transport velocity, the time at which the highest concentration would occur is also included. In the best-estimate case, the highest 70-y average concentration would be 0.15 ppb in 270 years. However, the health-conservative scenario yields maximum concentrations well above present regulatory limits for several individual compounds.

Dose-Response Assessment. The pertinent background data on the genotoxicity and carcinogenicity to laboratory animals and humans was reviewed for the chemicals identified as being of potential concern in groundwater and soil. Accordingly, the dose-response information, cancer potency factors (CPFs), and reference doses (RfDs) used in the risk characterization process were obtained from this review. All of this information is contained in the text and appendices of the Remedial Investigation Report (Thorpe et al. 1990) and the Baseline Public Health Assessment (Layton 1990).

Exposure Assessment. Exposures to predicted concentrations of VOCs in well water are governed principally by the potential uses of existing or future wells. Review of the wells located west of the Livermore site indicates that domestic and irrigation uses are the most significant. Accordingly, potential exposures to VOCs

were estimated for tap water uses in the home via ingestion of water, inhalation of VOCs volatilized during showers, and dermal uptake of VOCs in bath water. Potential irrigation-related exposures consist of the ingestion of fruits and vegetables from home gardens watered with contaminated well water and the inhalation of VOCs that volatilize during sprinkler irrigation.

The exposure assessment demonstrates that tap water use is the main exposure pathway and that ingestion accounts for a significant proportion of the daily predicted-dose rate. Inhalation of household air containing VOCs derived from tap water represents another significant fraction of the daily dose rate, and dermal uptake also accounts for a significant amount of the total intake. The exposure from ingestion of fruits and vegetables irrigated with well water contaminated with VOCs is shown to be less than the exposures estimated for tap-water uses in a home. Inhalation exposures to VOCs volatilized from sprinklers are found to be several orders of magnitude below those estimated for the other water-based pathways.

Risk Characterization. The incremental excess risk of developing cancer as a consequence of the predicted 70-y (lifetime) exposure to a VOC in well water is calculated as the product of the estimated dose rate and a carcinogenic-potency factor. Potencies for the VOCs of interest were obtained by fitting a dose-response model to tumor-incidence data from chronic animal bioassays (Bogen et al. 1987, 1988;

Table L-43. Summary of excess cancer risk from exposure to VOCs in groundwater.

Scenario	Highest 70-y average concentration of total VOCs (ppb)	Arrival time of maximum concentration (y)	Cancer risk
Best estimate ^a	0.15	270	2×10^{-7}
Health conservative ^a	440	110	1×10^{-3}
Health conservative ^b	584	35	2×10^{-3}

^a Based on receptor wells in downtown Livermore.

^b Based on a potential monitoring well drilled 250 ft west of the Livermore site.

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U.S. EPA 1985). The maximum excess cancer risk associated with the best-estimate case for the combined 70-y maximum exposure to VOCs at a municipal supply well in downtown Livermore is calculated to be 2×10^{-7} (an additional two-in-ten-million chance of developing cancer over a 70-year lifetime exposure). Under the health-conservative scenario, the highest predicted risk is 2×10^{-3} for exposure to contaminants in water from a potential monitoring well drilled 250 ft west of the Livermore site. Because no wells are likely to be drilled within this area, we also show the risk based on the downtown-Livermore recep-

tor sites under the health-conservative transport scenario. This scenario results in a maximum risk of 1×10^{-3} .

Risk Management. In summary, we emphasize that all of these analyses of risk are based on the premise that no remediation will occur. In fact, LLNL will remediate these contaminants, and actual risks will be much lower. Moreover, the risks that are reported are estimates based on a number of assumptions, and, for this reason, the risk may be as high as predicted or, on the other hand, it may be zero. We also stress that no members of the public are currently exposed to VOCs derived from the use of wells near the LLNL site.

SUMMARY OF ENVIRONMENTAL COMPLIANCE ACTIVITIES

Introduction

This section briefly describes environmental activities performed by LLNL in response to legal requirements. These environmental activities were performed by the Regulatory Affairs Division, the Environmental Restoration Division, the Environmental Guidance Division, and the Hazardous Waste Management Division of the Environmental Protection Department. Included is a description of environmental permits issued to or held by the Livermore site during the year. Also, environmental documents associated with the NEPA process are summarized. A table of public hearings, regulatory inspections, and regulatory permits is presented in **Table L-44**. In addition, this section summarizes pollution abatement projects and special environmental projects or studies conducted or in progress during 1989. For further information about these activities, the interested reader is referred to the documents contained in the Information Repositories located at the LLNL Visitor's Center and the City of Livermore Public Library. A list of these documents is presented in **Appendix B**.

Resource Conservation and Recovery Act (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 those wastes that are designated as hazardous. Similarly, the California Hazardous Waste Control Law sets requirements for the management of hazardous wastes in California. RCRA regulates treatment, storage, and disposal facilities through a permit program. The permit process requires regulatory agency review and approval of a facility's Part A and Part B permit applications. These applications provide information on the facility and the wastes managed at the facility.

In 1989, a waste minimization study was conducted for DOE for the purpose of compiling an historical database covering hazardous, mixed, and radioactive waste generation rates at LLNL from 1983 to 1988. This effort involved assimilating, analyzing and evaluating hazardous, mixed, and radioactive waste records in four databases. Since that time, the

database has been updated to include information about 1989. These data are presented in **Table L-45** and in **Figure L-26**.

Hazardous Waste Permits. The Interim Status Document (EPA identification number CA 2890012584) for hazardous waste storage and treatment at the Livermore site covers specific units, including container storage, tank storage, and treatment.

In February 1989, LLNL submitted a reformatted RCRA Part B permit application for a Final Permit, which combined previously submitted permit applications for the hazardous waste storage, treatment, and incineration units. Also, after completing modifications to the existing incinerator injection system and control system, LLNL performed the second liquid waste trial burn in February 1989. Initial results of this trial burn indicated that the incinerator operated in a manner that met or exceeded the required 99.99% destruction and removal efficiency of the selected principal organic hazardous constituents. This information was provided to EPA and DHS for their review as part of the ongoing permit review process.

In September 1989, the EPA issued a Notice of Intent to Deny the hazardous

Table L-44. Compliance summary—Livermore site.

Type of regulatory action	Regulatory agency
Public hearing (date)	
RCRA Treatment and Storage of Hazardous Waste (Nov. 16)	EPA
Permits (number)	
Underground Hazardous Waste Retention Tanks (22)	ACHD
Underground Hazardous Product Retention Tanks (43)	ACHD
Gasoline Recovery System (1)	BAAQMD
Paint Spray Booth (3)	BAAQMD
Particulate Capture Devices (cyclones/baghouses) (12)	BAAQMD
Solvent Cleaners (51)	BAAQMD
Boilers (96)	BAAQMD
Cleaning/Refurbishment Devices (6)	BAAQMD
Printing Presses (4)	BAAQMD
Paint Spray Booths (3)	BAAQMD
Vapor Recovery Systems (2)	BAAQMD
Groundwater Stripping Systems (2)	BAAQMD
Ovens (2)	BAAQMD
Fire Test Cell (1)	BAAQMD
Wet Scrubber (1)	BAAQMD
Miscellaneous sources (7)	BAAQMD
Interim Status Document No. CA 2890012584 for Hazardous Waste Storage and Treatment (1)	DHS/EPA
Discharge Permit to Sanitary Sewer Permit No. 1250	LWRP
NPDES Permit CA 0029829 Monitoring Well Discharges (1)	RWQCB
WDR 88-075 Groundwater Remediation Activities (1)	RWQCB

...continued

Table L-44. Compliance summary—Livermore site (concluded).

Type of regulatory action	Regulatory agency
Inspections (date)	
Building 611 Waste Accumulation Area (Jan. 10)	ACHD
Building 391 vapor recovery system, Building 403 groundwater treatment facility and system (Feb. 8)	BAAQMD
Annual Inspection of Permitted Sources (Feb. 28, Mar. 2, Apr. 11, May 2, July 11, July 14)	BAAQMD
Source test of air pollution control device at Building 403 (June 13)	BAAQMD
Inspected asbestos removal in Building 115 (Oct. 6)	BAAQMD
Inspected 26 boilers, Facility A (Oct. 17)	BAAQMD
Follow-up visit for 1988 Visual Site Inspection (Jan. 27)	EPA (contractor)
RCRA Compliance Evaluation Inspection of WAAs, plus Area 612, Area 514 and Building 419 Hazardous Waste Management Facilities (Mar. 30–31)	EPA (contractor)
Observed second liquid waste trial burn (Feb. 9–17)	EPA/DHS
Review of Hazardous Waste Management facilities and units (May 22)	DHS
Review areas being considered for hazardous waste storage and treatment (July 5)	DHS
Hazardous Waste Management Inspection (Sept. 29)	DHS
Sampling of Building 196 and Building 322 effluent (May 16, 19, 23, 25)	LWRP
Inspection of Building 196 (July 6)	LWRP
Inspection of 2020 Research Drive (Nov. 17)	LWRP

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waste facility permit for the LLNL site. Reasons for this included failure to provide an assessment of risks posed by emissions from the hazardous waste management facility, inconsistencies and deficiencies within the Part A and Part B permit applications and other written documents, and inadequate secondary containment to meet final permitting requirements in portions of the hazardous waste management facility. In response to this notification, and based on discussions with the regulatory agencies regarding uncertainties within the trial burn report, LLNL announced its intent to withdraw the permit application for the incinerator; LLNL also completed physical upgrades to several hazardous and mixed waste management units to provide better secondary containment and protection from the weather. These upgrades included the pouring of concrete-bermed pads to replace asphalt surfaces and the installation of either roofs or tents to provide protection from sun and rain. Moreover, LLNL completed the incineration risk assessment. In addition, LLNL is scheduled to submit a risk assessment for storage and treatment, and a risk assessment may be required in 1991 for the generator areas.

The Part A and Part B permit applications were significantly revised to describe more specifically the individual waste management units, to reflect physical or operational changes, such as the replacement of asphalt surfaces with concrete floors, and to add mixed waste management units. Written documentation included in the Part B permit application, such as the closure plan, were also revised to address concerns raised previously by DHS. Other items, such as the seismic studies and engineering drawings that had previously been submitted to DHS as part of the Hazardous Waste Operations Plan, were also incorporated into this Part B application. The revised permit application was submitted to the regulatory agencies in December 1989.

Public Hearing. A hearing was held by EPA on November 16th, 1989, to gather public comments on the EPA's intent to deny a RCRA permit for the treatment and storage of hazardous waste at the Livermore site. Initially, the operation of the existing incinerator constituted a portion of the permit application. However, prior to the hearing, LLNL decided to withdraw the incinerator portion of the application. A final decision on the permit

Table L-45. Historical generation or shipment rates of hazardous, mixed, and radioactive waste in gross tons.

Year	LLW ^a	TRU ^b	Mixed	Hazardous	Total
1983	673.00	18.70	NA	1350.00	2041.70
1984	451.67	75.70	151.50	1829.48	2508.35
1985	210.92	28.80	155.27	1618.95	2013.94
1986	265.76	13.70	164.78	1756.43	2200.67
1987	406.68	2.98	46.87	1476.70	1933.23
1988	211.24	3.96	184.11	1363.43	1762.74
1989	119.00	0.00 ^c	201.75	1486.00	1806.75

Note: The data for LLW, TRU, and hazardous waste were developed from shipping manifest and incinerator data (the incinerator has not been used since 1988), while the data for mixed waste were developed from incinerator data, storage data, and treatment data.

^aLow-level radioactive waste.

^bTransuranic-radionuclide-containing waste.

^cThere were no manifests for TRU wastes in 1989 because none were shipped.

denial is expected in 1990.

Inspections. The Livermore site was the subject of four RCRA-related inspections in 1989. On January 27, an EPA contractor visited the Livermore site to verify information collected during the Visual Site Inspection performed October 31 through November 11, 1988. The purpose of this inspection was to identify all types of current waste management areas and to identify areas which may have had releases of hazardous constituents into the environment. The draft RCRA Facility Assessment Visual Site Inspection report dated January 30, 1989, identified approximately 862 Solid Waste Management Units (SWMUs) and 34 Areas of Concern (AOCs). Most of the SWMUs were judged to have low release potential requiring no special review. The remaining SWMUs and AOCs are being addressed through the ongoing CERCLA investigation and remediation activities, the LLNL tank program, or through other regulatory agency permitting activities.

On March 30-31, EPA (through a contractor) conducted a RCRA Compliance Evaluation Inspection of Waste Accumulation Areas (WAAs) plus Area 612, Area 514, and Building 419 Hazardous Waste Management Facilities. A total of six potential violations were noted: (1) fire extinguishers not regularly maintained at four WAAs, (2) some waste containers were not properly closed at two WAAs, (3) accumulation start dates were not indicated on some containers in the 612 Yard Receiving and Segregation Area, (4) "No Smoking" signs were not placed in conspicuous locations at two WAAs, (5) seven incident reports were sent to DHS only and three of the reports did not meet the fifteen-day deadline, and (6) Land Disposal and Restriction Forms were not provided to the Regional Administrator or inappropriate forms were used.

The Compliance Evaluation Report stated that "overall, LLNL representatives provided needed assistance and exhibited a concern for the quality and effectiveness of LLNL's hazardous waste management practices."

LLNL took the following actions in response to the noted potential violations: (1) fire extinguishers at the four WAAs were inspected and certified by the LLNL Fire Chief; extinguishers at remaining WAAs were also inspected and certified, (2) generators were notified by formal memorandum to ensure that caps and lids are placed on all containers before placement in the WAA, (3) all generators were reminded of labeling requirements; current generator training has stressed this issue, (4) new, larger, "No Smoking" signs were placed at the WAAs, (5) in the future, reports will be submitted to both agencies within the fifteen-day allowable time, and, (6) appropriate notification forms are now being used.

On May 22, DHS reviewed Hazardous Waste Management facilities and units in preparation for a California Environmental Quality Act scoping meeting held in June and July. No actions or findings resulted from this review.

On September 29, 1989, DHS conducted an inspection of Hazardous Waste Management operations. The inspector stated during the close-out meetings "that compared to many military bases, this facility appeared to be doing a much better job."

Figure L-26. Historical generation of hazardous, mixed and radioactive wastes, 1983-1989.

He also stated that LLNL is the most complex facility he had ever inspected.

As a result of this inspection, 11 violations and potential violations were noted in the DHS inspection report letter: (1) operation of 3 State-regulated treatment units (drum crusher, silver recovery unit, and the Building 419 solidification and size-reduction unit) were without interim status, permit, or variance; (2) the 3 treatment units were not identified on the Part A application; (3) closure plans were not submitted within required time periods before closing the HF neutralization unit or upon relocation of the silver recovery unit; (4) the HF neutralization unit and the silver recovery unit were not closed in accordance with an approved closure plan; (5) certification statements were not submitted to DHS for the HF neutralization and silver recovery unit; (6) 10 drums of waste had been stored for more than 1 year; (7) a revised Closure Plan had not been submitted to DHS within their specified time frame; (8) National Fire Prevention Association (NFPA) placards were missing on 6 treatment tanks and 1 storage tank; (9) separation of hazardous waste drums containing incompatible materials was inadequate in Area 612-3; (10) a number of tanks and containers were improperly labeled (i.e., missing the words "hazardous wastes," incomplete information, or faded); and (11) the closure plan did not adequately describe activities to close individual waste management units.

In response to the DHS Report of Violation letter, as well as the EPA's September proposed Notice to Deny the LLNL Hazardous Waste Facility permit, the following actions were taken. The Part A and Part B permit applications were extensively revised to specifically address each unit used to manage hazardous and/or mixed wastes. These documents describe both current and proposed management activities. Documents previously submitted to DHS regarding closure of the HF treatment unit and relocation of the silver recovery system were resubmitted to DHS. Additional documentation was

submitted to DHS to demonstrate that it is LLNL's practice to request permission to store wastes for more than one year. The general hazardous waste facility closure plan was extensively revised to address DHS concerns and submitted both under separate transmittal letter and as part of the revised Part B permit application. NFPA placards were installed on the 1 storage tank and 6 treatment tanks. To ensure separation of incompatible wastes, best management practices, such as the use of molded containment pallets and separation by distance of drums containing incompatible wastes, have been employed in Area 612-3 for several years. LLNL has been working with DHS to gain occupancy of a state-of-the-art hazardous waste storage building to replace this particular area. New labels have been obtained that will be more resistant to fading. Storage areas have been equipped with tents or roofs to reduce the impact of weather on labels. Employee training has been and continues to be conducted to show how to properly use labels for waste identification. Finally, in response to the three potential violations, it is LLNL's position that the Building 231 HF scrubber is an air-pollution control device similar to those used widely in industry and is regulated by the BAAQMD. A permit has been obtained from this agency. However, until final resolution of discussions between DHS and LLNL on this issue, the scrubber has not and will not be operated.

In addition, on January 10, Alameda County inspected the Building 611 Waste Accumulation Area (WAA), which was in the process of being upgraded. No discrepancies were found; however, the inspector requested that he be notified when the WAA had been upgraded.

Construction of and Improvements to Waste Accumulation Areas. A Waste Accumulation Area is 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 (HWM) Division for offsite disposal. There are 53 WAAs at the Livermore site, 13 of which were established during 1989.

RCRA Personnel Training. Annual training sessions and as-needed briefings are conducted for generators of hazardous waste in the area of waste handling practices. This training is based upon requirements set forth in 40 *Code of Federal Regulations* Part 265.16 and 22 *California Code of Regulations* Section 67105. Employees learn to identify the basis (i.e., legal, regulatory, policy, and DOE Orders) for LLNL waste practices and the respective waste-management responsibilities for waste generators, Environmental Analysts, or HWM field technicians. The course also includes training in the identification of the factors used to determine if a waste is hazardous, in the determination of the need for permits and controls, and in the reduction of the volume of waste to be discharged. Other topics include preparation of waste for transport and for storage in WAAs, the protocol for sampling waste, preparation of documentation for waste disposal, and response to emergencies at the WAA or in a laboratory or a shop. During 1989, a total of 1995 LLNL Livermore-site employees received this training.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks

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 Law, found in 23 *California Code of Regulations* Chapter 3, Subchapter 16, regulates underground tank systems used for containment of hazardous products or hazardous waste. County health departments, such as the Alameda County Health Department (ACHD), have been delegated authority to enforce these regulations. Federal standards for hazardous products and petroleum products contained in USTs are

found in 40 *Code of Federal Regulations* Part 280, and standards for hazardous wastes in tanks, both aboveground and underground, are the subject of RCRA regulations in 40 *Code of Federal Regulations* Part 265. The Livermore site has 71 aboveground and 88 underground tanks in service. An additional 125 tanks at both the Livermore site and Site 300 have been closed or removed from service.

To ensure that LLNL's UST program is in full compliance with Federal and State regulations, a preliminary classification of USTs as hazardous or nonhazardous was made in 1989 based on existing data and known uses for each tank. In a second phase, these classifications will be verified by an extensive sampling program, a plan for which has been developed and submitted to ACHD for comment. Implementation of Phase II of the classification procedure will be completed in 1991.

Tank Integrity Testing. The tank leak-tightness testing program is in place. Underground tank systems are tested to determine their structural integrity in accordance with testing requirements set forth in Federal and State regulations. All 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 ACHD.

Thirty underground diesel fuel and gasoline systems were tested in 1989. All of these systems but one were leak tight; the leaking system was removed from service in 1989 (and removed from the ground in 1990).

In addition, 33 underground wastewater retention systems were tested. These systems exist to receive and retain wastewater from processes that have been identified as being of potential concern (i.e., metal plating, printed-circuit boards, and semiconductors). Water is retained by

these systems until the appropriate mode of disposal has been determined, based on the results of tank contents analyses. Testing in 1989 identified 10 wastewater systems that could not meet the minimum leak-rate criterion. Leak sites for three of these were repaired.

A program for necessary repairs or closure of the remaining seven systems is under way. Of the seven systems, four have been removed from service, one system was removed from service as a hazardous waste system but remains in service to collect rainwater or irrigation runoff, and two systems remain in service to collect nonhazardous materials.

Closure Plans, Closure Reports, or cleanup reports were completed in 1989 for tank systems or portions of systems that were out of service, previously removed but not officially closed, or planned for removal from service. Closure requirements for USTs include a Closure Plan prior to closure of the system, quarterly reports if a leak has been identified, and a Closure Report following closure activities. The Closure Plans require a detailed review of the uses of the tank, a sampling plan, a site plan, and other information pertinent to ensuring that no environmental contamination has occurred, or if it has occurred, that it is adequately corrected. Additional staff support was obtained to increase progress toward completion of Closure Plans/Reports; twenty-four Closure Plans/Reports were submitted for regulatory review in 1989.

Funding for fiscal year 1990 includes approval for 18 tanks requiring upgrades to meet Federal and State design specifications. Engineering assessments to certify the integrity of all single-wall hazardous waste systems and all newly installed systems are in progress, and are being conducted by staff dedicated to their completion. Additional funding has been requested for fiscal year 1991.

LLNL has also been working to establish a comprehensive inventory reconciliation program for petroleum USTs, and personnel

to conduct the program have been hired. In 1986 at the Livermore-site motor pool, a leak detection system was installed in lieu of an inventory reconciliation. Manual tank gaging for the emergency generator USTs at the Livermore site has been implemented where conversion charts are available. Finalization of an inventory reconciliation program for these tanks has been delayed due to the lack of manufacturer information about the tanks. An alternative procedure for developing the necessary conversion charts has been developed and the charts are being completed.

Personnel in the Tank Program is also working to develop and implement monitoring and release response plans for new double-contained tank systems.

Underground Tank Permits. There are 22 hazardous waste underground retention tanks and 43 hazardous product tanks at the Livermore site that are permitted by ACHD. Of these tanks, 13 of the hazardous waste retention tanks and 34 of the hazardous product tanks are in use, and 9 of the hazardous waste retention tanks and 9 of the hazardous product tanks are removed from service and scheduled to be closed.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I

Also known as the "Superfund" Act, CERCLA is a Federal statute that gives the Federal government the power to identify and clean up hazardous chemicals and substances released to the environment.

The Environmental Restoration Program (ERP) is a DOE program aimed at the cleanup of environmental contamination caused by past waste practices at DOE facilities. A general budget category was created for this program at the request of the House Armed Services Committee. Funding began in 1988; however, LLNL's environmental investigations have been ongoing since 1979. ERP efforts

at the Livermore site are directed mainly toward the Ground Water Project. (At Site 300, the funds are used for the ongoing Environmental Restoration Project.)

Ground Water Project. The Ground Water Project addresses contamination resulting from past releases of hazardous substances at and near the Livermore site. In 1979, an inventory discrepancy led to the discovery that approximately 17 000 gallons of gasoline had been lost from an underground fuel tank in the former-Building 403 area. In December 1983, additional investigations were initiated after volatile organic compounds (VOCs) were detected in offsite and onsite monitoring wells. Currently, efforts are ongoing to monitor the extent of VOCs and gasoline in soil and groundwater. In so doing, pilot remediation has been initiated at the west perimeter of the Livermore site and in the gasoline leak area. In addition, various groundwater computer models are being developed as part of the EPA Remedial Investigation/Feasibility Study process.

In November 1989, a draft of the Remedial Investigation Report for the Livermore site was prepared for agency review. The objectives of the report were to characterize the site and lay a foundation for the development of remediation strategies. Screening of groundwater, surface water, soil, sediments, and air for toxic materials has led to the conclusion that the primary medium of concern is groundwater. The principal compounds found to be of potential concern are volatile organic compounds (VOCs) and fuel hydrocarbons. Eight chlorinated solvents, trichloroethylene (TCE), tetrachloroethylene (also termed perchloroethylene, PCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethylene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethane (1,1-DCA), carbon tetrachloride (CCl₄), and chloroform have been detected in groundwater in the study area in concentrations exceeding Federal or State maximum contaminant levels (MCLs) or State Recommended Drinking Water Action Levels. TCE and PCE are the predominant VOCs and are locally present in concentrations up to about 5.1 and 1.6 ppm

maximum, respectively. Maximum concentrations of other VOCs are typically below several tens to several hundred ppb. Total VOC concentrations exceed 1 ppm in only 8 of 270 sampled wells. The fuel hydrocarbons occur almost exclusively in the area of the leaking underground fuel tank. These hydrocarbons are currently being extracted in a pilot study using vacuum-induced venting. Due to the very low groundwater velocity in the area, the fuel hydrocarbons have not migrated more than about 500 ft from the leak point. No groundwater in the study area has gross alpha or gross beta activities above MCLs. Tritium occurs in a concentration slightly above the MCL in one onsite well. Natural decay will reduce the concentration to below the MCL in a few years, long before the affected waters could migrate off site.

Details of these activities and investigations during 1989 can be found in the following documents: the LLNL Ground Water Project Monthly Progress Reports and Annual Report (Dresen et al. 1990; Dresen et al. 1989a-f; Devany et al. 1989; Iovenitti et al. 1989; Lawson et al. 1989 a-d) and other special topical reports (Layton 1990; Thorpe et al. 1990).

Superfund Amendments and Reauthorization Act (SARA)—Title III

SARA Title III is also 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, the location, the weight, the type of container, and the 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 were used to generate reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site.

SARA/OSHA Personnel Training. LLNL also provides training for hazardous waste operations and emergency response. This training is based upon requirements set forth in 40 *Code of Federal Regulations* Part 1910.120. There are two initial training courses. The first is a 40-hour course geared to general workers performing cleanup operations or investigations, and who are engaged in activities that expose or potentially expose the worker to hazardous substances and health hazards. The second is a 24-hour course for HWM operators and workers on site only occasionally for a specific limited task who are unlikely to be exposed over permissible exposure limits, and for workers regularly on site who work in fully monitored and characterized areas where there is no indication of the possibility of health hazards or an emergency developing. The course covers the hazards of waste sites, the general physical and hazardous properties of chemical compounds, the fundamental toxicological concepts important in determining the toxicity of materials and predicting their effect on exposed individuals, and the physical hazards (heat stress, noise, and ionizing radiation) involved in working at a waste site. The course also covers exposure guidelines, protective clothing and devices, air monitoring, site characteristics, control and safety planning, drum and container handling, confined-space entry, emergencies, and hazard communication. SARA/OSHA supervisory training is also offered. This training is an 8-hour course required for personnel who will be leading others in the field at cleanup operations and at HWM. The course emphasizes the safety and health program, planning, and coordination, site management, personal protective equipment, spill containment programs, and health hazard monitoring procedures.

In 1989, 105 employees received the initial SARA/OSHA training, and 60 employees received the supervisory training.

Toxic Substances Control Act (TSCA)

The Toxic Substances Control Act (TSCA) is a broad statute that empowers EPA to regulate hazardous chemicals produced, used, or imported into the United States that are not already regulated under another set of laws. The TSCA regulations that affect the Livermore site are those regulating the storage and disposal of polychlorinated biphenals (PCBs).

During 1989, LLNL removed and disposed of 5600 "small" capacitors (most of which weighed about 65 pounds) and 30 "large" capacitors (i.e., those heavier than 65 pounds and a few weighing nearly 358 000 pounds) containing PCBs. These capacitors were associated with the Tandem Mirror Experiment (TMX). Until 1989, DOE had required LLNL to keep TMX in a mothballed state so that it could be used again, if necessary. In 1989, DOE modified this requirement. Moreover, in 1989, it was discovered that some of these capacitors were leaking, which further prompted their removal and disposal. Plans were then developed to remove the three-story wooden structure that supported the capacitors, and finally to decontaminate the empty building section.

National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) establishes Federal policy for protection of environmental quality and provides the means for implementing that policy. The major means within NEPA to achieve established goals is the requirement for Federal agencies to assess the environmental impacts of their decisions through preparation of an Environmental Impact Statement (EIS) for any major Federal or Federally funded project that may have significant impacts on environmental quality. If the need for an EIS is not clear, an environmental assessment (EA) must be prepared with a definitive conclusion either calling for an EIS or making a finding of no significant impact (FONSI). In the latter case, no EIS is required.

Groups of actions that do not individually or cumulatively have a significant effect on the human environment can be

exempt from the NEPA process by establishing "categorical exclusions." A "Memorandum" is written when it is clear that a proposed action will have no significant environmental impacts, but because of limited DOE experience, the action has not yet been added to the list of categorical exclusions. An Action Description Memorandum (ADM) is written when the proposed action is not "clearly insignificant." The ADM is used by DOE to determine if an EA or an EIS is needed.

In 1989, over forty projects were evaluated under NEPA and the applicable policies and procedures for DOE compliance with NEPA (Federal Register Vol. 52, No. 240, December 15, 1987), as amended. Two of these were determined by DOE to require an EA; four were the subjects of ADM.

Environmental Assessments. The Nuclear Directed Energy Research Facility (NDERF) (DOE/EA-0364) will modernize portions of LLNL's engineering, physics, and chemistry laboratories, and consolidate the X-Ray Laser Program. NDERF is an office and laboratory complex that will provide the carefully controlled laboratory environment needed to ensure product quality; it will substantially increase laboratory space for developing new materials and production techniques. It will foster better communication between scientific and engineering teams, more efficient security, and increased flexibility to meet rapidly changing program needs. Based on the analyses in the EA, DOE has determined that the proposed action (building and operating NDERF at LLNL) does not constitute a major Federal action significantly affecting the quality of the human environment within the meaning of NEPA. Therefore, a FONSI was issued by DOE.

An EA was also completed for the High Explosive Applications Facility (HEAF) (DOE/EA-0384). As part of a nationwide program to revitalize nuclear weapons facilities, HEAF will provide the physical capability to perform advanced high explosive (HE) experiments. This new

facility will integrate, centralize, and extend many HE activities currently in progress at LLNL. It is a relocation and expansion of existing operations, particularly of LLNL's ability to test larger HE charges when necessary. Proposed experiments in HEAF will provide the technology to further improve safety in the design of nuclear weapons. Upon completion of an EA, a conditional FONSI was issued and became effective in early 1990.

Action Description Memoranda. An ADM was written for the construction and operation of a Sewer Diversion Facility. The purpose of the facility is to prevent releases to the City's sewer system and to prevent use of their diversion basin. The Sewer Diversion Facility will contain equipment to divert offsite flow of untreated sanitary sewage that exceeds alarm levels into onsite retention tanks. The facility will provide sewage containment and allow pH neutralization and biological neutralization by chlorination.

An ADM was also written for the addition of four laboratories to Building 166 and their subsequent operation. The laboratories will be used as a small-scale semiconductor fabrication and test facility for advanced applications in the Laser Program. The primary environmental concern was the use of toxic gases and other hazardous material in the laboratories. However, no significant impact to public health or the environment is expected to result from normal operations or a worst-case accident.

The third ADM was written for the construction and operation of a new building (proposed Building 153) to provide laboratory and office space for the fabrication of microelectronic components and equipment. These activities are currently performed in Building 131, which does not have adequate space to permit safe and effective performance of these operations. As for the addition of four laboratories to Building 166, the primary environmental concern was the use of toxic gases and other hazardous material in the laboratories. However, no significant impact to public health or the environment is

expected to result from normal operations or a worst-case accident.

In addition, an ADM was written for the construction and use of a 12-unit modular research laboratory complex to provide additional space to support the Human Genome, Robotics/Genome, National Gene Library, and basic molecular genetic research. Small amounts of hazardous waste will be generated in the laboratories, including wastes from organic solvents and ^{32}P , a weak beta-radiation emitter. Although administrative and engineered controls will be implemented to eliminate essentially the potential for the release of materials, under extreme conditions, small amounts of ^{32}P could be released. However, the maximum credible accident releasing radioactive materials or waste from the modular complex would not have a significant environmental impact.

Table L-46 lists NEPA-related documents submitted by LLNL to DOE in 1989.

National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements

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

Groundwater Discharge Permits. The Waste Discharge Requirements, Order 88-075 pertains to activities being undertaken to investigate and remediate groundwater contamination at the Livermore site. It allows discharge of

treated groundwater to specified areas on DOE property. The NPDES permit CA 0029289 applies to discharges to the ground from monitoring wells used in the groundwater investigation.

Wastewater Permits. The Livermore site had a Wastewater Discharge Permit from the City of Livermore Water Reclamation Plant (LWRP) for discharges to the city sanitary sewer system for 1988 to 1989 (Permit No. 1250). The text of this permit is presented at the end of the chapter on sewer monitoring. A permit application has been submitted for 1989 to 1990; however, the LWRP has not issued any official permits for that time period because the permitting system is being revised. LLNL maintains contact with LWRP and there is no reason to believe that the permit application will be denied.

Inspections. LWRP conducted a number of inspections in 1989. On May 16, 19, 23, and 25, LWRP sampled Building 196 and Building 322 effluent. No report was received. On July 6, LWRP inspected Building 196 for possible cause of a pink effluent at the LWRP. The inspection confirmed the pink color was associated with a dye test LLNL had reported earlier. No corrective actions were required. Finally, on November 17, LWRP conducted an inspection of property at 2020 Research Drive. No formal report was received, but a copy of the inspection notes did not show any violations.

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 to develop and execute air pollution prevention and control programs. The Bay Area Air Quality Management District (BAAQMD) is the local agency responsible for enforcing these standards, as well as State and local standards, for air emissions from stationary sources in the San Francisco Bay Area, including the Livermore site.

Air Permits. The BAAQMD issued 192 permits issued to LLNL. These 192 permits

Table L-46. NEPA-related documents submitted to DOE during 1989.

Document type	Subject
EA	High Explosives Applications Facility (HEAF) Nuclear Directed Energy Research Facility (NDERF)
ADM	Sewer Diversion Facility BER Laboratory Modular Complex (Building 361 Addition) Proposed Building 153 Building 166 Laboratory Addition
Memorandum	Building 153 Advanced Implementation Technology Trailer Complex Building 332 SAS Office Expansion (SSEII) Westside Drainage Project Building 185 Light Lab Project NTTC Temporary Parking Lot Project Parking Lots A-8 and D-1 Project Disaster Planning Triage Complex Building 165 Advanced Optical Laboratory High Explosive Rinse-Water Lagoons Closure Building 281 Chemistry and Materials Trailer 2632 Light Laboratory Tritium Evaporator at Well 8 Spring, Site 300 Waste Accumulation Area, Building 495
Categorical Exclusion	12-kV Replacement Project Trailer 4675 Central Cafeteria Expansion 15-kV Sectional Switch Modifications to Building 197 LLNL Polymer Group Relocation, Building 227 South Cafeteria Ventilation Hood Installation Technical Information Facility (TIF) Liquid Nitrogen Storage Tank Replacement Modifications to Building 323, a Fire Station at LLNL Exhaust Manifold in Building 131 Earth Science Division, Trailer 1409 Trailers 5927/5906 Building 490 Standby Power

Livermore Site
Summary of
Environmental
Compliance
Activities

were permits-to-operate for the following operations or equipment:

96 boilers, 51 solvent cleaners, 12 particulate capture devices (cyclones and/or baghouses), 6 cleaning/refurbishment devices, 4 printing presses, 4 oil shale experimental equipment, 3 paint spray booths, 2 vapor recovery systems, 2 groundwater stripping systems, 2 ovens, 1 gasoline station recovery system, 1 fire test cell, 1 wet scrubber, and 7 miscellaneous sources.

Inspections. No deficiencies were noted in the report of the BAAQMD annual inspection of permitted sources. The annual inspection included 5 visits conducted from February to May 1989. The BAAQMD conducted two other inspections in 1989. On October 6, BAAQMD conducted an inspection of asbestos removal in Building 115; no discrepancies were found. On October 17, BAAQMD conducted an inspection of 26 boilers and Groundwater Treatment Facility A; again, no discrepancies were found.

Pollution Abatement Projects

LLNL is involved in several projects to improve effluent monitoring and control systems. These pollution abatement systems will help to further reduce emissions to the environment. These projects are briefly described below.

Tritium Facility VERS/SCOTS. The Tritium Facility (Building 331) is installing two major effluent control upgrades. The Vacuum Effluent Recovery System (VERS) is designed to recover over 90% of the existing routine stack emissions. This will significantly reduce the amount of tritium discharged to the atmosphere from LLNL. VERS design and construction is complete, and the system is presently in the final acceptance phase. The Secondarily Contained Tritium System (SCOTS) will replace the existing high- and low-pressure tritium systems with a modern, totally secondarily contained system. This system is designed to capture and then recover (via VERS) any accidental release involving large quantities of tritium. The SCOTS system is in the final construction phase,

and system testing is scheduled to begin late in 1990.

Plutonium Facility Passive Air Monitoring (PAM). The stack monitoring system for the Plutonium Facility (Building 332), has been upgraded to include a PAM system featuring isokinetic sample probes located at optimal sampling locations. This system supplements the Continuous Air Monitors, and it provides representative stack effluent sampling under routine and off-normal conditions.

Sanitary Sewer Discharge Control Project. LLNL is in the process of improving its ability to monitor and control pollutants inadvertently released to the sanitary sewer system. The Sanitary Sewer Discharge Control Project addresses four key elements to achieve this goal: (1) an upgraded sewer monitoring system at Building 196 to provide increased detection capability, parameter-specific sensitivity, and improved reliability to reduce both system maintenance and downtime; (2) a sewage diversion system and structure to allow diversion of LLNL's and SNLL's entire sewer flow and to prevent a detected release from leaving the site; (3) satellite monitoring stations at nine key points in the sewer system to provide an early alarm warning and increased response time for those discharges accompanied by pH variations and samples of the discharge to assist in locating the cause of all types of sewer alarms; and (4) a facility-specific control program for LLNL including some upgraded and some new retention tank systems, enhanced building surveys of process discharges and building sewer layouts, and strengthened administrative controls.

Environmental Protection Department Internal Compliance Activities

The Environmental Operations Group is responsible for working closely with LLNL programs and departments in implementing environmental requirements so planned and current operations and experiments function in compliance

with Federal, State, and local environmental regulations. The group consists of environmental analysts who are assigned to specific LLNL programs and departments to assist in day-to-day environmental activities. These activities include management of hazardous wastes and implementation of appropriate pollution abatement controls. Compliance status is maintained and verified by staff who keep abreast of all existing and planned activities, review construction documents, inspect facilities, and audit waste management procedures.

Building Inspections. Formal, detailed building inspections are conducted for each LLNL facility every other year. These inspections scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of WAAs, potential release pathways to the environment (e.g., storm and sanitary sewer drains), hazardous product storage areas, wastewater retention systems, operating equipment (e.g., vacuum pumps, transformers, capacitors, baghouses), and laboratory and machine shop areas. An inspection report is prepared for the program/department and follow-up procedures are conducted to ensure imple-

mentation of recommendations and/or corrections. Walk-through inspections are conducted on an as-needed basis. A total of 93 formal building inspections were conducted during 1989.

Spill Response. Investigation, sampling, and evaluation of all potentially hazardous spills and leaks to the environment are conducted. This includes assisting in cleanup of spills, determining if a spill is reportable to regulatory agencies, and verifying that cleanup is complete. Environmental Operations provides guidance to the programs on preventing recurrence of spills.

During 1989, the Environmental Protection Department responded to six incidents, which were reported to regulatory agencies. All incidents were contained at the time of occurrence or notice, and cleanup has been verified to be complete.

Site Evaluations Prior to Construction. Sampling and analysis for potential contaminants is conducted at all proposed construction sites to ensure that any soil and debris generated is disposed of appropriately.

During 1989, Environmental Operations conducted site evaluations for 27 construction projects.

QUALITY ASSURANCE AND STATISTICAL METHODS

Introduction

The Environmental Monitoring Group (EMG) conducts quality assurance (QA) activities at both LLNL and Site 300 to comply with DOE Order 5700.6B (U.S. Department of Energy 1986). This order sets forth DOE policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs. The order identifies the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1 "Quality Assurance Program Requirements for Nuclear Facilities" (ASME 1989) as the preferred quality assurance standard. DOE Order 5400.1 specifically refers to quality assurance with respect to environmental monitoring and states that a quality assurance program consistent with DOE Order 5700.6B shall be established covering each element of environmental monitoring and surveillance. Furthermore, DOE Order 5400.xy specifies that the environmental monitoring plan shall contain appropriate QA sections, consistent with the 18-element format of ANSI/ASME NQA-1, regarding all monitoring/surveillance activities at the site. This order specifically identifies QA requirements for radiological effluent and surveillance monitoring.

In addition, the LLNL QA policy states "all programs and line organizations use QA to assist in providing confidence that objectives will be achieved with due consideration for health, safety, and environmental concerns" (LLNL 1985). Furthermore, the Environmental Protection Department (EPD) QA policy states "all EPD QA plans must include elements of national consensus standards that are judiciously and selectively applied. ANSI/ASME NQA-1 is the DOE preferred standard for quality assurance." The QA goal for EPD is to "assure that research, development, demonstration, scientific investigations and production activities are performed in a controlled manner; that components, systems and processes are designed, developed, constructed, tested, operated and maintained according to engineering standards, quality practices and technical specifications/operational safety requirements and that resulting technology data are valid and retrievable."

Environmental monitoring at LLNL takes place in accordance with the above-

mentioned DOE Orders and LLNL QA policies. A separate QA document has been prepared by EMG that addresses all 18 points of NQA-1 (Holland 1987). All sampling is conducted according to written procedures described in EMG Procedures Manual (Brekke et al. 1988).

Environmental monitoring samples are analyzed by LLNL or commercial laboratories. When available, EPA standard methods are used to analyze the samples. If EPA standard methods are not available, LLNL develops its own procedures. The radiochemical methods used by the Nuclear Chemistry Division are described in detail in another report (Garrison et al. 1985). When required analyses are performed by independent contractors, LLNL contracts with laboratories certified by EPA and the State of California. LLNL requires its contractors to maintain adequate quality assurance programs and documentation of methods.

Audits of both contract laboratories and onsite laboratories are required as part of the EMG QA plan. Furthermore, both internal and independent audits of EMG are

performed annually. Independent audits are performed by the LLNL QA office.

Deviations and Changes to the Sampling Program

The following paragraphs describe those regularly scheduled samples for which data are not reported because of an inability to collect the sample or loss of the sample during analysis, and also describe changes to the environmental sampling effort.

Air Sampling Program. No changes were made to the air sampling program. During 1989, 937 of 988 possible air particulate samples and 332 of 338 possible air tritium samples were taken as part of the routine monitoring program. These represent sample recovery rates of 95% and 98%, respectively. The EMG Quality Assurance Plan sets a minimum sample recovery rate of 85%. The reasons for lost air particulate samples were air sampler malfunction or loss of electric power to the samplers. Air tritium samples were lost due to air sampler malfunctions or breakage of sample flasks.

Sewer Monitoring Program. Sewage samples are centrifuged and the resultant supernatant is analyzed for tritium. However, it was determined in 1989 that the presence of chlorinated hydrocarbons in the supernatant was interfering with the analyses. Therefore, the analytical processing for sewage samples was changed so that tritium analyses were performed on supernatant samples only after the samples had been distilled.

Sewage samples from LWRP were not obtained for one day each during the months of January to May and during December. Three samples were not obtained during September. One sample was not obtained from LLNL during the months of May and November. Of the 730 scheduled samples, 719 were collected and analyzed, a collection efficiency of 98%.

Routine Water Sampling Program. No changes were made to the routine water sampling program. No rainfall was collected during the first quarter. Stormwater runoff samples were collected at four locations during rainfall in March 1989. No stormwater runoff samples were taken

from Locations 1 and 4 during March 1989 because there was insufficient flow at these locations. No stormwater runoff samples were available at any locations during the second half of 1989 because of inadequate rainfall for runoff. The stormwater samples that were taken were analyzed for gross alpha, gross beta, tritiated water, and various physical and chemical pollutants; however, only one rainwater sample had adequate volume for gross alpha and gross beta analyses in 1989. No water samples were collected from the LLNL swimming pool during the months of December and February. Local water supply wells 3S1E-12D2 and 3S1E-12G1 could not be sampled because they were dry. Two quarterly tap water samples (Locations 26 and 37) were not collected for gross alpha and gross beta analyses.

Vegetation and Foodstuff Sampling Program. No changes were made to the vegetation sampling program. No vegetation was collected at Location 15 during the first quarter due to a lack of available green vegetation.

The number of wine samples was increased over that of previous years. (See the Vegetation and Foodstuff chapter for a detailed discussion of the changes to the wine sampling plan.)

Additional honey samples were collected and analyzed in 1989 because additional producers of honey were identified from both local and background areas. Honey samples will continue to be collected on an as-available basis.

Milk samples, scheduled to be collected every month, were not always available from the producers. Samples from Location 12 were only available between February and August during 1989. The supplier at that location moved from the area and was not able to provide milk samples after August. Milk was unavailable from Location 13 until May. The supplier at Location 5 did not provide samples during February. No milk was collected from any suppliers during January or December. The goats do not normally produce milk during these winter months.

Additional suppliers of milk for sampling are being sought.

Environmental Radiation Monitoring Program. No changes were made to the environmental radiation monitoring program. During 1989, 18 of 308 environmental dosimeters (94% collection efficiency) were missing at the time of collection. All the missing dosimeters were from offsite locations. Dosimeter loss is usually a result of construction activities or vandalism.

The minor changes specified in 1988 regarding the calculation of radiological dose assessments were again applied in 1989 (use of the newly established property line, use of momentum-induced plume rise in atmospheric dispersion calculations, calculation of effective dose equivalents with dose factors supplied by DOE, Clean Air Act Code run with specific meteorological data, and air pathway doses calculated using exposures from ingestion and ground surface irradiation in addition to inhalation and submersion; Brekke et al. 1989). One additional change was instituted in 1989. Doses attributed to tritium gas (HT) were included with those due to tritium water vapor (HTO) in all tritium calculations. In past years, the HT component (25 000 times less significant) was not included in the calculations.

Meteorology Monitoring Program. No changes were made to the meteorological monitoring system. Data recovery from the meteorological monitoring program was calculated to be 100%. During 1989, equipment at the meteorological tower was nonoperational for a total of two 15-minute increments.

Soils/Sediments Monitoring Program. No changes were made to the soil and sediment monitoring program. All samples were acquired and analyzed according to the environmental monitoring plan. Soil samples were again collected from fixed locations, as described in the 1988 Annual Monitoring Report (Brekke et al. 1989).

Participation in Laboratory Intercomparison Studies

During 1989, LLNL participated in the EPA's Environmental Radioactivity Laboratory Intercomparison Studies

Program. **Table L-47** shows the comparison of analyses by LLNL with known values. The errors are calculated at the 1- σ level. None of the reported analyses are outside LLNL accuracy goals or the EPA control limits. Participation by onsite laboratories (Hazards Control and Nuclear Chemistry) was reduced from that of previous years. An investigation and reassessment of LLNL participation in the EPA cross-check program is being conducted in cooperation with Hazards Control and the Nuclear Chemistry Division. Contract laboratories are also required to participate in the program. However, permission to publish their results has not been granted.

LLNL also participated in the 1989 intercomparison studies by the DOE Environmental Measurements Laboratory. The data from this study are presented in **Table L-48**. Nine of the analyses fall outside the newly established 20% accuracy goal. Of these nine, four are far enough from the goal to be of concern (^{125}Sb in air, ^{144}Ce in air, ^{238}U in air, and ^{239}Pu in water). Comparison of the study air filter data is often difficult due to differences in filter types and counting apparatus geometry. LLNL analyses of the intercomparison air filters, while for some isotopes beyond the accuracy goal, compared well with analyses performed by other laboratories in the study. Nevertheless, all the analyses outside the accuracy goal are being investigated by LLNL's Nuclear Chemistry Division.

Duplicate Analyses. **Table L-49** presents data generated by the duplicate sampling regime. Samples from both the Livermore site and Site 300 areas are included to provide a larger data set for statistical analysis. The regression analyses for these sample media (where enough data pairs were generated to allow the analyses) show good agreement between routine samples and quality assurance duplicates, with the exception of ^{238}U and ^{239}Pu in air samples. These deviations are thought to be caused by the proximity of the levels to detection limits, but are under investigation by the Nuclear Chemistry Division. Individual ratios of quality

assurance duplicates to routine samples do occasionally exceed the data goal of 30%, but never do so for a sustained period. If that were the case, it would indicate a bias in the sampling and analysis system.

Statistical Methods

Data review and analyses are conducted in accordance with the EMG Quality Assurance Plan (Holland 1987) and the EMG Procedures Manual (Brekke et al. 1988). 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.

Statistical methods used in this report have been implemented pursuant to DOE Order 5400.xy, Chapter VII (Data Analysis and Statistical Treatment) (U.S. Department of Energy 1988d). The methods employed 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.

Radiological Data. The precision of radiological analytical results is displayed in the data tables as $2\text{-}\sigma$ counting errors, expressed as a percentage of the associated value. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a $2\text{-}\sigma$ counting error greater than 100% is said to be at the lower limit of detection (LLD) and is presented in the tables with a "less than" (<) sign to indicate its LLD status. However, the actual LLD values are used in the calculations of all summary statistics.

Nonradiological Data. Nonradiological data that are reported as being below the analytical detection limit are also displayed in the tables with a "less than" (<) sign. As with the radiological data, the actual detection limit values are used in the calculation of summary statistics.

Summary Statistics. Determinations of measures of central tendency and

associated measures of dispersion are calculated according to DOE Order 5400.xy protocols. For data sets containing few LLDs, measures of central tendency are reported as the arithmetic mean $\pm$ one standard deviation (SDM), with the standard deviation expressed as a percentage of the mean. For data sets containing many (one-third or more of the total) LLD values, measures of central tendency are reported as the median value $\pm$ the median absolute deviation (MAD; median of the differences of all data values from the median), with the MAD expressed as a percentage of the median. By convention, summary statistics are not expressed with "less than" (<) signs. It should be noted that the use of LLDs in computations leads to overestimates of the central tendency because the actual values of data expressed as being below the detection limit are quite likely less than the LLD value used in the calculations.

Where unusually high values were detected from areas of known contamination, means and standard deviations are calculated both with and without the inclusion of the high values, and the calculations without high values are reported in parentheses. This was done so that measures of central tendency are not skewed by the presence of the high values. Otherwise, the common use of such data could bias estimates of the overall impact of LLNL operations.

Statistical Comparisons. Standard comparison techniques (t-test and ANOVA) have been used where appropriate for the determination of the statistical significance of the difference 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.

Table L-47. Quality assurance analyses for the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program, 1989.

Analysis	Media	Value reported (pCi/L $\pm$ 1 σ)		Normalized deviation ^a from the known value
		LLNL	Known	
Gross alpha	Water	6.33 $\pm$ 0.58	8.00 $\pm$ 5.00	-0.58
Gross beta	Water	5.33 $\pm$ 0.58	4.00 $\pm$ 5.00	0.46
Tritium	Water	3017 $\pm$ 378	2754 $\pm$ 356	1.28
		4506 $\pm$ 21	4503 $\pm$ 450	0.01
		3473 $\pm$ 96.1	3496 $\pm$ 364	-0.11
Gamma	Water	19.00 $\pm$ 1.00	20.00 $\pm$ 5	-0.35
¹³⁴ Cs				
¹³⁷ Cs				
¹³⁷ Cs	Air (pCi/filter)	24.00 $\pm$ 1.00	20.00 $\pm$ 5	1.38
¹³⁷ Cs		49.00 $\pm$ 1.73	50.00 $\pm$ 5	-0.35

^a Acceptable deviations are $\leq \pm 2$.

Table L-48. Quality assurance for the DOE Environmental Measurements Laboratory (EML) Quality Assessment Program, 1989.^{a,b}

Analysis	Media	LLNL value	EML value	LLNL/EML ratio
⁷ Be	Air	2140	1950	1.10
		153	123	1.24
⁵⁴ Mn		5.33	3.74	1.43
		5.12	4.17	1.23
⁶⁰ Co		137	126	1.09
		9.35	8.17	1.14
¹²⁵ Sb		50.6	96.8	0.52
¹³⁴ Cs		9.68	9.33	1.04
¹³⁷ Cs		238	189	1.26
		4.79	3.58	1.34
¹⁴⁴ Ce		11.0	7.08	1.55
²³⁸ U		0.211	0.090	2.34
		0.765	0.720	1.06
²³⁹ Pu		0.216	0.270	0.80
		0.016	0.018	0.89
⁴⁰ K	Soil	23.9	24.1	0.99
		533	561	0.95
¹³⁷ Cs		22.8	20.8	1.10
		746	642	1.16
²³⁹ Pu		0.486	0.420	1.16
		15.7	17.1	0.92
³ H	Water	6.11	6.31	0.97
		364	395	0.92
⁵⁴ Mn		0.327	0.300	1.09
		67.7	65.0	1.04
⁵⁷ Co		154	135	1.14
⁶⁰ Co		0.89	0.94	0.95
		143	155	0.92
¹³⁴ Cs		60.5	68.3	0.89
¹³⁷ Cs		2.70	2.55	1.06
		73.2	68.3	1.07
¹⁴⁴ Ce		147	132	1.11
²³⁹ Pu		0.252	0.350	0.72
		0.0062	0.0059	1.05

^a All values are relative. The exponents are not included; therefore, values do not indicate actual concentrations.

^b All data were provided by LLNL's Nuclear Chemistry Division.

Table L-49. Quality assurance—duplicate sampling, selected parameters, 1989.

Media	Parameter	Data capture (%) ^b	Precision ^c	Ratio ^d	Regression analysis ^a		
					Correlation coefficient	Slope	Y-intercept
Sewage		98					
LLNL	³ H		52.8/-48.0		0.98	0.970	-1.1 × 10 ⁻⁶
LWRP	³ H			1.22			
Water		100					
Livermore Valley	³ H		7.6/-17.8		0.99	0.952	0.405
Vegetation		98					
Livermore Valley	³ H			1.17			
Site 300	³ H			1.31			
Air	²³⁹ Pu	96	118.2/-90.9		0.72	0.80	2.673
	³ H		22.25/-17.87		0.98	1.05	-0.118
	²³⁸ U		97.50/-89.08		0.02	0.17	5.145
Soil	²³⁹ Pu	97		1.11			
Groundwater		97					
	TOC		19.24/-38.28		0.99	0.91	-0.026
	Conductivity		15.58/-20.60		0.84	0.86	113.7
	As		25.24/-18.40		0.93	0.94	0.0025
Milk	³ H	80		1.03			

^a Only calculated for data sets with more than 8 valid data pairs.

^b Ratio of samples collected for that medium to the number of samples scheduled to be collected.

^c Calculated according to the methodology in *Quality Assurance Handbook for Air Pollution Measurement Systems* (U.S. EPA 1976) for data sets with more than 8 valid data pairs.

^d Only used for data sets with less than 8 valid data pairs. Value is the mean of the ratios of QA samples/routine samples.

Site 300
Aerial view
looking east

Introduction

The environmental effects of Site 300 operations are governed by location, climate, and geology. For example, the dispersal of airborne emissions from the site are controlled by wind patterns and rainfall. Data on wind and rainfall are used to calculate the effects of emissions on nearby populations. Similarly, the dispersal of any groundwater contaminants are constrained by the particular geology of the site. This chapter is a brief overview of facts about Site 300 surroundings that are used in determining environmental effects of various emissions.

Location

Site 300 is LLNL's high-explosives (HE) testing site. It is located 24 km (15 miles) east of the Livermore site in the Altamont Hills of the Diablo Range and occupies an area of 30.3 km² (10.2 miles²). Two additional HE testing facilities are located in close proximity to Site 300. To the east, and adjacent to Site 300, is a testing facility operated by Physics International. A similar facility operated by SRI International is located approximately 1 km (0.6 miles) south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300. Power-generating windmills are present northwest of the site. The remainder of the land around Site 300 is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 25 000), located 10 km (6 miles) to the northeast.

Climate

The climate at Site 300, while generally similar to the Livermore site, is modified by higher elevation and greater relief. The temperature range is somewhat more extreme than the Livermore site, and surface wind patterns are influenced by local topography. Annual wind data are presented in **Figure S-1** and **Table S-1**. Rainfall for 1989 was 138 mm (5.4 in.). For the 17-y period from 1973 through 1989, the average rainfall was 268 mm (10.55 in.).

Figure S-1. Wind rose showing the average annual wind speed frequency of occurrence and direction at Site 300 for 1989.

Table S-1. Average annual percent frequency of wind direction versus wind speed (m/s) for Site 300, 1989. Winds are based on one hour averages. (Row and column totals do not add up due to rounding of numbers.)

Direction	0.0-0.9 calm	1.0-2.9	3.0-4.9	5.0-6.9	≥7.0	Total
N	0.6	1.1	1.1	0.4	0.2	3.3
NNE	0.6	1.1	0.1	0.0	0.0	1.7
NE	0.6	1.8	0.0	0.0	0.0	2.4
ENE	0.6	1.8	0.0	0.0	0.0	2.4
E	0.6	1.5	0.1	0.0	0.0	2.1
ESE	0.6	1.0	0.1	0.0	0.0	1.6
SE	0.6	1.0	0.1	0.0	0.0	1.7
SSE	0.6	1.5	0.2	0.1	0.0	2.4
S	0.6	2.6	0.6	0.2	0.0	4.0
SSW	0.6	1.9	0.1	0.1	0.0	2.7
SW	0.6	1.8	0.5	1.2	1.3	5.5
WSW	0.6	2.9	5.4	16.2	5.5	30.6
W	0.6	4.3	3.9	2.6	0.1	11.4
WNW	0.6	3.4	1.3	0.5	0.0	5.7
NW	0.6	5.8	1.8	1.9	0.3	10.4
NNW	0.6	5.4	3.4	1.9	1.0	12.2
Total	9.0	38.9	18.7	25.2	8.4	100.1

Geology

The topography of the site is irregular, with a series of steep hills and ridges oriented along a generally northwest/southeast trend; these hills and ridges are separated by intervening ravines. The elevation ranges from approximately 150 m (506 ft) at the southeast corner of the site to approximately 538 m (1750 ft) in the northwestern portion.

Knowledge of the geology and hydrogeology of Site 300 is based on regional geologic mapping by Huey (1948), Raymond (1969), and Dibblee (1980). These and subsequent detailed geologic and hydrologic studies were reported in the Draft California Environmental Impact Report prepared to support the 1987 renewal of LLNL's contract with the Department of Energy (University of California 1986). More recent studies are reported in a series of topical and Remedial Investigation (RI) reports, e.g., Raber (1983), Raber and Carpenter (1983), Carpenter et al. (1983, 1986, 1988), Taffet and Lamarre (1988), Taffet et al. (1989a), Crow and Lamarre

(1990), and McIlvride et al. (1990). Detailed geologic and hydrogeologic investigations continue and will be discussed in subsequent reports.

Site 300 is underlain primarily by Tertiary sediments of Pliocene and Miocene age. Two stratigraphic units contain bedrock aquifers of hydrogeologic significance: the late Tertiary non-marine sequence (Dibblee 1980), which consists of poorly sorted sandstones, siltstones, and claystones with irregularly distributed channel fills of silty and gravelly sandstones; and the Miocene Neroly Formation, which consists of interbedded sandstones, siltstones, and claystones containing considerable amounts of volcanic ash and some tuff. Two zones in the Neroly Formation are characterized by relatively thick and persistent sandstones that are potential aquifers; these are informally named the Neroly upper blue sandstone and the Neroly lower blue sandstone. The bedrock is overlain locally by older alluvial and terrace deposits beneath Quaternary to Recent colluvium,

alluvium, valley fill, and stream deposits. Along the northern and southern borders of the site, older beds crop out. These include the marine Cierbo Formation, locally the Eocene Tesla Formation, and the Cretaceous Panoche Formation, part of the Great Valley Sequence.

The structural geology at Site 300 is complex (see **Figure S-2**). The axis of the Patterson Anticline extends across the northern part of the site from northwest to southeast. Two major faults are found at Site 300. The Carnegie Fault, which strikes along the southern boundary, is a regionally significant structural boundary between strongly folded rocks to the south and more gently folded rocks to the north. In the northern part of the site, the Elk

Ravine Fault, which strikes southeasterly across the site, offsets beds containing aquifers. Recently, LLNL has mapped previously undiscovered faults in the southwestern part of Site 300; their hydrogeologic significance is not yet clear. However, if the faulting extends south-eastward, it may cause hydrologic discontinuities in areas under investigation.

Local perched aquifers containing small amounts of water occur in some of the channel fill deposits in the non-marine Tertiary sequence. Perched aquifers are defined as containing unconfined water separated from an underlying main body of water by an unsaturated perching aquitard; normally they are highly localized and of small extent. Water quality is

Figure S-2. Topography and groundwater surface elevations at Site 300 (adapted from Crow and Lamarre 1990).

usually poor in these water bodies, and yields are low. Thus, these perched water bodies do not represent potential water supplies as defined by the State of California.

Small perched aquifers have been identified beneath Building 834 in the southeastern part of Site 300 (Carpenter et al. 1983, 1986; Bryn et al. 1990); in the vicinity of Building 815 in the south-central part of the site (Crow and Lamarre 1990); and between Pit 7 and Elk Ravine in the northern part of Site 300 (Buddemeier et al. 1987; Taffet et al. 1989a). The perched spring in the south part of the HE Process Area is an outcrop of the perched aquifer of Building 815. Other small perched springs and isolated perched aquifers occur, but are not known to be significant to investigations at Site 300. The perched aquifers are not shown on **Figure S-2**.

Regional aquifers are found in the sandstones of the Neroly formation. A water-table aquifer occurs in the Neroly upper blue sandstone beneath parts of the site; the aquifer is confined in the southern part of Site 300. Lower in the stratigraphic sequence, in the Neroly lower blue sandstone, the aquifers are usually confined, with some artesian head, except in the northwest, where the water is unconfined. Wells completed in the water-table aquifer tend to produce less water than wells completed in the confined aquifers. These shallower aquifers are not used to produce drinking and process water.

A thick Neroly sandstone, stratigraphically near the base of the formation, contains confined water. Wells 18 and 20, completed in this aquifer, are used to supply drinking and process water; these wells are located in the western part of the General Services Area (see **Figure S-2**).

Interstitial permeability is generally low in the Neroly sandstones. However, these beds are usually strongly fractured, and we think that much of the water flowing to wells moves through these fractures. Hydraulic tests indicate that hydraulic conductivity varies widely, from the range of 1×10^{-3} cm/sec in the better wells, approximately 1×10^{-4} cm/sec in average wells, to a low in the range of 1×10^{-6} cm/sec in the smallest producers (Buddemeier et al. 1987; Weiss Associates 1988; Taffet et al. 1989a; Crow and Lamarre 1990).

Figure S-2 shows the elevation of water in the regional aquifer at Site 300. The contours are based on water levels in aquifers present beneath those parts of Site 300 where water level measurements are available. The map of the piezometric surface (defined as the level to which water rises in a well penetrating an aquifer, whether the aquifer is unconfined or confined) is based primarily on water levels in the Neroly lower blue sandstone aquifer, except in the northwest part of the site near Pit 7 and Building 851. In that region, the water contoured is in a perched aquifer. The aquifer in the Neroly lower blue sandstone is under water-table conditions in the northwestern part of the site; the aquifer becomes confined to the southeast. The hydraulic head increases progressively in that direction. In the General Services Area, some wells completed in this aquifer flow spontaneously.

Generally, the piezometric surface is controlled by the structural configuration of the aquifers. The direction of flow, perpendicular to the contours of the piezometric surface (**Figure S-2**), is to the northeast in the northern part of the Site, becoming generally southerly to southeasterly in the southern part of the Site.

Introduction

LLNL carries out surveillance air monitoring to determine if airborne radionuclides or hazardous materials from operations at Site 300 impact the environment or public health. Air monitoring involves measurement of materials collected on filters in air samplers. Concentrations of various airborne radionuclides, including particulates, and beryllium are measured at the Site 300 perimeter and at offsite locations near Site 300. These chemicals are also measured to comply with the Clean Air Act National Emissions Standards for Hazardous Pollutants. Penetrating radiation, which cannot be measured by collection of material on filters, is discussed in the Environmental Radiation chapter.

Methods

Concentrations of various airborne radionuclides and beryllium are measured at Site 300 and in the town of Tracy. Analyses for plutonium, uranium, and gamma emitters are performed on a composite sample consisting of air filters from all sampling locations. Sampling locations are shown in **Figure S-3**; the samplers are positioned to ensure that any significant concentration of effluents from Site 300 operations will be detected, regardless of local meteorology. These samplers are operated at average flow rates of 400 to 1000 L/min. The flow rates are verified at monthly intervals with a portable field-calibration unit. If a sampler fails, it is repaired and then calibrated with a spirometer that was itself calibrated using an immersion unit traceable to the National Institute for Standards and Technology (NIST), formerly the National Bureau of Standards.

The eight samplers at Site 300 use $5.2 \times 10^{-2} \text{ m}^2$ Whatman 41 cellulose filters. An easily dissolvable filter and a low trace-metal background are required for airborne-beryllium analyses. Whatman 41 filters represent a balance between such requirements and particulate-collection efficiency (Lindeken et al. 1963).

All air filters are changed weekly. Each filter is identified by its location, date on,

date off, elapsed sampling time, and flow rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets and each sample filter is given a serial number that accompanies it throughout the analysis. After a 4-day delay for decay of radon-thoron daughters, gross alpha and beta activities on the filters are determined with an automatic gas-flow proportional counter using 20-min counting periods. Normally, this counter is used only for environmental samples to avoid possible contamination. Separate ^{239}Pu and ^{90}Sr standards are used to determine alpha and beta counting efficiencies, respectively. These standards are traceable to NIST or equivalent certification sources. Counting-efficiency measurements are made with each set of filters counted, and a background count is taken at the beginning of each run and between each set of 10 samples. Records are kept of background and counting-efficiency variations that occur in the counter.

Monthly composites of Site 300 filters are sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the Site 300 composites are analyzed for the presence of ^{239}Pu , ^{235}U , and ^{238}U . These filters are ashed and then dissolved

Site 300
Air Monitoring

in a mixture of nitric acid (HNO_3) and hydrochloric (HCl) and/or hydrofluoric (HF) acid. Plutonium and uranium are then separated by an ion-exchange process. Plutonium is further purified by ion exchange, electroplated onto a stainless steel disk, and submitted for alpha spectrometry. Uranium is further purified by ion exchange and submitted for analysis by mass spectrometry.

For beryllium measurements, every month, half of the weekly air filters from each of the Site 300 samplers are composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% HNO_3 and 20% HClO_4 (perchloric acid). The solutions are then evaporated to

a few milliliters, and care is taken to prevent the samples from baking dry. After the samples are diluted with water, they are filtered, any residues are discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is done by atomic absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200 ng of beryllium, and several samples spiked with essentially carrier-free ^7Be . Standards of 1, 2, and 5 g/L are prepared by diluting an intermediate 1-ppm stock solution obtained from an NIST-traceable 1000-ppm stock dilution. The diluent in all cases is 1% HNO_3 in water.

Figure S-3. Air sampling locations, Site 300, 1989.

Results

Airborne Radioactivity. LLNL analyzes air samples for gross alpha and gross beta activity to ensure that releases of radionuclides other than those specifically analyzed for will be detected and to identify trends in the Site 300 environs. Most of the determinations were at, or near, the analytical limit of detection for the method; typical gross alpha activity is 1.2×10^{-15} $\mu\text{Ci/mL}$, and typical beta activity is 1×10^{-14} $\mu\text{Ci/mL}$. Most of the observed gross alpha and beta activity results from naturally occurring radioisotopes of uranium and thorium and their decay products.

Table S-3 lists the activities of selected gamma-emitting radionuclides that normally contribute to gross beta activity in Site 300 and Tracy samples. Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th are naturally occurring. The primary source of ^{137}Cs and ^{22}Na is normally long-term global fallout and fallout resuspension. Other fission products are normally detectable only after such events as atmospheric nuclear tests by other nations or releases such as the Chernobyl accident. The Derived Concentration Guides (DCGs) for these radionuclides are also presented in **Table S-3**. DCGs are concentrations of radionuclides in air (or water) that could be continuously inhaled (or consumed) 365 days of the year and not exceed the DOE primary radiation protection standard to the public of 100 mrem/y effective dose equivalent (U.S. Department of Energy 1990). (The Radiological Dose Assessment chapter provides an explanation of this and other units of dose.) All of these radionuclides were measured at concentrations less than those measured in 1988 and were significantly below the DCGs.

Table S-4 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 May and October composites at a level of 0.09×10^{-17} $\mu\text{Ci/mL}$ (0.005% DCG). This is 11.8 times lower than the highest

monthly concentration seen in 1988, and represents a return to levels seen prior to 1988. The highest concentration of ^{238}U was observed in the February composite at a level of 18.9×10^{-5} $\mu\text{g/m}^3$ (0.06% of the DCG). The highest concentration of ^{235}U was also observed in the February composite at a level of 12.5×10^{-7} $\mu\text{g/m}^3$ (0.003% of the DCG). No other significant differences between locations or samples were noted, and the overall levels were essentially the same as those reported in previous years.

The ratio of ^{235}U to ^{238}U is used as an indicator of the source of the ^{238}U . Both ^{235}U and ^{238}U occur naturally in the area. The ratio of the two isotopes as they exist naturally is approximately 7×10^{-3} . LLNL does use small amounts of ^{238}U at Site 300, but does not use ^{235}U ; therefore, if the ratio remains constant (within the limit of sampling and analytical error), then the ^{238}U measured is due to natural sources. The $^{235}\text{U}/^{238}\text{U}$ ratio for October, November, and December show statistically significant deviations from the natural ratio, indicating the presence of depleted uranium from Site 300 operations. The measured concentrations of ^{238}U are well below the DCG (U.S. Department of Energy 1990).

Beryllium in Air. **Table S-5** shows average monthly concentrations of airborne beryllium for the Site 300 sampling locations. The concentrations average less than 2.6% of the ambient concentration limit established by the San Joaquin Air Quality Management District ($0.01 \mu\text{g/m}^3$). These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and Central Valley air typically contains 10 to $100 \mu\text{g}$ of particulates per cubic meter. By using a value of $50 \mu\text{g/m}^3$ for an average dust load and 1 ppm for beryllium content of this dust, an airborne beryllium concentration of 5.0×10^{-5} $\mu\text{g/m}^3$ can be calculated. In view of the range of natural variation to be expected in these background values, this value is in excellent agreement with the data in **Table S-5**.

Site 300
Air Monitoring

Figure S-4. Monthly mean concentration of beryllium on air filters, Site 300, 1989.

Table S-2. Nonradioactive airborne emissions, Site 300, 1989.

Pollutant	Estimated release (tons/day)
Particulates	0.0003
Organic compounds	0.0062
Oxides of sulfur	0.0001
Oxides of nitrogen	0.0023 ^a
Carbon monoxide	0.0006 ^a
Chlorofluorocarbons	0.0045

^a These values are estimates based on the combustion products from diesel-fuel-fired boilers.

The monthly airborne beryllium concentrations for Site 300 and Tracy are plotted in **Figure S-4**. Values plotted for September through December represent the limit of detection for the contract laboratory, which modified its analytical procedures during those months. This procedures modification, which was instituted by the contract laboratory, raised the detection limit; consequently, very low values cannot be determined. Although the detection limit of the new method still allows adequate analysis of data with respect to regulatory guidelines, we have requested the previous analysis technique be reinstated. (The previous analysis technique was a graphite furnace beryllium analysis technique that has a lower limit of detection.)

Environmental Impact

The concentrations of beryllium and radionuclides measured around Site 300 and in the City of Tracy were well below all standards and, except uranium isotopes, reflect background or naturally occurring levels of these chemicals. The $^{235}\text{U}/^{238}\text{U}$ ratios shown in **Table S-4** are less than 7×10^{-3} , the ratio of naturally occurring concentrations of these isotopes. These ratios confirm the presence of depleted uranium at Site 300.

Certain equipment operations at Site 300 require permits from San Joaquin County, and the total estimated emissions are reported to the San Joaquin County Air Pollution Control District. The total estimated air emissions during 1989 from equipment operations at Site 300 are given in **Table S-2**.

Table S-3. Gamma activity on air filters—Site 300^a, 1989.

	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Month	[10 ⁻¹³ μCi/mL ± 2σ (%)]	[10 ⁻¹⁶ μCi/mL ± 2σ (%)]					
Jan.	0.586 ± 2	<0.528	0.074 ± 49	<0.020	— ^b	— ^b	2.203 ± 68
Feb.	4.005 ± 2	<0.652	0.052 ± 71	0.095 ± 84	— ^b	— ^b	<0.070
Mar.	0.813 ± 2	<0.493	<0.017	<0.037	— ^b	— ^b	<1.130
Apr.	1.176 ± 2	<0.717	<0.025	0.127 ± 82	— ^b	0.392 ± 84	<0.077
May	1.079 ± 2	<0.872	<0.030	<0.128	— ^b	0.419 ± 61	<0.086
June	0.779 ± 2	1.424 ± 78	0.062 ± 59	0.103 ± 52	0.136 ± 55	<0.171	<0.054
July	1.339 ± 2	3.855 ± 32	<0.023	<0.032	<0.177	— ^b	<0.071
Aug.	0.715 ± 2	2.583 ± 36	0.070 ± 58	<0.024	— ^b	0.229 ± 56	<0.052
Sept.	1.138 ± 2	3.004 ± 52	0.097 ± 44	<0.043	— ^b	0.266 ± 75	<1.269
Oct.	1.133 ± 2	<1.169	0.063 ± 73	<0.033	0.270 ± 41	— ^b	<0.076
Nov.	1.010 ± 2	<1.800	<0.029	<0.034	0.185 ± 87	— ^b	<0.085
Dec.	0.764 ± 2	<0.576	<0.020	<0.049	0.102 ± 91	0.218 ± 80	1.638 ± 8
Mean	0.96	1.02 ^c	0.041 ^c	0.040 ^c	0.177 ^c	0.284 ^c	0.081 ^c
SDM (%)	24	84 ^d	51 ^d	33 ^d	23 ^d	31 ^d	24 ^d
DCG (μCi/mL)	5 × 10 ⁻⁸	9 × 10 ⁻¹⁰	4 × 10 ⁻¹⁰	1 × 10 ⁻⁹	1 × 10 ⁻¹²	3 × 10 ⁻¹²	4 × 10 ⁻⁴
Percent of DCG	2 × 10 ⁻⁴	1 × 10 ⁻⁵	1 × 10 ⁻⁶	4 × 10 ⁻⁷	2 × 10 ⁻³	9 × 10 ⁻⁴	2 × 10 ⁻

^a All Site 300 samples composited.

^b Not detected; detection limits not reported by analytical laboratory.

^c Median. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

Table S-4. Plutonium and uranium on air filters—Site 300, 1989.^a

Month	²³⁹ Pu [10 ⁻¹⁷ μ Ci/mL $\pm$ 2 σ (%)]	²³⁸ U [10 ⁻⁵ μ g/m ³]	²³⁵ U [10 ⁻⁷ μ g/m ³]	²³⁵ U/ ²³⁸ U [10 ⁻³]
Jan.	0.013 $\pm$ 29	1.24	0.71	5.73
Feb.	0.009 $\pm$ 35	18.9	12.5	6.61
Mar.	0.020 $\pm$ 30	1.62	0.96	5.93
Apr.	0.014 $\pm$ 35	2.48	1.60	6.00
May	0.094 $\pm$ 15	3.36	2.00	5.95
June	0.020 $\pm$ 31	3.83	2.26	5.90
July	0.027 $\pm$ 23	3.49	2.34	6.70
Aug.	0.015 $\pm$ 33	4.03	2.68	6.65
Sept.	0.020 $\pm$ 28	4.52	3.04	6.73
Oct.	0.088 $\pm$ 18	6.19	2.94	4.75
Nov.	0.018 $\pm$ 35	4.04	2.19	5.42
Dec.	0.010 $\pm$ 41	5.11	2.26	4.42
Mean	0.030	4.90	2.96	
SDM (%)	96	94	104	
%DCG	0.001 ^b	0.016 ^c	0.001 ^d	

^a Composite of all Site 300 samples.

^b DCG = 2×10^{-14} μ Ci/mL for ²³⁹Pu activity in air.

^c DCG = 0.3 μ g/m³ for ²³⁸U activity in air (1×10^{-13} μ Ci/mL).

^d DCG = 0.047 μ g/m³ for ²³⁵U activity in air (1×10^{-13} μ Ci/mL).

Table S-5. Beryllium on air filters—Site 300, 1989.

Month	Location ^a	Beryllium concentration [10 ⁻⁵ µg/m ³]	Percent of SJCAPCD monthly standard ^b	Month	Location ^a	Beryllium concentration [10 ⁻⁵ µg/m ³]	Percent of SJCAPCD monthly standard ^b
Jan.	1	0.29	0.03	June	1	2.3	0.2
	2	0.39	0.04		2	2.0	0.2
	3	0.58	0.06		3	2.1	0.2
	4	0.60	0.06		4	2.1	0.2
	5	0.25	0.03		5	2.8	0.3
	6 ^c	3.2	0.3		6 ^c	4.0	0.4
	8	1.0	0.1		8	2.6	0.3
	9	1.3	0.1		9	2.5	0.3
	10	1.4	0.1		10	3.1	0.3
Feb.	1	1.1	0.1	July	1	1.7	0.2
	2	1.2	0.1		2	1.4	0.1
	3	1.5	0.2		3	2.1	0.2
	4	2.2	0.2		4	2.0	0.2
	5	<0.31	0.03		5	0.20	0.02
	6 ^c	4.0	0.4		6 ^c	2.2	0.2
	8	1.2	0.1		8	1.8	0.2
	9	1.4	0.1		9	1.7	0.2
	10	2.6	0.3		10	1.8	0.2
Mar.	1	0.44	0.04	Aug.	1	3.3	0.3
	2	0.11	0.01		2	2.8	0.3
	3	0.17	0.02		3	2.3	0.2
	4	0.19	0.02		4	2.7	0.3
	5	0.53	0.05		5	9.0	0.9
	6 ^c	0.85	0.09		6 ^c	3.9	0.4
	8	0.27	0.03		8	2.5	0.3
	9	0.19	0.02		9	2.6	0.3
	10	0.76	0.08		10	2.7	0.3
Apr.	1	1.5	0.2	Sept. ^e	1	<3.5	0.4
	2	0.96	0.1		2	<4.2	0.4
	3	1.6	0.2		3	<3.3	0.3
	4	0.52	0.05		4	<3.1	0.3
	5	2.3	0.2		5	<11	1.1
	6 ^c	— ^d	— ^d		6 ^c	<4.7	0.5
	8	0.73	0.07		8	<5.3	0.5
	9	0.78	0.08		9	<3.8	0.4
	10	5.2	0.5		10	<5.4	0.5
May	1	0.85	0.09	Oct. ^e	1	<5.5	0.6
	2	1.0	0.1		2	<6.4	0.6
	3	3.2	0.3		3	<4.9	0.5
	4	0.73	0.07		4	<4.8	0.5
	5	3.4	0.3		5	<7.5	0.8
	6 ^c	0.85	0.09		6 ^c	<6.9	0.7
	8	2.5	0.3		8	<15	1.5
	9	1.3	0.1		9	<9.9	1.0
	10	1.1	0.1		10	<8.5	0.9

...continued

Table S-5. Beryllium on air filters—Site 300, 1989 (concluded).

Month	Location ^a	Beryllium concentration [10 ⁻⁵ µg/m ³]	Percent of SJCAPCD monthly standard ^b
Nov. ^e	1	<16	1.6
	2	<17	1.7
	3	<13	1.3
	4	<13	1.3
	5	<20	2.0
	6 ^c	<20	2.0
	8	<21	2.1
	9	<20	2.0
	10	<26	2.6
Dec. ^e	1	<5.6	0.6
	2	<5.7	0.6
	3	<5.2	0.5
	4	<5.2	0.5
	5	<6.0	0.6
	6 ^c	<6.0	0.6
	8	<6.4	0.6
	9	<6.2	0.6
	10	<5.8	0.6

Location ^a	Median [10 ⁻⁵ µg/m ³]	MAD(%) ^f
1	2.0	70
2	1.7	71
3	2.2	48
4	2.2	69
5	3.1	93
6 ^c	4.0	48
8	2.5	65
9	2.1	50
10	2.9	68

^a See Fig. S-3.

^b Ambient monthly concentration guide set by the San Joaquin County Air Pollution Control District (SJCAPCD) is 0.01 µg/m³ (1000 x 10⁻⁵ mg/m³).

^c Tracy Firehouse.

^d Sample lost in analytical digestion process, see Quality Assurance chapter.

^e Beginning in September, the analytical laboratory changed analysis techniques.

^f Median absolute deviation (%). See Quality Assurance chapter.

ROUTINE WATER MONITORING

Introduction

The Environmental Monitoring Group conducts an ongoing routine monitoring program for surface and domestic water in the vicinity of Site 300. Groundwater monitoring around the landfills and surface impoundments is described in the Compliance Groundwater Monitoring subsection.

Sewage from the administrative area in the southeast corner of Site 300 is discharged to a lined pond for digestion and evaporation. Other facilities at Site 300 are served by septic tanks.

Methods

Surface water samples (Figure S-5) are collected quarterly from an offsite creek

(Location 14), rainfall (Location 20), and a spring-fed pond near Bunker 812 (Location 21). The water samples are

Figure S-5. Surface water sampling locations, Site 300, 1989.

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analyzed for gross alpha, gross beta, and tritium activity. Because the tritium levels typically found are very low, it is necessary to distill and enrich the samples before liquid-scintillation counting.

The water supply wells sampled in 1989 are shown in **Figure S-6**. Only Wells 04, 18, and 19 were used in 1989 for the production of drinking water. Location 23 is an offsite water supply well.

All water supply wells are sampled quarterly for gross alpha, gross beta, and tritium activity, as well as chromium, copper, lead, beryllium, and volatile organic compounds (VOCs). If gross alpha or gross beta activity is detected at or above maximum contaminant levels

(MCLs), the samples are then analyzed for isotopes of radium and uranium to determine if the activity is due to naturally occurring radionuclides. As with the surface water samples, all tritium samples are enriched prior to counting. In addition, the active water supply wells (Wells 04, 18, and 19) are sampled monthly for VOCs.

Samples were taken from 10 ground-water sources from the area surrounding Site 300 to characterize local groundwater quality and to better assess potential Site 300 environmental impacts. These samples were analyzed for pesticides, VOCs, metals, minerals, phenolic compounds, gross alpha activity, gross beta activity, and tritium.

Figure S-6. Water supply wells, Site 300, 1989.

In accordance with RWQCB, Central Valley Region, Waste Discharge Order No. 80-184, ponded water is collected at active landfills (Pits 1 and 7) during the rainy season and analyzed for gross alpha activity, gross beta activity, tritium, and beryllium.

Grab samples are obtained of surface sources such as ponds, creeks, and reservoirs with a tethered plastic pail. A 500-mL sample is collected for tritium analysis in an argon-flushed glass container fitted with a ground-glass stopper. Samples for other radiological analyses are collected in 500-mL polyethylene bottles.

Groundwater monitoring wells are purged of stagnant water prior to sampling. In the case of wells with high water-production rates, this entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For wells with low water-production rates, the well is manually bailed to dryness. Sampling occurs after the well has produced sufficient water for the required samples. All sampling equipment is chosen so that it will not add compounds to the analysis sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

As samples are collected in the field, they are labeled with the sampling location and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 10% of the water samples are duplicates.

For those samples that are analyzed for gross alpha and beta activities, a 100-mL sample or less, depending on the solid content, is digested with a mixture of 80% HNO_3 and 20% HClO_4 and dried. The residue is taken up with HNO_3 and a few milliliters of 5% H_2O_2 . The solution is evaporated to about 5 mL and transferred to a 5-cm-diameter serrated, stainless steel planchet. After the planchet is dried and flamed, the sample is counted for 30 minutes in a proportional counter. A blank is processed with each set of samples. The ^{239}Pu and ^{90}Sr standards are counted with

every sample set. Background measurements are made between every 10 sample-counting measurements.

Samples analyzed for tritium are electrolytically enriched and then counted by liquid-scintillation spectrometry. Each counting set includes a total of eight standards to establish quench corrections and eight blanks to determine background.

For beryllium analysis, a 100-mL sample is digested with HNO_3 . The residue is diluted to 100 mL with deionized water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Table S-6 lists the standardized methods used in the analyses of groundwater and/or stormwater samples for nonradioactive contaminants.

Results

Radioactivity in Water. **Table S-7** shows the gross alpha activities in Site 300 surface water samples. Gross beta activities for Site 300 samples are shown in **Table S-8**. Gross alpha and beta activities in these surface water samples collected in 1989 were below EPA and DHS MCLs (U.S. Environmental Protection Agency 1977; 22 *California Code of Regulations* Section 64443).

Table S-9 shows tritium data for Site 300 surface water samples. The samples have concentrations that are well below recommended concentration guide values. The highest concentration of tritium in water, $1.83 \times 10^{-7} \mu\text{Ci/mL}$, occurred at Location 20 in the rain that was collected on April 11, 1989. This represents 0.23% of the DCG. [The DCG, or Derived Concentration Guide, is the concentration of a radionuclide in water that could be continuously consumed 365 days of the year and not exceed the DOE radiation protection standard to the public for drinking water of 4 mrem/y effective dose equivalent (U.S. Department of Energy 1988b).] It is 0.9% of the MCL specified by DHS for drinking water (22 *California Code of Regulations* Section 64443).

Table S-6. EPA groundwater standard methods.

Analyte	EPA method	Analyte	EPA method
Metals			
Antimony	204.1	Manganese	243.1
Arsenic	206.2	Mercury	245.1
Barium	208.1	Molybdenum	246.1
Beryllium	210.2	Nickel	249.1
Cadmium	213.1	Selenium	270.2
Chromium	218.1	Silver	272.1
Cobalt	219.1	Sodium	273.1
Copper	220.1	Thallium	279.1
Iron	236.1	Vanadium	286.1
Lead	239.2	Zinc	289.1
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)	350.2	Chloride	325.3
All alkalinities	310.2	Sulfate	375.3
Organic compounds			
Volatile organic compounds		Low level phenolic compounds	
Purgeable halocarbons	601	Total organic halide (TOX)	9020
Purgeable priority pollutants	624	Total organic carbon (TOC)	9060
Title 22 organic compounds	608	Oil and grease	413.1
Extractable priority pollutants	625	Chemical oxygen demand (COD)	410.1

Table S-9 also includes an estimate of the annual effective dose that may be delivered to an adult who consumes water containing the listed tritium concentrations. These doses, which are all less than 0.003 mrem, are based on a water consumption of 2 L/day and the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b). The actual dose (if any) from these water sources would be considerably less because these sources are not used as drinking water

sources. Methods used to calculate doses are presented in **Appendix A**.

Water Supply Wells. Results of the water supply well monitoring are shown in **Tables S-10** and **S-11**. The tabulated results in **Table S-10** represent the highest value detected for the parameter over the year, as well as constituents sporadically detected during the year. Therefore, the values are conservative estimates of groundwater constituents.

Although not presented in **Table S-10**, a constituent of concern observed in the

active water supply wells is a small amount of TCE that was sporadically detected in Well 19 and that averaged approximately 3.3 µg/L (below the California DHS MCL of 5 µg/L). Well 19 was only used as a backup water supply and was taken out of service in the fourth quarter of 1989.

NC7-61, a monitoring well established in 1989 in the Pit 7 area, shows tritium concentrations in excess of the California MCL. The tritium contamination in this area is well documented in the *LLNL Site 300 Environmental Investigation Quarterly Reports* (Taffet et al. 1989a; Lamarre et al. 1989; Lamarre 1989a-b) and is under investigation for remediation.

Site 300 Area Groundwater. Table S-12 shows the data from the 10 groundwater sampling locations in the vicinity of Site 300. The results of these analyses indicated no concentrations above background, with the exception of nitrate in Well W2, which was above the MCL. This well is not used for drinking water supplies. Methylene chloride was detected in two installations at the level of 2 µg/L. However, the analysis of the laboratory

blank sample made and submitted during the same sampling interval also indicated 2 µg/L of methylene chloride, so this result is believed to be an artifact of the sampling or analytical process.

Environmental Impact

Tables S-9 and S-11 include an estimate of the annual effective dose that may be delivered to an adult who consumes water containing the listed tritium concentrations. Doses from the active water supply wells (Wells 04, 18, and 19) are all less than 0.0006 mrem. These doses are based on a water consumption of 2 L/day and the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b). The actual dose (if any) from these water sources would be considerably less because many of these sources are not used as drinking water sources. Methods used to calculate doses are presented in **Appendix A**. The tritium concentrations of the inactive water supply wells (Wells 01, 03, 06, 07a) are all a small fraction of the California MCL or drinking water standard (DWS).

Table S-7. Gross alpha activity in surface water—Site 300, 1989.

Location ^a	Number of samples	Maximum	Minimum	Median ^b	MAD (%) ^b
		[10 ⁻⁹ μCi/mL ± 2σ (%)]			
14	3	11 ± 17	0	3	100
20	1	<2	<2	N/A ^c	N/A ^c
21	3	<9	0	5	80

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

^b For a discussion of median and median absolute deviation (MAD), see the Quality Assurance chapter.

^c Not applicable, only one data point.

Table S-8. Gross beta activity in surface water—Site 300, 1989.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[10 ⁻⁹ µCi/mL ± 2σ (%)]			
14	3	14 ± 12	6 ± 5	10	40
20	1	<5	N/A ^b	N/A ^b	N/A ^b
21	3	26 ± 7	<7	15 ^c	53 ^d

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

^b Not applicable, only one sample was taken.

^c Median. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

Table S-9. Tritium in water—Site 300, 1989.

	Location ^a		
	14 ^b	20 ^c	21 ^b
	[10 ⁻⁷ µCi/mL ± 2σ (%)]		
First quarter	0.50 ± 12	0.66 ± 11 0.57 ± 13 1.83 ± 6	0.15 ± 41
Second quarter	0.44 ± 14	0.25 ± 76	0.15 ± 41
Third quarter	0.45 ± 13	0.36 ± 17 0.44 ± 13	0.16 ± 34
Fourth quarter	0.53 ± 11	0.18 ± 27 0.31 ± 20	0.22 ± 23
Average	0.48	0.58	0.17
SDM (%)	9.0	93	20
Percent of DWS ^d	0.24	0.29	0.09

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

^b Surface water.

^c Rain water.

^d DWS (State of California drinking water standard) = 2×10^{-5} µCi/mL.

^e Effective dose based on DOE standard of 4 mrem for drinking water.

Table S-10. Positively detected parameters in Site 300 water-supply wells and other monitoring installations, 1989.

Parameters ^a	Well								
	WELL01	NC7-61 ^b	WELL04	GALLO1	CON1	CARNRW2 ^d	WELL18	WELL19	CDF1
<u>Physical and chemical (mg/L)</u>									
Ammonia nitrogen	— ^d	— ^d	0.62	— ^d	1.4	— ^d	0.73	0.55	0.012
Arsenic	0.009	0.014	<0.002	<0.002	0.002	0.002	<0.002	<0.002	0.005
Barium	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium	<0.001	<0.04	0.0004	<0.01	0.0008	<0.001	0.0006	0.0007	0.0006
Calcium	59.0	— ^d	26.0	8.2	51.0	34.0	21.0	4.0	80.0
Carbonate alkalinity	<1.0	— ^d	<1.0	<1.0	<1.0	<1.0	18.0	68.0	<1.0
Chloride	58	— ^d	60	130	180	110	100	80	120
Total chromium	<0.01	<0.01	<0.02	<0.01	<0.005	<0.02	0.008	<0.005	<0.02
Conductivity (µmhos)	650	— ^d	870	1220	2240	1200	1010	1040	1410
Fluoride	0.4	— ^d	— ^d	0.6	0.4	0.2	— ^d	— ^d	0.3
Iron	0.04	— ^d	0.19	<0.04	<0.04	<0.03	0.05	<0.04	<0.04
Lead	0.003	0.011	0.004	0.003	0.005	0.003	0.009	0.002	0.015
Magnesium	21.0	— ^d	6.9	0.5	7.5	3.8	3.4	0.1	30.0
Manganese	<0.04	— ^d	0.10	<0.04	0.20	0.06	0.06	<0.04	<0.04
Nitrate (as NO ₃)	25.0	— ^d	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	5.8
Nitrate (as N)	3.2	— ^d	<0.1	— ^d	<0.1	— ^d	<0.1	<0.1	1.3
Total Kjeldahl nitrogen	— ^d	— ^d	0.8	— ^d	<0.5	— ^d	0.8	0.7	<0.5
pH (units)	7.3	— ^d	8.0	7.8	8.2	7.9	8.6	9.0	7.7
Potassium	3.7	— ^d	12.0	2.2	11.0	2.4	7.9	3.2	11.0
TDS	440	— ^d	570	830	1500	720	670	640	830
Total alkalinity (as CaCO ₃)	160.0	— ^d	200.0	250.0	190.0	220	200	230	240.0
TSS	1.0	— ^d	— ^d	1.0	1.0	<1.0	— ^d	— ^d	<1.0
Sodium	48	— ^d	140	220	450	200	210	240	180
Sulfate	84	— ^d	170	210	940	220	180	170	290
Zinc	0.09	— ^d	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.05
<u>Purgeable pollutants (EPA Methods 601/624, µg/L)</u>									
Benzene	— ^d	<1.0	<0.5	<1.0	<1.0	<1.0	0.6	<0.5	<1.0
Chloroform	<0.5	1.0	<0.5	<1.0	<0.5	<1.0	<0.5	<0.5	<1.0
Ethylbenzene	— ^d	<1.0	2.8	<1.0	<1.0	<1.0	<0.5	<0.5	<1.0
Toluene	— ^d	<1.0	8.3	<1.0	<1.0	<1.0	<0.5	<0.5	<1.0
Trichlorofluoromethane	<0.5	0.8	<0.5	<1.0	<0.5	<1.0	<0.5	<0.5	<1.0
Total xylene isomers	— ^d	<1.0	9.1	<1.0	— ^d	— ^d	1.0	2.9	— ^d

...continued

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Table S-10. Positively detected parameters in Site 300 water-supply wells and other monitoring installations, 1989 (concluded).

Parameters ^a	Well								
	WELL01	NC7-61 ^b	WELL04	GALLO1	CON1	CARNRW2 ^b	WELL18	WELL19	CDF1
<u>Radiological (10⁻⁹ µCi/mL)</u>									
Gross alpha	<2.0	3.0	6.0	<8.0	6.0	3.0	<3.0	<6.0	<6.0
Gross beta	3.0	8.0	7.0	11.0	13.0	9.0	9.0	2.0	10.0
Tritium	2420	379 000	0	<519	<210	0	0	0	<210

^a The following parameters would have been reported had they appeared above the detection limits indicated below:

Metals (mg/L)	Detection limit	For gross alpha >5 × 10 ⁻⁹ µCi/mL in wells 04, 18, 19 (10 ⁻⁹ µCi/mL)	Detection limit
Copper	0.02	Uranium-234	0.2
		Uranium-235	0.2
		Uranium-238	0.2
		Radium-226	0.1
		Radium-228	1
Extractable priority pollutants (EPA 601/624, µg/L)	Detection limit		
Acrolein	10		
Acrylonitrile	10		
All other analytes	0.5		

^b Monitoring well.

^c Location CARNRW1, which was only tested for organic compounds, showed 130 µg/L of dichlorodifluoromethane as the highest annual value detected.

^d Sample not analyzed for that parameter.

Table S-11. Tritium (HTO) in water—Site 300 active and inactive water supply wells^a, 1989.

	Wells							
	01	03 ^b	04	06 ^b	W7A	08 ^b	18	19
	[10 ⁻⁷ μCi/mL ± 2σ(%)]							
First quarter	22.0 ± 2	0.40 ± 15	<0.05	0.19 ± 28	0.28 ± 23	<0.08	0.08 ± 63	<0.04
	22.3 ± 2							
Second quarter	22.6 ±	— ^b	0.11 ± 51	— ^b	0.10 ± 59	— ^b	<0.07	0.21 ± 28
Third quarter	22.7 ±	— ^b	0.19 ± 66	— ^b	0.23 ± 24	— ^b	0.21 ± 24	0.09 ± 59
			0.09 ± 55					
Fourth quarter	27.0 ±	— ^b	— ^c	— ^b	— ^c	— ^b	0.10 ± 61	— ^c
Mean	23.3	0.40	0.11	0.19	0.20	0.08	0.12	0.09 ^d
SDM (%)	9	N/A	58	N/A	46	N/A	56	56 ^e
Percent of DWS ^f	11.7	0.20	0.06	0.10	0.10	0.04	0.06	0.05
Effective dose (mrem)	0.12	0.002	0.0006	0.001	0.001	0.0004	0.0006	0.0005

^a Only Wells 04, 18, and 19 are currently used for the production of drinking water at Site 300.

^b Wells abandoned and sealed during second quarter.

^c Data unavailable. See Quality Assurance chapter.

^d Median. See Quality Assurance chapter.

^e Median absolute deviation (%). See Quality Assurance chapter.

^f DWS (State of California drinking water standard) = 2×10^{-5} μCi/mL.

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Table S-12. Positively detected water-quality parameters in groundwater in the vicinity of Site 300, 1989.

Parameter ^a	Location (compass direction from Site 300 given in parentheses)									
	C3(S)	CON1(SE)	F1(SE)	G4(S)	G5(S)	M1(N)	M4(N)	V4(W)	V7(E)	W2(W)
<u>Physical and chemical (mg/L)</u>										
Ammonia nitrogen	—b	1.4	0.12	0.32	—b	0.04	0.12	0.04	0.07	<0.02
Arsenic	0.002	0.002	0.005	<0.002	<0.002	0.003	<0.002	<0.002	0.012	0.0190
Beryllium	<0.0001	0.0002	0.0001	<0.0005	0.0001	—b	—b	<0.0005	<0.0005	<0.0001
Cadmium	<0.001	0.0008	0.0006	<0.04	<0.01	0.0001	0.0001	<0.0001	0.0002	<0.01
Calcium (EDTA titration)	34.0	51.0	80.0	—b	8.2	73.0	160.0	140.0	38.0	35.0
Carbonate alkalinity (as CaCO ₃)	<1.0	<1.0	<1.0	48.0	<1.0	<1.0	<1.0	<1.0	<1.0	32.0
Chloride	110	180	120	130	130	52	68	93	83	210
Total chromium	<0.02	<0.005	<0.005	<0.05	<0.01	<0.001	0.002	0.005	0.009	0.002
Conductivity (µmhos/cm)	1200	2240	1410	1270	1220	910	1580	1210	970	1930
Fluoride	0.2	0.4	0.3	0.8	0.6	—b	—b	—b	—b	—b
Lead	0.004	0.005	0.015	<0.002	0.003	—b	—b	0.001	0.006	0.002
Magnesium	3.8	7.5	30.0	—b	0.48	28.0	42.0	18.0	21.0	26.0
Manganese	0.06	0.20	<0.04	0.05	<0.04	<0.04	0.06	0.04	0.05	<0.04
Nitrate (as N)	—b	<0.1	1.3	0.4	—b	0.6	1.6	2.3	5.7	13.0
Nitrate (as NO ₃)	—b	<0.4	5.8	—b	<0.4	2.8	7.2	10.0	25.0	57.0
pH (units)	7.9	8.2	7.7	8.1	7.8	7.8	7.3	7.2	7.7	8.3
Potassium	2.4	11.0	11.0	—b	2.2	4.2	6.6	2.7	7.2	7.7
Selenium	<0.002	<0.002	<0.002	0.004	<0.002	0.004	0.003	<0.002	0.002	0.003
Silver	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.0001	<0.0001	0.01
Sodium	200	450	180	<0.09	220	70	120	77	120	260
Sulfate	220	940	290	210	210	180	540	230	120	310
TDS	720	1500	830	810	830	530	1000	720	560	1100
TSS	<1.0	1.0	<1.0	5.0	1.0	—b	—b	—b	—b	—b
Total alkalinity (as CaCO ₃)	220	190	240	270	250	190	190	280	210	260
Vanadium	—b	—b	—b	<0.03	—b	<0.2	<0.2	<0.03	0.05	<0.2
Zinc	—b	<0.01	0.05	—b	<0.01	0.05	0.04	<0.01	0.04	<0.01
<u>Organic compounds (µg/liter)</u>										
Methylene chloride	<0.5	<0.5	<0.5	<0.5	<0.5	2.0	2.0	<1.0	<1.0	2.0
Vinyl chloride	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<1.0	<1.0	<1.0	<1.0
<u>Radioactive materials (pCi/L)</u>										
Gross alpha	3.0	6.0	<3.0	—b	<8.0	—b	—b	—b	—b	—b
Gross beta	14.0	13.0	10.0	—b	4.0	—b	—b	—b	—b	—b
Tritium	19.8	22.2	44.6	—b	9.2	—b	—b	—b	—b	—b

^a Samples were analyzed for all California Title 22 metals and organic compounds, EPA Method 624 organic compounds, general minerals, gross alpha and gross beta activity, and tritium. Only positively detected analytes having a California primary maximum contaminant level or State action level are reported in this table.

^b Analysis not performed.

Introduction

Groundwater monitoring is conducted under two programs at LLNL. One program is designed to meet regulatory commitments established for specific site investigations, such as the investigation of trichloroethylene (TCE) and tritium in groundwater at Site 300. Details of this program are described in the *LLNL Site 300 Environmental Investigations Quarterly Reports* (Lamarre et al. 1989a-c; Taffet et al. 1989a); they are not discussed in this report.

The other program consists of routine compliance monitoring around landfill and wastewater surface impoundment units, as required by the Regional Water Quality Control Board Central Valley Region (RWQCB), California Department of Health Services (DHS), and the EPA. The latter program is described below.

Methods

Groundwater monitoring in the vicinity of Site 300 landfills Pits 1 and 7 is regulated by RWQCB, DHS, and EPA. All other landfills are subject to RWQCB requirements alone. At Pit 1, which is in the detection monitoring mode, groundwater samples from eight monitoring wells are analyzed quarterly for drinking water parameters, groundwater quality parameters, and indicators of groundwater contamination, as specified in 40 *Code of Federal Regulations* Part 265.92. At Pit 7, eight monitoring wells are sampled quarterly for VOCs, lead, beryllium, gross alpha, gross beta, and tritium activities. The shallow Well K7-10 is sampled for groundwater compliance monitoring. Pit 7 wells also provide monitoring data for inactive landfills 3, 4, and 5. Because of the detection of tritium and TCE in some Pit 7 wells, the Pit 7 network is in the assessment monitoring mode, as described in 40 *Code of Federal Regulations* Part 265.92.

Groundwater from wells that monitor inactive Pits 2 and 8 is also analyzed for the same parameters as the groundwater from Pit 7 wells, with the addition of analyses for nitrate, nitrite, ammonia, and total Kjeldahl nitrogen. Well NC2-07, located at the Site's eastern boundary, is the most downgradient monitoring point for Pits 2, 3, 4, 7, and 8. This well is sampled

quarterly for tritium and semiannually for gross alpha, gross beta, and purgeable priority pollutants. Barcads, which are used to monitor the deeper water-bearing zones beneath Pits 1 and 2, are sampled quarterly for gross alpha, gross beta, tritium, lead, and beryllium. Once a year, the barcads are sampled for a larger suite of metals, including those listed in 22 *California Code of Regulations* Part 66699, with total or soluble threshold concentration limits (TTLC and STLC, respectively).

Inactive Pit 6 is monitored for drinking water parameters, groundwater quality parameters, and indicators of groundwater contamination, as specified in 40 *Code of Federal Regulations* Part 265.92, even though this landfill is not regulated under RCRA. This monitoring is done because records indicate that potentially hazardous waste was buried in this pit between 1964 and 1973. (This waste included capacitors suspected to contain polychlorinated biphenyls (PCBs), beryllium, mercury, miscellaneous chemicals, and other materials.)

In 1985, the Central Valley Region of the RWQCB issued new groundwater monitoring requirements (as part of Waste Discharge Order No. 85-188) for LLNL's two new Class II surface impoundments. These impoundments contain treated non-hazardous HE process wastewater and

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nonhazardous photo rinse water. Samples from four wells in these areas are analyzed quarterly for pH; total organic halides (TOX); total organic carbon (TOC); specific conductance; several HE compounds (HMX, RDX, nitrate, and nitrite); VOCs; and metallic elements. Samples for VOCs, HE compounds, and tritium are also obtained from Well W-817-03A, a shallow well near the surface impoundments. Each quarter, an attempt is made to sample the five lysimeters underlying the surface impoundments. If water is present, it is analyzed for HE compounds.

LLNL has developed analytical procedures for HE compounds. The HE compounds are analyzed using a high-pressure liquid chromatograph (HPLC). First, 100 μ L of the sample are injected

into an HPLC fitted with a Hewlett Packard RP-8 column. The flow rate is set at 1.0 mL/min, with a 35% methanol and 65% water solvent. An ultraviolet detector at 230 nm is used for measurements, and measurements are taken at 254 nm for comparison.

Detection limits and analysis parameters for the compliance groundwater monitoring wells (Figure S-7) are shown in Table S-13.

Results

Results of the quarterly monitoring are shown in Tables S-14–19. The tabulated results present the highest value detected for the parameter over the four quarters of 1989, as well as compounds sporadically

Figure S-7. Landfills (active and inactive) and monitoring wells, Site 300, 1989.

detected. Therefore, the values found within the tables are conservative estimates of the groundwater constituents. Details of the quarterly sampling and results can be found in the *LLNL Site 300 Groundwater Monitoring Program Quarterly Reports* (Carlsen and Brown 1989; Brown and Carlsen 1989a-b; Brown 1989).

At Pit 1 (**Table S-14**), very 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 at maximum concentrations of 0.9 µg/L, 5.8 µg/L and 9.7 µg/L, respectively. Freon-113 was also detected in Well K1-05 during the second quarter at a concentration of 0.9 µg/L. These levels are far below the MCL of 1200 µg/L (22 *California Code of Regulations Section 64444.5*). A quality assurance investigation was performed during the second quarter sampling to confirm the presence of Freon-113 in these installations. Additional duplicate and blank samples clearly identified Freon as a groundwater constituent in well K1-08 and K1-09. Other sporadically occurring halogenated hydrocarbons detected in the Pit 1 monitoring installations are believed to be the result of laboratory error or sample contamination.

Resource Conservation and Recovery Act regulations in the *Code of Federal Regulations* mandate that the Student's t-test be applied comparing pH, conductivity, TOC, and TOX concentrations in 1989 to a 1986 background data set. These tests showed no statistically significant increase in TOC or TOX concentrations throughout 1989 (Carlsen and Brown 1989; Brown and Carlsen 1989a-b; Brown 1989). Although significant differences in conductivity and pH were observed in 1989 between upgradient and downgradient wells, it is believed that these differences were representative of natural groundwater chemical variability and did not represent a landfill-induced change in the groundwater chemistry. An alternative, analyte-specific method for statistical detection of changes in groundwater chemistry at both the Pit 1 and 817 areas is presently being developed by LLNL using EPA guidance

(U.S. EPA 1989b) and will be applied in 1990. This method should decrease the incidence of sporadic findings unrelated to any landfill changes in groundwater chemistry. Elevated levels of nitrate in the Pit 1 wells continue to be observed; these are considered to be natural constituents of the area groundwater (Buddemeier et al 1987; Carlsen et al. 1987).

Table S-15 shows that TCE, 1,1-dichloroethylene, and tritium concentrations in the Pit 7 area wells are similar to those reported last year. The Pit 7 area groundwater is included in the Site 300 investigations of TCE and tritium discussed in the *LLNL Site 300 Environmental Investigations Quarterly* reports. During the second quarter, slightly elevated levels of gross alpha activity were detected in K7-01. This is likely the result of levels of naturally occurring uranium in the groundwater (Raber and Carpenter 1983). Samples taken during the third and fourth quarters from K7-03 indicated the tritium level in this installation has decreased significantly, from approximately 131 000 pCi/L to approximately 38 100 pCi/L. The latter value is similar to the values reported for 1988; this apparent decrease is being investigated. In the fourth quarter, NC7-25 exhibited 39 pCi/L of alpha activity, above the State MCL of 15 pCi/L. Isotopic uranium analysis indicated that this alpha activity was likely due to natural uranium.

Table S-16 shows monitoring data from Pit 2 (Wells K2-01C, K2-04S, and K2-04D); Pit 8 (Well K8-01); and Well NC2-07. As mentioned previously, the slightly elevated nitrate levels (above the MCL in K8-01) are considered to be natural constituents of this area's groundwater. In K8-01, TCE and 1,2-dichloroethane (1,2-DCA) continue to be detected at or above the MCLs. Additional characterization of the groundwater in this vicinity is being conducted as part of the Site 300 TCE investigation. The tritium values for Wells K2-01C and K2-04S have dropped below the State MCL of $20\,000 \times 10^{-9}$ pCi/L. The previous years' levels had been higher than the MCL. These wells are part of the Site 300 tritium investigation.

Table S-17 shows monitoring data from the Pits 1 and 2 barcads. The only data point exceeding any State action level or MCL is an arsenic value of 0.09 mg/L (MCL is 0.05 mg/L) observed in K2-02A. The elevated arsenic levels are comparable to those observed in the Pit 1 monitoring wells and elsewhere at Site 300, and these levels are considered to be a natural constituent of the area groundwater.

Table S-18 shows the monitoring data for the Pit 6 wells. TCE continues to be detected in small amounts in EP6-09 throughout the year. As a result, the Pit 6 area was added to the ongoing Site 300 TCE investigation.

Table S-19 shows data for lysimeters and wells in the vicinity of the HE process-water surface impoundments. The lysimeters underlying the impoundments did not produce any water during 1989. Monitoring Well W817-01 continues to consistently show small amounts of RDX (a high-explosive compound). In addition, the high explosive HMX was detected in W-817-01 for the first time in the fourth quarter of 1989. As required by DHS, four wells (W-817-01, 02, 03, and 04) were subjected to the Student's t-test comparing 1989 TOX and TOC concentrations to the 1986 background data set. These tests showed no significant increase in TOX or TOC concentrations during 1989 (Carlsen and Brown 1989; Brown and Carlsen 1989a-b; Brown 1989). As in Pit 1, significant differences in pH and conductivity were observed between upgradient and

downgradient wells. It is believed that these differences are representative of natural groundwater chemical variability and do not represent a surface-impoundment-induced change in the Building-817 area groundwater chemistry. The alternative, analyte-specific statistical method discussed in the Pit 1 section of this report will also be applied to the data from the Building-817 monitoring wells in 1990. Elevated nitrate, selenium, and arsenic levels have been consistently detected in the wells of this area since their installation in 1985. These are considered to be natural constituents of the area groundwater (Carlsen et al. 1987). TCE above the State action level was observed in Wells W-817-03, 03A, and 04. Investigations of the RDX (and other explosives) in Well W-817-01 and the TCE occurrences are part of the Site 300 groundwater investigations.

Environmental Impact

As discussed previously, this report does not cover investigations of areas of known groundwater contamination or proposed remedial action for those areas. Routine monitoring did reveal groundwater contamination in the Pit 6 area. The Environmental Restoration Division is now undertaking the investigation and cleanup of this area. Because they are not currently used for potable water supplies, the contaminated aquifers are not considered to have any adverse impact on the population in the area.

Table S-13. Water-quality parameters for Site 300 monitoring wells, 1989.

Parameters analyzed					
Physical and chemical	Pits ^a	Detection limit (mg/L) ^b	Purgeable priority pollutants (EPA Method 624)	Pits 1, 2, 6, 7, 8 and HE	Detection limit (µg/L)
Ammonia nitrogen (as N)	1, 2, 6, 8	0.10	Acrolein		1
Antimony	HE	0.1	Acrylonitrile		1
Arsenic	1, 6, HE	0.002	4-Pentanone		10
Barium	1, 6, HE	0.1	Methyl ethyl ketone		20
Beryllium	1, 2, 6, 7, 8, HE	0.0005	All other analytes		1
Bicarbonate alkalinity (as CaCO ₃)	1, 6	1			
Cadmium	1, 6, HE	0.002	Title 22 organic compounds	Pits 1 and 6	Detection limit (µg/L) ^b
Calcium	1, 6	1	2,4,5-TP (Silvex)		1
Carbonate alkalinity (as CaCO ₃)	1, 6	1	2,4-D		10
Chloride	1, 6	1	Endrin		0.1
Total chromium	1, 6, HE	0.02	Lindane		0.4
Cobalt	HE	0.05	Methoxychlor		10
Conductivity (µmhos/cm)	1, 6, HE	NAC	Oil and grease (mg/L)		5
Copper	HE	0.08	Toxaphene		0.5
Filterable residue (TDS)	1, 6	NAC			
Fluoride	1, 6	0.1	Other organic compounds	Pits 1, 6, HE	Detection limit (µg/L) ^b
Hydroxide alkalinity (as CaCO ₃)	1, 6	1	Explosives		
Iron	1, 6	0.04	RDX and HMX		20
Lead	1, 2, 6, 7, 8, HE	0.002	TNT		30
Manganese	1, 6, HE	0.09	Benzidine		80
Mercury	1, 6, HE	0.0003	Bis(2-ethylhexyl)phthalate		200
Molybdenum	HE	0.1	2,4-Dinitrophenol		10
Nickel	1, 6, HE	0.05	Low-level phenolics (mg/L)		0.005
Nitrate (as N)	1, 2, 6, 8, HE	0.10	4-Nitrophenol		10
Nitrite (as N)	1, 2, 6, 8, HE	0.1	TOC (mg/L)		0.5
Non-filterable residue (TSS)	1, 6	1	TOX		0.25
pH (Units)	1, 2, 6, 7, 8, HE	NAC			
Potassium	1, 6	0.1			
Selenium	1, 6, HE	0.4			
Silver	1, 6, HE	0.02			
Sodium	1, 6	0.09			
Sulfate	1, 6	1			
Surfactants	1, 6, HE	0.02	Radiological	Pits	Detection limit (pCi/L) ^b
Thallium	HE	0.2	Gross alpha	1, 2, 7, 6, 8	17
Total alkalinity (as CaCO ₃)	1, 6	1	Gross beta	1, 2, 7, 6, 8	11
Total Kjeldahl nitrogen	1, 2, 6, 8	0.5	Tritium	1, 2, 7, 6, 7, HE	200
Vanadium	1, 6, HE	0.2	²³⁸ U	1, 6	0.1
Zinc	HE	0.01	²³⁵ U	1, 6	0.1
			²³⁴ U	1, 6	0.1
			²²⁶ Ra	1, 6	0.1
Purgeable halocarbons (EPA Method 601)	Detection Pits 1, 2, 6, 7, 8 and HE	limit (µg/L)			
All analytes		0.5			

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

^b Detection limits can vary from sample to sample, depending on such items as matrix interference and instrument sensitivity. The table reflects maximum (worst-case) detection limits reported for the year from any analysis.

^c Not applicable.

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Table S-14. Positively detected water-quality parameters, Site 300 Pit 1 monitoring wells, 1989.

Parameter	Well							
	K1-01C	K1-02B	K1-03	K1-04	K1-05	K1-07	K1-08	K1-09
<u>Physical and chemical (mg/L)</u>								
Alkalinity (as CaCO ₃)	160	180	150	150	130	140	130	130
Ammonia nitrogen (as N)	0.85	0.7	<0.5	0.02	0.04	0.02	0.03	0.05
Arsenic	0.017	0.026	0.014	0.016	0.015	0.014	0.016	0.014
Beryllium	<0.0001	<0.0001	<0.0001	0.0001	0.0001	0.0002	0.0002	0.0001
Bicarbonate	160	180	150	150	130	140	130	130
Cadmium	0.0012	0.0029	0.0003	0.0028	0.0002	0.0011	0.0005	0.0005
Calcium (EDTA titration)	49	52	46	46	38	40	38	39
Chloride	42	48	38	40	43	50	42	45
Total chromium	<0.02	<0.02	<0.02	<0.02	0.006	0.006	0.008	0.006
Conductivity (µmhos/cm)	620	630	610	620	540	560	560	550
Copper	<0.08	<0.08	<0.08	<0.08	<0.08	0.17	<0.08	<0.08
Filterable residue (TDS)	390	370	350	360	370	370	370	350
Fluoride	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.4
Iron	0.12	<0.04	<0.04	0.05	0.05	<0.04	0.40	0.06
Lead	0.001	0.005	0.005	0.002	0.011	0.016	0.007	<0.05
Magnesium	19	21	18	24	19	19	19	18
Nickel	<0.05	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	<0.05
Nitrate (as N)	11.0	7.6	8.1	7.0	9.9	10.0	11.0	10.0
Nitrate (as NO ₃)	48	33	36	31	44	48	46	46
Nonfilterable residue (TSS)	5.0	16.0	4.0	2.5	20.0	23.0	14.0	5.0
pH (Units)	7.6	7.6	7.6	7.5	7.7	7.8	7.8	7.6
Potassium	2.8	2.9	2.6	3.1	2.6	3.8	3.0	2.4
Selenium	0.004	0.002	0.004	0.001	0.002	0.004	<0.002	<0.05
Sodium	38.0	41.0	37.0	41.0	44.0	45.0	42.0	42.0
Sulfate	39.0	59.0	38.0	53.0	45.0	43.0	48.0	49.0
Total Kjeldahl nitrogen	0.9	0.8	0.7	<0.5	<0.5	<0.5	<0.5	<0.5
Vanadium	0.04	0.04	0.03	<0.2	0.05	0.06	<0.2	0.2
Zinc	0.01	0.01	0.12	0.01	0.09	0.11	<0.01	0.02
<u>Organic compounds</u>								
TOC (mg/L)	1.7	1.1	1.1	1.4	1.5	1.4	1.3	2.3
<u>Purgeable pollutants (EPA Methods 601/624, µg/L)</u>								
Chloroform	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5.9	<0.5
Freon-113	<0.5	<0.5	<0.5	<0.5	0.9	<0.5	5.8	9.7
Low level phenolics	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.005
<u>Radiological (10⁻⁹ µCi/mL)</u>								
Gross alpha	3.0	6.0	2.0	<2.0	1.0	3.0	4.0	<2.0
Gross beta	22.0	9.0	13.0	4.0	2.0	7.0	3.0	3.0
Tritium	— ^a	241 ± 120	<210	<219	<500	<500	<500	<500
Uranium-234	2.4	1.3	1.4	1.4	1.5	1.6	1.1	1.1
Uranium-235	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Uranium-238	1.3	0.9	0.6	0.8	0.6	0.8	0.5	0.6
Radium-226	0.2	<0.1	0.04	0.2	0.07	0.04	2.4	<0.1

^a Sample not taken, see Quality Assurance chapter.

Table S-15. Positively detected water-quality parameters, Site 300 Pit 7 monitoring wells, 1989.

Parameter	Well							
	K7-01	K7-03	K7-06	K7-09	K7-10	NC7-25	NC7-26	NC7-47
<u>Physical and chemical (mg/L)</u>								
Barium	0.2	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	0.004	0.004	0.012	<0.001	0.003	0.01	<0.002	0.003
<u>Purgeable pollutants (EPA Methods 601/624 µg/L)</u>								
1,1-Dichloroethylene	1.4	1.3	<0.5	<1.0	<0.5	<0.5	<0.5	<0.5
Trichloroethylene	8.0	11.0	<0.5	1.5	<0.5	<0.5	<0.5	<0.5
Freon-113	4.7	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<0.5
Tetrachloroethylene	0.8	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<0.5
<u>Radiological (10⁻⁹ µCi/mL)</u>								
Gross alpha	14.0	<4.0	4.0	<2.0	<5.0	39.0	5.0	3.0
Gross beta	21.0	7.0	<7.0	<6.0	13.0	36.0	<11.0	<9.0
Tritium	43 700	131 000	853	<765	<237	403 000	2790	<219
Uranium-234	6.4	3.1	0.7	0.4	1.1	12.7	0.2	7.0
Uranium-235	0.4	0.5	<0.1	<0.2	<0.1	0.6	<0.1	0.32
Uranium-238	6.6	2.4	0.5	0.3	0.7	9.6	<0.1	7.0

Table S-16. Positively detected water-quality parameters, Site 300 Pit 2 and Pit 8 monitoring wells and Well NC2-07, 1989.

Parameters	Well				
	K2-01C	K2-04D	K2-04S	K8-01	NC2-07
<u>Physical and chemical (mg/L)</u>					
Ammonia nitrogen	0.9	1.0	0.08	0.04	— ^a
Arsenic	— ^a	— ^a	0.014	0.02	— ^a
Barium	— ^a	— ^a	<0.05	1.9	— ^a
Bicarbonate alkalinity (as CaCO ₃)	— ^a	— ^a	— ^a	210	— ^a
Cadmium	— ^a	— ^a	<0.04	0.04	— ^a
Chloride	— ^a	— ^a	— ^a	75	— ^a
Total chromium	— ^a	— ^a	<.005	0.043	— ^a
Conductivity (µmhos/cm)	— ^a	— ^a	— ^a	880	— ^a
Copper	— ^a	— ^a	0.06	0.02	— ^a
Fluoride	— ^a	— ^a	— ^a	0.4	— ^a
Lead	0.006	0.007	0.29	0.007	— ^a
Nitrate (as N)	5.4	9.3	9.9	11.0	— ^a
TOC	— ^a	— ^a	— ^a	1.3	— ^a
Total Kjeldahl nitrogen	1.1	1.0	0.7	<0.5	— ^a
Total alkalinity (as CaCO ₃)	— ^a	— ^a	— ^a	210	— ^a
TSS	— ^a	— ^a	— ^a	2.0	— ^a
Selenium	— ^a	— ^a	<0.002	<0.002	— ^a
Sodium	— ^a	— ^a	— ^a	66	— ^a
Sulfate	— ^a	— ^a	— ^a	78	— ^a
<u>Purgeable pollutants (EPA Methods 601/624 µg/L)</u>					
Bromodichloromethane	0.7	<0.5	<0.5	<1.0	<0.5
Carbon tetrachloride	0.6	<0.5	<1.0	<1.0	<0.5
Chloroform	13.0	<0.5	<1.0	<1.0	<0.5
1,2-Dichloroethane	<0.5	<0.5	<1.0	4.0	<0.5
1,1-Dichloroethylene	0.5	<0.5	<1.0	<1.0	<0.5
Methylene chloride	<0.5	<0.5	1.8	<1.0	<0.5
1,1,1-Trichloroethane	1.4	<0.5	<1.0	1.0	<0.5
Trichloroethylene	<0.5	<0.5	1.0	5.0	<0.5
Trichloroethene	0.7	<0.5	<0.5	<0.5	<0.5
<u>Radiological (10⁻⁹ µCi/mL)</u>					
Gross alpha	15.0	3.0	<2.0	4.0	5.0
Gross beta	13.0	7.0	4.0	18.0	16.0
Tritium	18 100 ± 440	9280 ± 290	12 500 ± 380	500 ± 500	<500
Uranium-234	— ^a	— ^a	1.5	5.4	— ^a
Uranium-235	— ^a	— ^a	<0.2	0.3	— ^a
Uranium-238	— ^a	— ^a	1.0	3.1	— ^a

^a Not analyzed for these parameters.

Table S-17. Positively detected water-quality parameters, Site 300 Pits 1 and 2 area barcads, 1989.

Positively detected parameters	Well (Barcad)						
	K1-01A	K1-01B	K1-02A	K2-01A	K2-01B	K2-02A	K2-02B
<u>Physical and chemical (mg/L)</u>							
Arsenic	0.006	0.009	0.014	<0.002	0.020	0.090	<0.002
Barium	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Beryllium	0.0001	<0.01	0.0001	<0.01	<0.01	<0.01	<0.01
Iron	<0.03	0.08	0.03	<0.03	<0.03	0.22	0.30
Lead	0.003	0.002	0.004	0.003	0.005	0.006	0.003
Manganese	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
<u>Radiological (10⁻⁹ µCi/mL)</u>							
Gross alpha	4.0	<6.0	<4.0	<5.0	6.0	4.0	7.0
Gross beta	14	4.0	15	6.0	20	10	6.0
Tritium	<186	<244	<332	<293	260	<186	<202
Uranium-234	1.5	2.6	1.2	4.1	6.0	4.8	3.7
Uranium-235	0.2	<0.1	<0.1	<0.1	0.2	<0.1	0.2
Uranium-238	0.6	2.5	1.0	2.6	2.9	1.3	3.7
Radium-226	0.5	<0.1	0.4	0.4	0.4	0.4	0.4

Table S-18. Positively detected water-quality parameters, Site 300 Pit 6 monitoring wells, 1989.

Parameters	Well					
	K6-01	K6-03	K6-04	EP6-07	EP6-08	EP6-09
<u>Physical and chemical (mg/L)</u>						
Total alkalinity (as CaCO ₃)	350	180	170	180	190	190
Ammonia nitrogen (as N)	0.11	0.25	<0.1	0.24	<0.1	<0.1
Arsenic	0.013	0.020	0.030	0.022	0.018	0.036
Barium ^a	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate alkalinity (as CaCO ₃)	330	180	170	180	190	190
Cadmium ^a	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (EDTA titration)	64	55	51	56	51	63
Carbonate alkalinity (as CaCO ₃)	16	<1.0	<1.0	<1.0	8.0	<1.0
Chloride	98.0	95.0	180.0	95.0	100.0	130.0
Conductivity (μmhos/cm)	1180	1120	990	1090	1890	1180
Filterable residue (TDS)	790	740	680	770	710	760
Fluoride	0.4	0.4	0.4	0.4	0.4	0.4
Iron	0.28	0.07	0.09	<0.1	1.3	0.46
Lead	0.004	0.016	0.004	0.004	0.006	0.004
Magnesium	28	31	26	31	26	30
Manganese	0.1	0.1	<0.04	0.16	<0.04	<0.04
Nickel	<0.05	<0.05	<0.05	0.06	0.07	<0.05
Nitrate (as NO ₃)	<0.4	<0.4	9.2	<0.4	5.0	5.9
Nitrate (as N)	<0.1	<0.1	2.4	<0.1	1.3	1.6
Non-filterable residue (TSS)	<5.0	6.0	8.0	6.0	<5.0	<5.0
pH (units)	7.6	7.6	7.8	7.8	7.6	7.7
Potassium	6.9	8.0	8.7	7.7	8.4	7.9
Selenium ^a	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Sodium	160	130	120	130	140	140
Sulfate	280	240	200	240	220	250
Total Kjeldahl nitrogen	0.8	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	0.16	0.19	0.17	0.12	<0.01	0.15
<u>Organic compounds (mg/L)</u>						
Low-level phenolic compounds	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total organic carbon (TOC)	1	0.7	0.7	0.9	0.7	1.0
<u>Purgeable pollutants (EPA Methods 601/624 μg/L)</u>						
1,2-Dichloroethane	<0.5	<0.5	<0.5	<0.5	<0.5	0.8
1,1,1-Trichloroethane	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Trichloroethylene	<0.5	<0.5	<0.5	<0.5	<0.5	8.1
<u>Radiological (10⁻⁹ μCi/mL)</u>						
Radium-226	<0.1	0.2	<0.1	0.2	0.3	<0.1
Uranium-234	0.6	0.6	1.3	0.6	1.2	1.6
Uranium-238	0.4	0.4	0.8	<0.5	0.8	1.5
Gross alpha	<5.0	<3.0	<3.0	4.0	<5.0	4.0
Gross beta	120.0	13.0	17.0	12.0	11.0	11.0

^a If the numerical value of a positive result for one sampling period is less than a detection-limit value for another sampling period, the detection-limit value (which is higher, and therefore more conservative) is reported.

Table S-19. Positively detected water-quality parameters, Site 300 high-explosive process-water surface impoundment wells, 1989.

Parameter	Well				
	W-817-01	W-817-02	W-817-03	W-817-04	W-817-03A
<u>Physical and chemical (mg/L)</u>					
Total alkalinity (as CaCO ₃)	260	240	250	250	— ^a
Arsenic	0.072	0.069	0.048	0.065	— ^a
Beryllium	0.0002	<0.0005	0.0004	<0.0005	— ^a
Cadmium	0.0007	— ^a	0.0012	— ^a	— ^a
Calcium (EDTA titration)	22	43	26	23	— ^a
Carbonate alkalinity (as CaCO ₃)	16	<1	<1	16	— ^a
Chloride	250	300	280	240	— ^a
Cobalt	0.008	<0.05	<0.05	<0.05	— ^a
Conductivity (µmhos/cm)	1700	2630	2080	1930	— ^a
Iron	0.12	0.2	<0.04	<0.04	— ^a
Lead	0.011	0.004	0.008	0.014	— ^a
Magnesium	8.9	21.0	13.0	12.0	— ^a
Manganese	0.04	0.09	0.08	0.09	— ^a
Nitrate (as NO ₃)	110	110	110	120	— ^a
Nitrate (as N)	26	26	25	28	— ^a
pH (units)	8.1	8.0	8.1	8.1	— ^a
Potassium	18	14	37	12	— ^a
Selenium	0.045	0.087	0.024	0.027	— ^a
Sodium	330	470	390	390	— ^a
Sulfate	170	450	280	330	— ^a
Surfactants	— ^a	<0.02	0.02	<0.02	— ^a
TDS	1100	2100	1200	1200	— ^a
Vanadium	0.18	0.14	0.13	0.14	— ^a
Zinc	0.21	1.0	1.0	0.75	— ^a
<u>Organic compounds</u>					
HMX (µg/L)	41	<20	<20	<20	<20
RDX (µg/L)	105	<30	<30	<30	<30
TOC (µg/L)	1.5	2.0	1.5	1.4	— ^a
TOX (µg/L)	<0.025	<0.025	0.053	<0.025	— ^a
<u>Purgeable pollutants (EPA Methods 601/624, µg/L)</u>					
Chloroform	<0.5	<0.5	<0.5	2.8	0.6
1,2-Dichloroethene TOT	<0.5	<0.5	36	24	81
1,2-Dichloropropane	<0.5	<0.5	<0.5	<0.5	0.6
Freon 113	0.8	<0.5	<0.5	<0.5	<0.5
Methylene Chloride	<0.5	<0.5	<0.5	3.6	<0.5
1,1,2-Trichloroethane	<0.5	<0.5	<0.5	<0.5	0.6
Trichloroethylene	<0.5	<0.5	<0.5	15.0	<0.5

^aNot analyzed for these parameters.

Introduction

Soil is an integrating medium that can account for contaminants released to the atmosphere or through liquid effluents (U.S. Department of Energy 1988d). An intensive soil sampling program conducted in 1971 and 1972 (Lindeken 1973) provided a data base for the concentration ranges of various radionuclides in soil near the Livermore site and at Site 300. Since 1972, soil sampling at Site 300 has been part of the continuing LLNL monitoring program designed to document any changes in environmental levels of radioactivity that have occurred and to evaluate any increase in radioactivity that might have resulted from LLNL operations. Because HE tests at Site 300 occasionally involve the use of depleted uranium, one of the purposes of the annual soil sampling is to determine how these tests perturb the natural uranium content of the soil. The rationale for including the naturally occurring nuclides (^{40}K , ^{232}Th , and ^{238}U) and the long-lived fission product (^{137}Cs) is to provide baseline data on global fallout and to allow monitoring of the containment of the small inventories of mixed fission products and radiochemical tracers used at the Livermore site and at Site 300.

Methods

In 1989, 13 soil samples were collected at Site 300. Ten of the samples were collected from locations that have been sampled annually since 1973. Two samples were collected from locations in drainage channels added to the soil surveillance network in 1986. One new sampling location, near Bunker 801, was added to the network in 1989. **Figure S-8** shows the soil sampling locations at Site 300.

Soil sampling activities follow standardized written procedures (Brekke et al. 1988). Samples are taken from reasonably level areas that represent undisturbed soil. A 2-m square is marked off in each area, and an 8.25-cm diameter coring tool, designed at LLNL, is used to collect 5-cm-deep subsamples at the corners and center of the square. All subsamples are collected to a depth of 5 cm because surface deposition from the air is the primary pathway for potential contamination. The five subsamples of soil collected from each 2-m square are combined into a single composite sample in a plastic bag. A label is affixed

to the bag, and the sample is identified by number. This number is entered in a log-book, together with all pertinent sampling information and a description of the sample location. The number is used to identify the sample throughout the laboratory analyses and is used throughout this report.

After collection, the soil samples are dried, ground, and blended. Plutonium-239 content is determined in each sample, following an acid-leaching procedure. The soil is leached by heating for 4 h with a mixture of concentrated HNO_3 and HCl . The plutonium is then separated and purified by ion exchange and electroplating and is analyzed by alpha spectroscopy. Gamma spectroscopy is performed on the soil samples after they are dried at 110°C for a minimum of 2 days, pulverized, passed through a 32-mesh sieve, and blended. Approximately 300-g aliquots of the soils are sealed in 200-cm³ thin-walled aluminum cans and are counted for gamma emitters with a $\text{Ge}(\text{Li})$ detector.

Approximately 10% of the sites are sampled in duplicate to comply with quality

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assurance protocols (Holland 1987). For duplicate collections, two adjacent cores, 5-cm deep, are taken from the corners and center of each 2-m square. Separate composites of the five cores are then made, and the composites are identified with unique sample numbers.

Results

Table S-20 presents data on the concentrations of ^{239}Pu , ^{40}K , ^{137}Cs , ^{232}Th , and ^{238}U in soils from the Site 300 sampling locations; only positively detected parameters are shown. The concentrations and distributions of all observed nuclides in Site 300 soil for 1989 are similar to the levels measured in 1988 and are

within the ranges reported in previous years. The soil samples show that greater-than-background concentrations of ^{238}U , including the sample from the new sampling location near Bunker 801, are limited to isolated regions near the firing tables. The highest value of $98.2\text{ }\mu\text{g/g}$ (about 25 times greater than background) was observed in the vicinity of a now-inactive firing table. In 1988, a value of $570\text{ }\mu\text{g/g}$ was observed in this area. However, in 1988, the gravel from this firing table was removed to an onsite landfill after the sample that yielded the $570\text{-}\mu\text{g/g}$ value was taken. The 1989 value is probably an indication of residual material in this area.

Figure S-8. Soil sampling locations, Site 300, 1989.

Environmental Impact

In the past, ^{238}U -contaminated gravel from the firing tables was removed to an onsite landfill. The landfills at Site 300 were closed in 1988. As in the past, the 1989 analyses indicated that increased ^{238}U in soil is essentially limited to areas adjacent to the firing bunkers (Gudiksen et al. 1973; Holland et al. 1987; Holland and Brekke 1988). However, the level of

contamination has been reduced, probably due to the clean-up operations at the bunkers that removed contaminated gravel to the landfills.

With the exception of elevated ^{238}U concentrations observed near the bunkers, the activities observed in samples collected are representative of background or naturally occurring radionuclides.

Table S-20. Positively detected radionuclides in soil—Site 300, 1989 (sampling depth of 0 to 5 cm).

Location ^a	^{239}Pu	^{40}K	^{137}Cs	^{238}U	^{232}Th
	[10^{-9} $\mu\text{Ci/dry g} \pm 2\sigma$ (%)]	[10^{-6} $\mu\text{Ci/dry g} \pm 2\sigma$ (%)]		[$\mu\text{g/dry g} \pm 2\sigma$ (%)]	
1103	5.6 ± 8	13.0 ± 3	0.24 ± 3	2.7 ± 54	9.1 ± 4
1113	1.2 ± 15	13.8 ± 4	0.06 ± 11	8.6 ± 16	8.8 ± 3
1112	2.3 ± 12	17.6 ± 3	0.13 ± 8	<2.1	7.6 ± 3
1110	4.3 ± 14	15.3 ± 3	0.13 ± 9	<2.0	11 ± 3
1111	3.4 ± 10	9.7 ± 4	0.19 ± 5	3.9 ± 68	7.9 ± 4
1115	3.4 ± 9	10.6 ± 5	0.21 ± 5	98.2 ± 4^b	12 ± 3
1114	3.6 ± 9	11.5 ± 4	0.17 ± 5	4.1 ± 53	7.9 ± 4
1116	2.0 ± 13	14.5 ± 4	0.11 ± 8	3.1 ± 58	8.2 ± 3
1107	5.0 ± 14	13.9 ± 4	0.13 ± 7	4.4 ± 45	13.8 ± 3
1109	0.4 ± 24	10.5 ± 4	0.02 ± 25	6.5 ± 19	4.4 ± 4
1108	— ^c	— ^c	— ^c	— ^c	— ^c
1104	5.1 ± 8	14.9 ± 4	0.27 ± 3	3.7 ± 74	9.2 ± 3
1106	4.9 ± 14	11.2 ± 3	0.15 ± 6	2.1 ± 93	9.4 ± 2
1117	0.1 ± 61	12.5 ± 5	0.22 ± 5	62.8 ± 5^b	11 ± 3
Mean	3.2	13.0	0.16	3.93 (15.7)	9.3
SDM (%)	56	18	45	52 (189)	25

^a See Fig. S-8 for sampling locations.

^b Data from area of known contamination. Summary data with these data included in the calculations are parentheses.

^c No data. See Quality Assurance chapter.

Introduction

Sampling and measurement of native vegetation can provide information about the buildup of radionuclides in the environment. Native vegetation is specifically mentioned by DOE in its monitoring regulations as a medium that is appropriate for sampling and analysis (U.S. Department of Energy 1988d). The requirements also call for vegetation radionuclide pathway analyses. LLNL collects and analyzes vegetation samples from Site 300, and a potential human dose from this pathway is calculated.

Methods

At quarterly intervals, samples of vegetation (usually native grasses) are collected at Site 300 and at offsite locations near Site 300. **Figure S-9** shows the 1989 vegetation-sampling locations at Site 300. The sampling locations are the same as those sampled in 1988. The use of constant sampling locations allows for better trending of the data and closer monitoring of areas of concern. Sampling activities follow standardized written procedures (Brekke et al. 1988). Grass samples are cut at ground level, and any soil or dead tissues are discarded. The bulk volumes of the samples are between 0.5 and 1 L (approximately 1 kg). As each sample is collected, it is double-bagged in plastic, labeled according to sample type and location, and frozen in a dry-ice chest to minimize water loss on the bag's surface. A label is affixed to the bag, and the sample is identified by number. This number is entered in a logbook, together with all pertinent sampling information and a description of the sample location. The number is used to identify the sample throughout the laboratory analyses and is used throughout this report. The samples are later transferred to a freezer in the laboratory. Two subsamples of vegetation are collected each quarter at each sampling location. One subsample is analyzed and the other is preserved in the laboratory freezer, in case the first sample is lost during analysis or the measurement result is in question

and reanalysis of the sample is necessary for data verification.

Water from the vegetation samples is collected utilizing freeze-drying techniques. The tritium content of the recovered water is determined by liquid-scintillation counting.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, a total of four subsamples of vegetation from a sampling location are collected using identical methodology. Two of the bags serve as the official sample, and the other two bags are considered the duplicate sample. The duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Results

Table S-21 shows tritium data for vegetation collected at Site 300. The values are mostly at detection limits, with the exception of two locations, and are very similar to those reported in 1988. As was the case in 1988, vegetation samples from Locations 6 and 13 contained the highest tritium values detected. The highest observed concentration (Location 6) was 1.58×10^{-3} $\mu\text{Ci/mL}$. Because of this high value, the sample was reanalyzed using the preserved subsample. The result was verified.

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Vegetation
Monitoring

Location 6 is in the area presently under investigation by ERD for tritium contamination of groundwater. The 1989 maximum levels from these sampling locations are greater than those reported in previous years. Tritium has been observed in the vegetation of these areas since 1971, although tritium is not presently used at the site (Lamarre 1989b). These sampling locations are adjacent to landfills that include tritium-containing debris from firing tables. As a result of seasonal rains spreading tritium from this debris, the tritium is present in the soil and groundwater in the area where these samples are routinely collected. The landfill areas continue to be under investigation for soil and groundwater tritium contamination, as described in reports published by the

Environmental Restoration Division of LLNL's Environmental Protection Department (see e.g., Lamarre et al. 1989a-c; Taffet et al. 1989a).

The effective dose equivalents shown in **Table S-21** were derived using the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b) and the dose-pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). The calculated annual average dose from vegetation at Location 6, based on the mean value of $3.97 \times 10^{-4} \mu\text{Ci/mL}$, is 7 mrem/y using conservative pathway modeling assumptions (assuming that an adult's diet includes vegetables with the highest observed average tritium concentration, and meat and milk derived from livestock

Figure S-9. Vegetation sampling locations, Site 300, 1989.

fed on grasses with the same concentration). In actuality, this dose would never be received because vegetation at Site 300 is neither consumed by people nor by grazing livestock.

Environmental Impact

In general, LLNL impacts on vegetation at Site 300 for 1989 were minimal. Tritium levels found in the Site 300 vegetation, with the exception of vegetation from the

two known sites of contamination, were generally comparable to those observed in previous years. Concentrations detected at the sites of contamination are not of concern because the contamination is very localized, and the affected vegetation is neither ingested directly by people nor consumed by livestock. Tritium levels in vegetation at Site 300 will continue to be monitored, with special attention given to the areas of known contamination.

Table S-21. Tritium in vegetation—Site 300, 1989.

	Sampling location ^a					
	1	2	3	6	12	13
	[10 ⁻⁷ μCi/mL of moisture content ± 2σ (%)]					
First quarter	1.4 ± 92	1.4 ± 91	<1.2	57 ± 3	2.6 ± 48	22 ± 7
Second quarter	<1.2	<1.2	<1.2	21 ± 7	<1.2	788 ± 1
Third quarter	<1.2	<1.2	<1.2	15 800 ^b ± 0	<1.2	420 ± 1
Fourth quarter	<1.2	<1.2	<1.2	4.2 ± 31	<1.2	102 ± 2
Mean	<1.2 ^c	<1.2 ^c	<1.2 ^c	27 (3971) ^b	<1.2 ^c	333
SDM (%)	0 ^d	0 ^d	0 ^d	99 (199) ^b	0 ^d	105
Effective dose (mrem) ^e	2.1 × 10 ⁻³	2.1 × 10 ⁻³	2.1 × 10 ⁻³	4.8 × 10 ⁻² (7)	2.1 × 10 ⁻⁴	5.9 × 10 ⁻¹

^a See Fig. S-9 for sampling locations.

^b Sample from area of known contamination. Summary statistics with this value included in calculation are in parentheses.

^c Median value.

^d Median absolute deviation (%).

^e This dose represents the total effective dose equivalent from the forage-cow-milk pathway.

NOISE MONITORING

Introduction

As noted earlier, LLNL's HE testing is conducted at Site 300. Because the site is remote, these experiments can be performed with minimal offsite impact from annoying noises or damaging overpressures. On the basis of meteorological measurements made at least twice each day, a limit is set on the weight of HE that can be detonated without impact in populated areas. To monitor this limit, 6 microbarograph sensors are maintained in or near the City of Tracy.

Methods

Figure S-10 shows the locations of the environmental noise monitoring stations in Tracy and surrounding areas. Each station consists of an outdoor weatherized B&K sound level meter, and a UHF radio telemetry link back to Site 300. Acoustic data are analyzed for overpressures in excess of regulatory limits during explosives testing, taking into account the acoustic propagation time.

Results

LLNL conducted 55 high explosives tests at Site 300 during 1989. Microbarograph measurements in the vicinity of Site 300 and the City of Tracy demonstrated that the noise limit of 400 μ bar was not exceeded. There were no complaints of noise or overpressure from residents in the vicinity of the test site. Furthermore, none of the 55 tests produced sound levels, at any of the 6 microbarograph stations, above 65 μ bar.

Environmental Impact

Through compliance with the limit of 400 μ bar, LLNL has prevented any significant noise impact.

Figure S-10. Noise monitoring locations in Tracy, 1989.

ENVIRONMENTAL RADIATION MONITORING

Introduction

Beginning July 1, 1988, the Environmental Monitoring Group at LLNL implemented an environmental radiation monitoring program at Site 300. This report contains the first full calendar year of data, which will be evaluated with the 1988 data to assess the design of the dosimetry network and potential environmental impacts. LLNL carries out environmental radiation monitoring to evaluate the level of environmental radiation. Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters. The dosimeters provide a measure of the total amount of radiation, both background and any radiation that has manmade origins, at a particular location.

Methods

The program was designed to measure external doses from penetrating radiation (primarily gamma rays) at 13 Site 300 perimeter locations and 3 offsite locations (Figure S-11). These measurements are made with Panasonic UD814 thermoluminescent dosimeters (TLDs). This dosimeter contains three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Each dosimeter is heat-sealed in a 3-1/2-in. $\times$ 2-1/4-in., 4.5-mm-thick foil pouch to protect against light and moisture. The dosimeters are mounted in the field on existing structures (such as fence lines) at approximately 1 m above ground level. The dosimeters are exchanged and analyzed quarterly.

The TLDs measure environmental radiation exposure in milliroentgens (mR). The measured exposure is converted to dose by calibrating the dosimeters to read out in absorbed dose and applying a quality factor for a beta/gamma radiation field. The resulting dose equivalents (mrem) are compared to radiation protection standards.

The TLDs measure radiation exposure from all sources of penetrating radiation. These include natural sources, fallout from nuclear weapons testing, and any contribution from Site 300. Offsite dosimeters are located in areas accessible to the public.

These areas are considered background and are used for comparison with the perimeter dosimeters.

Results

Table S-22 presents the TLD data, expressed as dose equivalents (mrem) for 1989. The perimeter average measured dose in 1989 was 77 mrem (ranging from 69 to 89 mrem). The offsite measured doses are 76 mrem just west of Site 300 and are 68 and 56 mrem in the City of Tracy.

Environmental Impact

Initial network design limited monitoring to the site perimeter and three locations in the San Joaquin Valley near the City of Tracy. The offsite locations were chosen to provide exposure information about nearby population centers and background radiation levels. The regions chosen have different terrain and geological composition. The region around Site 300 has elevated levels of naturally occurring uranium and may be different than the San Joaquin Valley region. The differences observed between the two locations may account for the different measured external radiation doses. We are investigating these differences and will increase the offsite monitoring east of Site 300.

Site 300
Environmental
Radiation
Monitoring

The TLDs measure radiation exposure from all sources of penetrating radiation. Based on past calculations (Lindeken et al. 1973), environmental terrestrial exposure rates in this region

vary from 30 to 60 mR/y. Cosmic radiation is about 35 mR/y, calculated from local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966).

Figure S-11. Location of Site 300 gamma dosimeters, 1989.

Table S-22. Environmental radiation measurements (TLD)—Site 300, 1989.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual Total
	(mrem)				
<u>Site 300 Perimeter</u>					
78	17	18	18	18	71
79	16	17	18	18	69
80	16	18	17	18	69
81	20	23	23	21	87
82	17	20	19	19	75
83	20	22	22	21 ^b	85
84	17	21	18	22	78
85	17	20	19	19	75
86	17	19	19	18	73
87	19	24	24	22	89
88	17	20	18	18	73
89	17	20	19	20	76
90	18	20	20	20	78
Mean	18	20	20	20	77
SDM (%)	8	10	11	8	9
<u>Offsite</u>					
91	16	20	20	20	76
92	15	17	18	18	68
93	13	14	14	15	56
Mean	15	17	17	18	67
SDM (%)	10	18	18	14	15

^a See Fig. S-11.

^b No data available; the dosimeter was missing at collection time. This value is the mean of the values from the other three quarters.

RADIOLOGICAL DOSE ASSESSMENT

Introduction

A general discussion of radiation is presented in the Radiological Dose Assessment chapter for the Livermore site. The reader unfamiliar with the terms used throughout this chapter, such as "rad" and "rem," are referred to that chapter. [The reader interested in more information is referred to *Radiation: Doses, Effects, Risks* (U.N. Environment Programme 1985).]

Radiation Protection Standards

The DOE environmental radiation protection standards are provided in DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (U.S. Department of Energy 1990). The order incorporates a new system for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 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 definition of "effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards, which apply to air emissions, are contained in 40 *Code of Federal Regulations* Part 61, Subpart H of the Clean Air Act and are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway. (On December 15, 1989, the standard was changed to 10 mrem/y effective dose equivalent; this value will be reflected in the 1990 report.)

The EPA standard specifies that the AIRDOS-EPA-Clean Air Act Code (CAAC) model code be used to estimate doses, while LLNL, to fulfill the DOE requirement, historically has used the Continuous-Point-Source Code (CPS Code). This results in somewhat different calculated individual doses because of the differences in model assumptions and calculations. The results of both codes are presented in **Tables S-23-S-26**.

Potential Radiological Dose from Site 300

In accordance with DOE environmental protection orders and other Federal and State requirements, EMG assessed the radiological impact from operations at Site 300 during 1989. Potential radiation doses to the public calculated from radionuclide concentrations in environmental media (determined by surveillance sampling) are presented with the data in the various chapters; doses calculated from emissions of radioactive materials to the atmosphere are presented here.

There are two major sources by which radioactivity can enter the atmosphere at Site 300: operations at the Advanced Test Accelerator (ATA) and high explosives tests. Because airborne emissions from high explosives tests cannot be monitored, potential impacts from these operations are assessed by a network of ambient air monitors.

The total airborne discharge from ATA in 1989 was 0.57 Ci of ^{13}N and 0.57 Ci of ^{15}O . These nuclides are air-activation products generated during the interaction of the accelerator beam with air. Nitrogen-13 has

a half-life of about 10 minutes, and ^{15}O has a half-life of about 2 minutes.

As stated above, radiation doses based on emissions were calculated by two methods: the EPA Clean Air Act Code (CAAC) (40 *Code of Federal Regulations* Part 61, Subpart H), which contains the AIRDOS-EPA and RADRISK models, and the Continuous-Point-Source (CPS) Code (Peterson et al. 1976).

The CAAC Code was used to calculate the estimated dose at the site dose to the nearest resident, and dose at the maximum offsite exposure location for each emission source. The CPS Code was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and maximum offsite dose as well as collective person-rem dose to the population residing within 80 km of the Livermore site. Both of these methods are based on conservative assumptions, and any actual dose received by an individual would be much less.

These codes were used to determine the doses due to releases of ^{13}N and ^{15}O .

Appendix A contains definitions of the doses discussed in this chapter and the mathematical equations used to perform this assessment.

EPA Clean Air Act Code. The air pathway doses calculated using the Clean Air Act Code included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The Clean Air Act Code was run using specific meteorology for Site 300. The air pathway dose calculated is expressed as dose equivalents.

The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Site 300 operations in 1989 was 1.5×10^{-4} mrem; the dose to the nearest resident was 3.7×10^{-7} mrem; and the dose at the point of maximum offsite exposure was 1.5×10^{-4} mrem. These doses represent only 0.006% or less of the EPA limit (see **Table S-23**).

Continuous-Point-Source Code. Air pathway doses are also calculated using

the CPS Code (**Table S-24**). The maximum inhalation dose from airborne emissions at the Site 300 perimeter was 6.3×10^{-4} mrem. The maximum inhalation dose from airborne emissions to the nearest resident was 1.6×10^{-4} mrem.

Table S-25 is a summary of the radiological dose to the maximally exposed individual in the public; this is a hypothetical person who lives at a location and has a lifestyle that results in receipt of the maximum possible calculated radiation dose from Site 300 operations. This dose includes all significant exposure pathways, not just the air pathway, and is derived using the most conservative, but realistic, exposure data and assumptions. The inhalation submersion pathways are calculated using the CPS Code. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1989 was 6.3×10^{-4} mrem. The DOE radiation protection limit to the public is 100 mrem/y. For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation (including radon) during this same period (see **Table S-26**).

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 1.3×10^{-3} person-rem during 1989. This dose is based on a population of 6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources during the same period of time was estimated to be 1.9×10^6 person-rem.

Table S-26 compares the dose to the public resulting from Site 300 operations with the dose to the public from natural and other background sources of radiation. The dose resulting from Site 300 operations is negligible.

Summary

Overall, the measured and calculated radiation doses are well below the applicable standards for radiation protection of the public. Moreover, the potential radiological doses from Site 300 operations are substantially less than the doses normally received from natural sources of background radiation. The doses presented

above were calculated using conservative assumptions; they are not the doses actually received by anyone. Any dose actually received by an individual would be considerably less. Thus, these maximum credible doses show that Site 300 operations had no significant impact on public health during 1989.

Site 300
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Table S-23. Radiation dose from the air pathway (Clean Air Act Code^a calculations) for Site 300, 1989.

Facility	Nuclide (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Advanced Test Accelerator	¹³ N, ¹⁵ O (0.57, 0.57)	0.00015	3.7×10^{-7}	0.00015
Total		0.00015	3.7×10^{-7}	0.00015
Percent of Federal Emission Standard ^c		0.006	1×10^{-5}	0.006

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations* Part 61, Subpart H.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose.

^c The Federal Emission Standards for radionuclides (contained in 40 *Code of Federal Regulations* Part 61, Subpart H) limit doses to the public to 25 mrem/y to the whole body and 75 mrem/y to any critical organ. On December 15, 1989, a new standard of 10 mrem/y effective dose equivalent took effect; the percentages of this standard for dose at the site perimeter, dose to nearest resident, and dose at maximum offsite exposure are 0.0015%, $3.7 \times 10^{-6}\%$, and 0.0015%, respectively.

Site 300
Radiological
Dose
Assessment

Table S-24. Estimated radiation dose to the public from Site 300 airborne effluents during 1989 (Continuous-Point-Source Code).

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Advanced Test Accelerator (ATA)	¹³ N/0.57 ¹⁵ O/0.57	0.00063	0.00016	0.00063	0.0013
Total		0.00063	0.00016	0.00063	0.0013

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less. It is not used to calculate population dose.

^b The population dose is the collective (combined) dose of all individuals residing within an 80-km radius. These calculations are based on the same population distribution as that around the Livermore site (6 000 (70)). The population densities within 80 km of Site 300 are actually less. Therefore, the collective person-rem dose is conservative—the actual dose to the public within 80 km around Site 300 is actually lower. The population dose is calculated directly with the Continuous-Point-Source Code.

Table S-25. Summary of radiological dose assessment for 1989 for Site 300.

Effective dose equivalent to the maximally exposed individual in the public						
Nuclide	Pathways				Percent of DOE primary radiation protection standard for the public ^b	
	Inhalation/ submersion ^a (mrem)	Ingestion- foodstuffs (mrem)	Ingestion- water (mrem)	Total		
				(mrem)		(mSv)
¹³ N, ¹⁵ O	0.00063	N/A ^c	N/A ^c	0.00063	6 × 10 ⁻⁶	0.0006
Site 300 Total ^d				0.00063	6 × 10 ⁻⁶	0.0006

^a The inhalation/submersion dose was derived using the Continuous-Point-Source code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c There is no ingestion dose from short half-life air activation products.

^d This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table S-26. Comparison of radiation doses—Site 300, 1989.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
<u>Site 300 Sources</u>		
Atmospheric Emissions	0.00063 ^b	0.0013 ^c
<u>Other Sources</u>		
Natural radioactivity ^d		
Cosmic radiation	40	240 000
Terrestrial radiation	50	300 000
Internal (food consumption)	28	168 000
Radon	200	1 200 000
Medical radiation ^{e,f}		
(Diagnostic procedures)	55	330 000
Weapons test fallout ^{g,h}	5	30 000
Nuclear power production ^{g,h}	5.5	33 000

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of LLNL (approximately 6 000 000).

^b This dose represents the maximum committed effective dose equivalent from all Site 300 emissions. It is calculated using the Continuous Point Source Code and the most conservative exposure assumptions and is not a dose actually received by any member of the public. Therefore, it is not used to calculate Site 300 population dose.

^c Population dose from Site 300 emissions is calculated directly with the Continuous-Point-Source Code.

^d These values vary with location and represent approximate averages in the vicinity of Site 300.

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

^f From Mettler et al. (1990).

^g From Glasstone and Jordan (1980).

SUMMARY OF ENVIRONMENTAL COMPLIANCE ACTIVITIES

Introduction

This section briefly describes additional environmental activities performed by LLNL to comply with Federal, State, and local laws and regulations. These related environmental activities were performed by the Regulatory Affairs Division, the Environmental Guidance Division, and the Environmental Restoration Division of the Environmental Protection Department. Included is a description of environmental permits issued to or held by LLNL for Site 300 during the year. A table of public hearings, regulatory inspections, and regulatory permits is presented in **Table S-27**. For further information about these activities, the interested reader is referred to the documents contained in the Information Repositories located at the LLNL Visitor's Center and the City of Livermore Public Library. A list of these documents is presented in **Appendix B**.

Resource Conservation and Recovery Act (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 those that are designated as hazardous. Similarly, the California Hazardous Waste Control Law sets requirements for the management of hazardous wastes in California. RCRA regulates treatment, storage, and disposal facilities through a permit program. The permit process requires regulatory agency review and approval of a facility's Part A and Part B permit application. Applications provide information on the facility and wastes managed at the facility.

Hazardous Waste Permits. Landfill Pits 1 and 7 were operated at Site 300 under provisions of the Interim Status Document CA 2890090002 until November 1988 when their use ceased. They had been used for disposal of firing table gravel and debris. In May 1988, Closure and Post-Closure Plans were prepared for the landfills and submitted to the EPA, RWQCB, and DHS for their review. In June 1989, LLNL submitted to the regulatory agencies Volume II of the Closure Plan, which contained technical

specifications for closure as well as a construction quality assurance plan. Upon final review and approval of the Closure Plans by the regulatory agencies, the landfills will be closed. The RCRA Part A permit application was revised to show the change in landfill status.

A RCRA Part B permit application was submitted to EPA and DHS in January 1989 for the hazardous waste container storage facility, which will be used only for the storage of hazardous wastes identified in the permit application. A public hearing was held by DHS on August 3rd regarding the proposed Site 300 Building 883 Hazardous Waste Container Storage Facility permits. The purpose of this hearing was to receive comments from the public on the EPA and DHS draft permits, as well as the DHS Negative Declaration under the California Environmental Quality Act. The final Part B permits were issued by EPA and DHS in November 1989. The permits allow the facility to store specific wastes in containers provided that certain administrative and operational conditions are met. The permits also require development and implementation of a waste minimization program. Finally, as part of the EPA permit, a condition was included citing the March 1989 proposed RCRA cleanup order issued under

Table S-27. Compliance summary—Site 300.

Type of regulatory action	Regulatory agency
Public hearing (date)	
RCRA Waste Disposal Permit (Aug. 3)	DHS/EPA
Permits (number)	
RCRA Hazardous Waste Container	
Storage Facility Permits (2)	DHS/EPA
Interim Status for HE burn pit (1)	DHS/EPA
WDR 80-184 for Class II-1 Solid Waste	RWQCB
Disposal Sites (1)	
WDR 82-105 (NPDES Permit CA0081396) for	RWQCB
Cooling Tower Wastewater Discharge (1)	
WDR 85-188 for Domestic and Industrial	RWQCB
Wastewater to Septic Systems and	
Evaporation Ponds (1)	
Gasoline Recovery System (2)	SJCAPCD
Paint Spray Booth (1)	SJCAPCD
Sawdust Collector (cyclone) (1)	SJCAPCD
Boilers (5)	SJCAPCD
Inspections (date)	
Landfill Closure Inspection (Mar. 10)	EPA/DHS/RWQCB
RCRA Annual Inspection (Mar. 26)	EPA
Annual Inspection of Permitted Sources (Apr. 4)	RWQCB
Underground Tank Soil Sampling (June 26)	SJCHD
Annual Inspection of Endangered	U.S. Fish and Wildlife/
Wildflower (Mar. 30)	California Fish & Game
Annual Inspection of Permitted Sources (Nov. 28)	SJCAPCD

Section 3008(h) (U.S. EPA Docket No. RCRA-09 8g-OQ16), which requires investigation and remediation of other areas of concern located at Site 300.

The Part B application for a new high-explosives burn pit at Site 300 is scheduled to be submitted in 1990.

Inspections. On March 10, 1989, staff from the EPA, DHS, and RWQCB met at Site 300 to discuss technical and regulatory issues involved in the proposed closure of Landfill Pits 1 and 7. After the meeting, the staff from EPA and DHS also visited the landfill areas and the container storage facility, Building 883. This visit provided information to the regulatory agencies for the ongoing review and discussions regarding the landfill closure plan and the hazardous waste container storage facility permit application.

On March 26, 1989, an EPA contractor performed the annual RCRA inspection of hazardous waste generating operations and storage and treatment units. Various potential violations were noted in the resulting inspection report. The potential violations are generally described as follows: inspectors had been denied access to one building; containers used to collect waste being generated at two locations were open; the waste accumulation start dates on labels were being inappropriately completed on drums; the waste accumulation areas were not clearly marked in two areas; two of the inspected accumulation areas were overcrowded and needed better emergency response equipment; the waste analysis plan did not state what information is to be provided by generators who send waste to Site 300, how a

representative sample of these wastes would be collected, or how landbanned wastes are to be analyzed; the hazardous waste storage facility operating log was not available during the inspection; and no analysis was readily available for one unlabeled drum in the container storage area.

LLNL responded to EPA with the following information regarding the noted potential violations: it was explained that certain areas require authorized access for safety reasons and had the inspectors wished to proceed, authorization would have been obtained; open drums were fitted with self-closing attached funnels to collect waste; proper accumulation start dates were applied to labels; waste accumulation areas were upgraded to provide proper spacing and emergency response equipment; the waste analysis plan was revised to address concerns about waste generated at the Livermore site and landbanned waste; operating records are now maintained in the onsite Hazardous Waste Management technologist's office; and the unidentified container of waste was properly identified and labeled. No additional enforcement action has been taken by EPA.

Construction of and Improvements to Waste Accumulation Areas. A Waste Accumulation Area (WAA) is 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 offsite disposal.

There are 17 WAAs at Site 300. Prior to 1989, these areas were satellite accumulation areas; they were upgraded to WAAs in 1989 to increase operational flexibility.

RCRA Personnel Training. Annual training sessions and as-needed briefings are conducted for generators of hazardous waste in the area of waste handling practices. This training is based upon requirements set forth in 40 *Code of Federal Regulations* Part 265.16 and 22 *California Code of Regulations* Section 67105. Employees learn to identify the basis (i.e., legal, regulatory, policy, and DOE Orders)

for LLNL waste practices and the respective waste-management responsibilities for waste generators, Environmental Analysts, or Hazardous Waste Management field technicians. The course also includes training in the identification of the factors used to determine if a waste is hazardous, in the determination of the need for permits and controls, and in the reduction of the volume of waste to be discharged. Other topics include preparation of waste for transport and for storage in waste accumulations areas (WAAs), the protocol for sampling waste, preparation of documentation for waste disposal, and response to emergencies at the WAA or in a laboratory or a shop. During 1989, 20 LLNL Site 300 employees received this training.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks

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 Law, found in 23 *California Code of Regulations* Chapter 3, Subchapter 16, regulates underground tank systems used for containment of hazardous products or hazardous waste. County health departments, such as the San Joaquin County Health District (SJCHD) have been delegated authority to enforce these regulations. Federal standards for hazardous products and petroleum products contained in underground storage tanks (USTs) are found in 40 *Code of Federal Regulations* Part 280, and standards for hazardous wastes in tanks, both aboveground and underground, are the subject of RCRA regulations in 40 *Code of Federal Regulations* Part 265.

Underground tanks at Site 300 contain diesel fuel, gasoline, and potentially contaminated wastewater; aboveground tanks contain diesel fuel, insulating oil, and potentially contaminated wastewater. Some of the wastewater systems are a combination of underground and

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aboveground tanks. Site 300 has a 11 aboveground and 20 underground tanks in service.

To ensure that LLNL's UST program is in full compliance with Federal and State regulations, a preliminary classification of USTs as hazardous or nonhazardous was made in 1989 based on existing data and known uses for each tank. In a second phase, these classifications will be verified by an extensive sampling program. Implementation of Phase II of the classification procedure is expected to be completed by 1991.

Tank Integrity Testing. The tank leak-tightness testing program is in place. Underground tank systems are tested to determine their structural integrity in accordance with testing requirements set forth in Federal and State regulations. All 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 SJCHD. Eleven underground diesel fuel and gasoline systems were tested in 1989.

Two underground wastewater retention tanks were tested for leak tightness in 1989. These systems exist to receive and retain oily wastewater 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 analyses of representative samples. Testing in 1989 identified one leaking wastewater system. The leak site was repaired, and the system was retested and shown to be leak tight. However, when soil-boring operations were conducted next to the tank to permit collection of samples of gravel fill, the tank was accidentally punctured. The tank was taken out of service. It was decided to replace the punctured tank with a new doubly contained tank. This will occur in 1990.

LLNL has established a program to reconcile on a daily basis the inputs into and

withdrawals from underground vehicle-fuel tank systems. The results of the program are reported to SJCHD quarterly. The underground diesel fuel tanks that serve as fuel supplies for emergency generators are monitored according to a program of routine tank gaging and reconciliation.

The Tank Program also completed monitoring and release response plans for new double-contained tank systems and submitted the plan to SJCHD.

Underground Tank Fees. LLNL has paid annual fees to SJCHD for 15 tanks at Site 300. All of these tanks are in service.

Inspection. On June 26, SJCHD witnessed soil sampling at Building 801. Sampling was conducted to verify that there was no appreciable contamination from leaks that had been identified and subsequently repaired. However, an appropriate sample could not be obtained. No report was required or received.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA) — Title I

Also known as the "Superfund" Act, CERCLA is a Federal statute that gives the Federal government the power to identify and clean up hazardous chemicals and substances released to the environment.

At Site 300, ongoing remedial investigations, feasibility studies, and remedial actions are being performed. Until recently, these investigations were being conducted under the provisions of the California Clean Water Act as administered by the RWQCB. In March 1989, LLNL received a proposed RCRA cleanup order from EPA, and in July the EPA proposed to include Site 300 on the National Priorities List (NPL) for regulation under CERCLA. At this point, the terms of the RCRA cleanup order have not been finally negotiated with EPA, nor has EPA officially placed Site 300 on the NPL. Until these issues are resolved, investigations and remedial actions continue under the joint oversight

of EPA, RWQCB and DHS. The areas of investigation include the following: TCE in soil, rock, and/or groundwater at the Building 834 complex, Building 815, the General Services area, Pit 6, the Pit 7 complex, and Pit 8; high explosives (HE) compounds in the HE Process Area; and tritium in the Pit 7 complex and the Building 850 area. Details of these activities and investigations during 1989 can be found in the following documents: *LLNL Site 300 Environmental Investigation Quarterly Reports* (Taffet et al. 1989; Lamarre et al. 1989; Lamarre 1989a-b) and other special topic reports (Lamarre 1989c). Highlights of these activities are presented below.

Remedial Investigations/Feasibility Studies (RI/FS). Remedial investigations of TCE, tritium, and HE compounds in soil and groundwater continued during 1989. At the Building 834 Complex, LLNL determined the extent of TCE in the subsurface and conducted pilot remediation tests of the groundwater extraction and induced-venting system that LLNL designed and built specifically for this facility. A Remedial Investigation/Feasibility Study Report for the Building 834 complex was nearly completed by the end of the year (Bryn et al. 1990). At Building 833, LLNL conducted a soil-vapor sampling program and outlined the probable extent of TCE in underlying groundwater. Two potential TCE release sites were identified. In the General Services Area (GSA), a soil-vapor survey was conducted, which resulted in the detection of TCE in offsite soils east of the southeast corner of Site 300. Subsequent installation of monitor wells allowed us to identify a plume of TCE (concentrations up to 58 ppb) in shallow groundwater extending about 4000 ft from the site boundary beneath private and State of California property. A groundwater treatment system has been designed to begin remediation of these low concentrations of TCE. By year end, the treatment unit was being constructed and applicable permits had been sought. LLNL installed additional monitor wells adjacent to Landfill Pit 6 and in the HE Process Area to improve

our understanding of the extent of TCE in those areas. Remedial Investigation Reports were begun for these two areas also.

LLNL's investigation of tritium in groundwater at the Landfill Pit 7 Complex was completed, and an RI/FS Report was submitted to EPA, RWQCB, and DHS (Taffet et al. 1989b). We concluded from the study that groundwater is moving at a maximum of about 15 m/y toward the northern site boundary. Given this flow rate and the radioactive decay half-life for tritium of 12.3 y, by the time the groundwater reaches the site boundary along a most-direct flow path, tritium activities will be at or below background activities, i.e., less than 200 pCi/L. Investigations of groundwater chemistry beneath inactive Landfill Pits 8 and 9 were completed (Taffet and Lamarre 1989; Taffet 1989), and it was determined that the materials in the pits do not have an impact on groundwater quality.

In 1989, LLNL continued its investigation of the extent of HE compounds and TCE in groundwater beneath the HE Process Area. Both plumes are small, with concentrations of HE compounds at 350 ppb or less and TCE at 280 ppb or less. A report of the investigation of the HE burn pits at Building 329 and a conceptual closure plan for that facility were submitted to the regulatory agencies.

Soils adjacent to 16 inactive dry wells were sampled and analyzed for volatile organic compounds, metals, and HE compounds. None of the soils was found to contain these substances in concentrations that would render them hazardous or a threat to groundwater quality.

Remedial Actions. During 1989, the RWQCB approved LLNL's plan to close the nine decommissioned HE rinsewater lagoons in the HE Process Area. By October 1989, LLNL had filled the lagoons to grade level with native soils, placed a clay cover on each lagoon, and seeded them with native grasses. The lagoons have now been formally closed in accordance with the regulatory-agency-approved closure plan.

As part of LLNL's environmental remediation efforts, six inactive water-supply

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wells at Site 300 were sealed and abandoned. These older wells posed a potential threat of cross-contamination of water-bearing zones because of their long well screens or sand packs. The wells were sealed and abandoned in accordance with San Joaquin County regulations.

Superfund Amendments and Reauthorization Act (SARA)—Title III

SARA Title III is also known as the Emergency Planning and Community Right-to-Know Act. It requires owners/operators of facilities that have certain hazardous chemicals onsite 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 State Office of Emergency Services, the county, and local fire departments.

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, the location, the weight, the type of container, and the 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 were used to generate reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site.

National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements

Clean water is the subject of Federal, State, and local laws and regulations. The National Pollutant Discharge Elimination System (NPDES), under the Federal Clean Water Act, establishes the permit requirements for discharges into surface waterways. In addition, the State of California requires permits for any discharges that have potential to adversely impact beneficial uses of waters of the State. The

Regional Water Quality Control Boards (RWQCBs) are responsible for issuance and enforcement of both types of permits.

Groundwater and Surface Water Discharge Permits. Site 300 has three permits issued by the Regional Water Quality Control Board. Waste Discharge Requirement, Order 80-184, for a Class II-1 solid waste disposal site pertains to inactive landfills located at Site 300. Waste Discharge Requirement, Order 82-105, is a permit that applies to the cooling tower discharges at Site 300. This permit is also an NPDES permit because discharges may enter stormwater drainages. Finally, Waste Discharge Requirement, Order 85-188, is a permit for the sewer lagoons, septic tanks, leachfields, and the high explosives rinse-water Class II surface impoundment at Site 300.

Inspection. On April 4, 1989, RWQCB performed an inspection of permitted discharges. This included review of cooling tower discharges, landfill operations, HE process water discharges to a surface impoundment system, and septic system discharges. No inspection report was received.

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 to develop and execute air pollution prevention and control programs. The San Joaquin County Air Pollution Control District (SJCAPCD) is the local agency responsible for enforcing these standards, as well as State and local standards, for air emissions from stationary sources in San Joaquin County.

Air Permits. Site 300 holds 9 air permits from the SJCAPCD for the following equipment: 2 gasoline station vapor recovery systems, 1 paint spray booth, 1 sawdust collector, and 5 boilers.

Inspections. On November 29, 1989, SJCAPCD conducted an inspection of 5 boilers, 2 tanks, 2 fuel dispensers, 1 cyclone, 1 paint shop; no discrepancies were found.

Endangered Species Act Activities

Staff from the California Department of Fish and Game and the U.S. Fish and Wildlife Service performed their annual inspection of the endangered wild flower, *Amsinckia grandiflora*, on March 30, 1989. A newly discovered second population located at Site 300 was also inspected.

Environmental Protection Department Internal Compliance Activities

The Environmental Operations Group is responsible for working closely with LLNL programs and departments in implementing environmental requirements so planned and current operations and experiments function in compliance with Federal, State, and local environmental regulations. The group consists of environmental analysts who are assigned to specific LLNL programs and departments to assist in day-to-day environmental activities. These activities include management of hazardous wastes and implementation of appropriate pollution abatement controls. Compliance status is maintained

and verified by staff who keep abreast of all existing and planned activities, review construction documents, inspect facilities, and audit waste management procedures.

Building Inspections. Formal, detailed building inspections are conducted for each LLNL facility every other year. In these inspections, environmental analysts scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of waste accumulation areas (WAA), 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, baghouses), and laboratory and machine shop areas. An inspection report is prepared for the program/department and follow-up procedures are conducted to ensure implementation of recommendations and/or corrections. Walk-through inspections are conducted on an as-needed basis. A total of 40 building inspections were conducted at Site 300 during 1989.

Introduction

The purpose of LLNL's Quality Assurance Program is presented in the Livermore-site Quality Assurance chapter; that discussion is not repeated here. Similarly, LLNL's participation in the EPA Environmental Radioactivity Laboratory Intercomparison Studies and the intercomparison study conducted by the DOE Environmental Measurements Laboratory, as well as results of the duplicate sampling regime, are discussed in the Livermore-site section. That discussion also applies to Site 300.

Deviations and Changes to the Sampling Program (Site 300)

Air Sampling Program. As part of the Site 300 routine monitoring program, 552 of 575 possible air particulate samples were collected, a sample recovery rate of 96%. The loss of samples in 1989 was due to air sampler malfunction or loss of electric power to samplers.

Routine Water Sampling Program. During 1989, all water supply wells were sampled quarterly, as scheduled, except Wells 7A, 4, and 19 were not available for sampling during the fourth quarter because they were closed. Wells 1, 3, 6, and 8 were sampled for tritium only in the first quarter; after that time, they were closed and sealed. All scheduled quality control samples were also collected. Several sampling points were changed in 1989 due to closure of inactive water supply wells. Specifically, monitoring well NC2-11D replaced water supply Well 03, Well G1 (an offsite water supply well) replaced Well 06, Well 7A replaced water supply Well 07, and NC7-61 replaced water supply Well 08. Each replacement well was in the same general location of the well that it replaced. In addition, no rainfall was collected during the second quarter.

Some analyses were not completed. Samples from Well 18 were not analyzed for aromatic compounds in the first quarter and were not analyzed for gross alpha and gross beta during the second quarter. Samples from Well 4 were not analyzed for

aromatic compounds in the first quarter and were not analyzed for gross alpha, gross beta, and high explosives in the second quarter. Samples from offsite wells G4, M1, M4, V4, V7, and W2 were not analyzed for gross alpha, gross beta, or tritium activity.

Compliance Groundwater Sampling Program. No changes were made to the compliance groundwater sampling program. All compliance groundwater installations were sampled as scheduled in 1989, except three scheduled sampling locations (Wells K7-07, NC7-22, and NC7-37) were dry during each quarter, so samples were unavailable for collection. The resultant missing data from these sampling locations accounts for 3% of the 13 120 analyses performed annually as part of the Site 300 compliance groundwater sampling program. All remaining scheduled samples were collected and were analyzed for the full suite of scheduled analyses with the following exceptions: no radium data were reported for Wells K6-03 and K6-04; no analyses for total suspended solids were performed during the fourth quarter for samples from Wells K1-04, K1-05, K1-08, and K1-09; no field blank was prepared for the Pit 7 area in the second quarter, and no tritium analysis sample was prepared for the sample from Well K1-01C.

Soil Monitoring Program. No soil sample was collected from Location 1108 during 1989. An additional soil sampling location (1117) was established to the north of

Bunker 801. Samples from all locations will be taken during future sampling periods.

Vegetation Sampling Program. No changes were made to the vegetation sampling program at Site 300. All samples were collected as specified in the environmental monitoring plan.

Environmental Radiation Monitoring Program. During 1989, 1 of 64 environmental dosimeters at the Site 300 perimeter was missing at the time of collection (98% collection efficiency). No changes were made to the environmental radiation monitoring program.

Statistical Methods

Data review and analyses are conducted in accordance with the EMG Quality Assurance Plan (Holland 1987) and the EMG Procedures Manual (Brekke et al. 1988). 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.

The statistical methods used in this report have been implemented pursuant to DOE Order 5400.xy, Chapter VII (Data Analysis and Statistical Treatment) (U.S. Department of Energy 1988d). The methods employed 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.

Radiological Data. The precision of radiological analytical results is displayed in the data tables as $2\text{-}\sigma$ counting errors, expressed as a percentage of the associated value. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a $2\text{-}\sigma$ counting error greater than 100% is said to be at the lower limit of detection (LLD) and is presented in the tables with a "less than" (<) sign to indicate its LLD status. However, the actual LLD values are used in the calculations of all summary statistics.

Nonradiological Data. Nonradiological data that are reported as being below the analytical detection limit are also displayed in the tables with a "less than" (<) sign. As

with the radiological data, the actual detection-limit values are used in the calculation of summary statistics.

Summary Statistics. Determinations of measures of central tendency and associated measures of dispersion are calculated according to DOE Order 5400.xy protocols. For data sets containing few LLDs, measures of central tendency are reported as the arithmetic mean $\pm$ one standard deviation (SDM), with the standard deviation expressed as a percentage of the mean. For data sets containing many (one-third or more of the total) LLD values, measures of central tendency are reported as the median value $\pm$ the median absolute deviation (MAD; median of the differences of all data values from the median), with the MAD expressed as a percentage of the median. By convention, summary statistics are not expressed with "less than" (<) signs. It should be noted that the use of LLDs in computations leads to overestimates of the central tendency because the actual values of data expressed as being below the detection limit are quite likely less than the LLD value used in the calculations.

Where unusually high values were detected for areas of known contamination, means and standard deviations are calculated both with and without the inclusion of the high values, and the calculations without high values are reported in parentheses. This was done so that measures of central tendency are not skewed by the presence of the high values. Otherwise, the common use of such data could bias estimates of the overall impact of LLNL operations.

Statistical Comparisons. Standard comparison techniques (t-test and ANOVA) are used where appropriate for the determination of the statistical significance of the difference 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.

METHODS OF DOSE CALCULATIONS

Introduction

The radiological impact to the public from operations at LLNL is assessed in accordance with applicable DOE orders. Based on releases of radioactivity to the environment and measurements of environmental media, four potential doses are calculated: the dose at the site perimeter, the dose to the nearest resident, the dose at the point of maximum exposure in an uncontrolled area, and the dose to the population residing within an 80-km radius of the site. The doses in this report may be compared to the radiation protection standards established by DOE and other regulatory bodies.

For the purposes of this report, doses are reported in terms of "effective dose equivalent," which is defined as the sum of the dose from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during a 1-y period. This dose is a measure of the potential health effects from radiation exposure. It also accounts for the radiation dose delivered to the body from intakes of radionuclides with a long effective half-life (i.e., radionuclides with long residency in the body). Thus, the "effective dose equivalent" includes the total dose received over a 50-y period following a 1-y exposure. The effective dose equivalents in this report were calculated using the dosimetric parameters recommended by the International Commission on Radiological Protection (ICRP) in Publications 26 (1977) and 30 (1980).

Pursuant to the National Emission Standards for Hazardous Air Pollutants, 40 *Code of Federal Regulations* Part 61, Subpart H, doses from the air pathway are also reported in terms of "dose equivalent." These doses refer to a measure of radiation dose and are calculated based on the whole body/critical organ concept of ICRP Publication Number 2. These doses were derived using the Clean Air Act Code, which contains models (AIRDOS-EPA and RADRISK) approved by EPA for calculating atmospheric transport and exposure. Population exposure was converted to radiation dose using dose conversion factors and weighting factors specified by the EPA.

Radiological Dose Assessment Performed for 1989

Each of the doses used to measure the radiological impact from LLNL during 1989 are described briefly in the following paragraphs.

1. *External "fence-line" dose.* The fence-line dose rate is a measure of the maximum external dose at locations of nearest uncontrolled public access. Dose rates from external penetrating radiations

(primarily gamma rays and neutrons) are measured using environmental dosimeters (thermoluminescence 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 offsite (Livermore Valley) locations. Moreover, these measurements are made at points of maximum exposure and assume an occupancy of 24 h/d, 365 d/y. In actuality, no member of the public resides at these locations for extended periods of time; these estimates are, therefore, 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 the individual. The following radionuclide exposure pathways are assessed by means of field measurements: tritium in water, tritium in milk, and tritium in vegetation (which includes the forage-cow-milk pathway).

3. Inhalation/submersion dose. Air pathway doses are calculated for each airborne radioactive discharge to the atmosphere. Inhalation/submersion doses are calculated at the site perimeter, to the nearest resident, and at the point of maximum offsite exposure. The amount of radioactivity released by LLNL is usually too low to accurately measure radionuclide concentrations in ambient air and to determine dose. Therefore, environmental transport and exposure pathway models are used to calculate potential doses resulting from effluent emissions (i.e., measurements made at a building stack). These doses are calculated by two methods to comply with both the DOE standards (equivalent to current ICRP recommendations) and the National Emission Standards for Hazardous Air Pollutants, 40 *Code of Federal Regulations* Part 61, Subpart H.

Dose calculations were made using the Continuous-Point-Source computer code based on the Gaussian plume model (Peterson et al. 1976). This code provides ratios of concentration to release rate (χ/Q) through sixteen 22.5-degree compass sectors and distances from 0.1 to 100 km from

potential release points. The average annual χ/Q values have been calculated using local meteorological data. These data were obtained from sensors on the LLNL meteorological tower from a height of 40 m. From records of these data, wind speed, wind direction, and atmospheric stability estimates were tabulated at one-quarter-hour intervals over the calendar year. Digitized meteorological data became available at Site 300 in May of 1986, and these were used to perform dispersion calculations for the Advanced Test Accelerator emissions.

Variance in the horizontal wind direction was used to estimate Pasquill-Gifford stability categories based on the method described by Slade (1968). Lateral and vertical standard deviations σ_y and σ_z are entered in the computer code as functions of these stability categories and the respective distances. Based on the annual effluent data (release rate Q) and the appropriate χ/Q values, the radionuclide concentrations at the site perimeter and the nearest resident are calculated. "Nearest resident" refers to the resident nearest to the site perimeter.

4. Maximally exposed individual dose. This dose represents the maximum credible dose to any "hypothetical" member of the general public. It includes contributions from all potential exposure pathways and 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 h/d, 365 d/y. 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., over estimate) 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-km 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-rem.

The effective dose equivalents shown in this report have been calculated using models and methods consistent with 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 factor 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.

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 has been calculated using the following equation:

$$D_{\text{whole body}} = C_w U_w D_w \quad (\text{F-1})$$

where

- C_w = concentration of tritium in water (pCi/L),
- U_w = intake rate (L/y) = 730 L/y for maximum exposed individual,
- D_w = dose factor (mrem/pCi) = 6.3×10^{-8} mrem/pCi for the whole-body ingestion pathway for an adult,
- $D_{\text{whole body}}$ = effective dose equivalent in mrem 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 Ci/mL of tritiated water (HTO) for the maximum exposed individual has been calculated using the following equation:

$$D_{\text{whole body}} = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \quad (\text{F-2})$$

where

- D_{veg} = dose from ingestion of vegetables,
- D_{meat} = dose from ingestion of meat,
- D_{milk} = dose from ingestion of milk.

Vegetation.

$$D_{\text{veg(leafy)}} = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}} \quad (\text{F-2a})$$

where

- U_{veg} = intake rate (kg/y): 64 kg/y for maximum-exposed individual,
- C_{veg} = concentration: 10^9 pCi/kg $\times C_{\text{veg}}$ $\mu\text{Ci/mL}$ $\mu\text{Ci/mL}$ (measured),
- D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway,

thus,

$$D_{\text{veg}} = 0.40 \times 10^4 C_{\text{veg}} \mu\text{Ci/mL (measured)}.$$

Meat.

$$D_{\text{meat}} = U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}} \quad (\text{F-2b})$$

where

- U_{meat} = 110 kg/y,
- C_{meat} = $(F_f)(Q_f)(C_{\text{veg}})e^{(-\lambda_{\text{H}}t_{\text{H}})}$,
- D_{HTO} = 6.3×10^{-8} mrem/pCi.
- 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,

Appendix A

$$\begin{aligned}
 Q_f &= \text{amount of feed consumed (kg/d),} \\
 C_{veg} &= \text{same as above,} \\
 \lambda_i &= \text{radiological decay constant, d}^{-1}, \\
 t_s &= \text{time between slaughter to consumption (d),} \\
 C_{meat} &= (1.2 \times 10^{-2} \text{ d/kg}) \\
 &\quad (50 \text{ kg/d}) (C_{veg} \mu\text{Ci/mL}) \\
 &\quad \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \\
 &\quad \times \\
 &\quad \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \\
 &\quad e^{-1.5 \times 10^{-4}(20)} \\
 &= 0.6 \times 10^9 \\
 &\quad \times C_{veg} \mu\text{Ci/mL (measured),} \\
 D_{meat} &= 0.41 \times 10^4 \times C_{veg} \mu\text{Ci/mL (measured).}
 \end{aligned}$$

Milk.

$$D_{milk} = U_{milk} \times C_{milk} \times D_{HTO}, \quad (\text{F-2c})$$

where

$$\begin{aligned}
 U_{milk} &= 310 \text{ L/y,} \\
 D_{HTO} &= 6.3 \times 10^{-8} \text{ mrem/pCi,} \\
 C_{milk} &= F_m Q_f C_{veg} e^{(-\lambda_i t_f)}, \\
 F_m &= \text{fraction of daily intake of nuclide per liter of milk (pCi/L in milk per pCi/d ingested by the animal), d/L,} \\
 Q_f &= \text{amount of feed consumed (kg/d),} \\
 C_{veg} &= \text{same as above,} \\
 \lambda_i &= \text{radiological decay constant, d}^{-1}, \\
 t_f &= \text{trans- pCi/kg port } \mu\text{Ci/mL time from the feed to milk receptor,} \\
 C_{milk} &= (1.0 \times \frac{\text{pCi/kg}}{10^{-2} \mu\text{Ci/mL}} \text{ d/L}) (50 \text{ kg/d}) (C_{veg} \mu\text{Ci/mL}) \\
 &\quad \times 10^9
 \end{aligned}$$

Whole Body.

$$\begin{aligned}
 D_{\text{whole body}} &= 0.40 \times 10^4 C_{veg} \mu\text{Ci/mL (measured)} \\
 &\quad + 0.41 \times 10^4 C_{veg} \mu\text{Ci/mL (measured)} + 0.97 \times 10^4 C_{veg} \mu\text{Ci/mL (measured)}.
 \end{aligned}$$

Thus,

$$D_{\text{whole body}} = 1.78 \times 10^4 C_{veg} \mu\text{Ci/mL (measured).}$$

Inhalation/Submersion Dose

The Continuous-Point-Source computer code was used to calculate the air pathway dose at the Livermore-site perimeter, to the nearest resident, and at the point of maximum exposure.

Inhalation Dose (^3H).

$$D_{\text{whole body}} = C \times U \times D, \quad (\text{F-3})$$

where

$$\begin{aligned}
 C &= \text{radionuclide concentration at the receptor,} \\
 U &= \text{intake rate (the inhalation rate for adult maximally exposed individual is } 8400 \text{ m}^3/\text{y}, \text{ and} \\
 D &= \text{dose conversion factor for } ^3\text{H; } 9.45 \times 10^{-8} \text{ mrem/pCi.}
 \end{aligned}$$

(The tritium dose conversion factor was obtained by multiplying the inhalation dose factor, 6.3×10^{-8} mrem/pCi, by 1.5 to include absorption through the skin.)

$$C = 3.17 \times 10^{-4} (\chi/Q)(Q), \quad (\text{F-3a})$$

where

$$\begin{aligned}
 \chi/Q &= \text{diffusion parameter (s/m}^3\text{),} \\
 Q &= \text{release rate, Ci/y, and}
 \end{aligned}$$

$$\begin{aligned}
 3.17 \times 10^4 &= \frac{1 \times 10^{12} \text{ pCi/Ci}}{3.15 \times 10^7 \text{ s/y}}
 \end{aligned}$$

External Immersion Dose (^{13}N and ^{15}O).

$$D_{\text{whole body}} = C \times \text{DRF}, \quad (\text{F-4})$$

where DRF, the dose-rate factor, is the external dose-equivalent rate mrem/y per unit radionuclide concentration, pCi/m³.

$$\text{For } ^{13}\text{N}, \text{DRF} = 5.11 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

$$\text{For } ^{15}\text{O}, \text{DRF} = 5.12 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

Annual Population Dose

For population dose, the diffusion parameters and population figures for a sector (i) within 80 km of LLNL were summed over all directions (n). These values are determined in the units, person-rem.

$$\begin{aligned} \text{Dose} = & \left[\sum_i^n (\chi/Q)_i P_i \right] \\ & 3.17 \times 10^4 \\ & \times \\ & \sum_i^n (\chi/Q)_i P_i \\ & \times Q \times U \times D, \end{aligned} \quad (\text{F-5})$$

where

= Summation of the (χ/Q) for sector i times the population in region i for all regions n , person-s/m³.

Q = release rate, Ci/y,

U = inhalation rate, average individual (adult),

D = dose factor, mrem/pCi,

P_i = the population of the i th sector.

DOCUMENTS CONTAINED IN THE INFORMATION REPOSITORIES

Technical documents about a number of LLNL environmental projects are available in three information repositories. One of the information repositories is located at the LLNL Visitors Center. The documents that are available include reports, data summaries, and permit applications for the Ground Water Project, the Site 300 Environmental Restoration program, the RCRA Part B permit for hazardous materials storage and treatment, the Draft Environmental Impact Statement (DEIS) for the proposed Decontamination and Waste Treatment Facility and all reference documents for that DEIS, and the Environmental Impact Report for the University of California Contract with the Department of Energy for the Operation and Management of LLNL. Many of these documents are also available at the Livermore Municipal Library. Those documents that are not at the Municipal Library pertain to Site 300 or the DEIS for the proposed Decontamination and Waste Treatment Facility; however, the latter documents are available at the Main Alameda County Library in Oakland. A list of the documents, compiled by applicability to the Livermore site and Site 300 collectively and individually, follows.

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Other Documents

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7. California Regional Water Quality Control Board (1988), *Order No. 88-103: Site Cleanup Order for LLNL and U.S. Department of Energy*, prepared by California Regional Water Quality Control Board, San Francisco Region, for Lawrence Livermore National Laboratory, Livermore, CA.

Permit Application

1. Lawrence Livermore National Laboratory (1987), *NPDES Permit Application to Discharge Waste for Lawrence Livermore National Laboratory and U.S. Department of Energy, Livermore, Alameda County, Lawrence Livermore National Laboratory, Livermore, CA.*

Ground Water Project Data Submissions (Quarterly)

The Quarterly Data Submissions to regulatory agencies contain the complete analytical results of the ground water sampling project. Upon request, these data can be made available to interested parties (see list of report dates below). The large number of wells sampled to date, however, has resulted in approximately 6000 pages of chemical data (currently a stack approximately 4 feet high). To minimize the bulk of these lengthy analyses, we report only the analytical results of VOCs of concern (as suggested by the regulatory agencies) in Appendices B and E of our monthly progress reports.

Submissions of chemical analyses are currently available for

Apr. 1985	Feb. 1986
May 1985	May 1986
Aug. 1985	Aug. 1986
Nov. 1985	Nov. 1986

Aug. 1987	Aug. 1988
Feb. 1987	Feb. 1988
May 1987	May 1988
Nov. 1987	Nov. 1988

Feb. 1989.

Please contact Pat Post, Community Relations Coordinator, at 423-4255 to see these data.

SITE 300**Environmental Investigation Quarterly Reports**

1. Buddemeier, R. W., D. W. Carpenter, and M. R. Ruggieri (1987), *LLNL Site 300 Environmental Investigations Quarterly, March 31, 1987*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-87-1).
2. Buddemeier, R. W., D. W. Carpenter, and M. R. Ruggieri (1987), *LLNL Site 300 Environmental Investigations Quarterly, June 30, 1987*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-87-2).
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7. Lamarre, A. L., W. A. McIlvride, M. J. Taffet, N. B. Crow, and J. A. Oberdorfer (1988), *LLNL Site 300 Environmental Investigations Quarterly, July–September 1988*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-88-3).
8. Lamarre, A. L., W. A. McIlvride, M. J. Taffet, J. M. Beiriger, S. E. Booth, S. M. Bryn, P. L. Cederwall, N. B. Crow, R. O. Devany, R. A. Ferry, R. K. Landgraf, R. L. Nations, J. A. Oberdorfer, J. P. Pavletich, B. J. Qualheim, and S. P. Vonder Haar (1988), *LLNL Site 300 Environmental Investigations Quarterly, October–December 1988*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-88-4).
9. Taffet, M. J., A. L. Lamarre, and W. A. McIlvride (1989), *LLNL Site 300 Environmental Investigations Quarterly, January–March, 1989*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-89-1).
10. Lamarre, A. L., W. A. McIlvride, M. J. Taffet, and N. B. Crow (1989), *LLNL Site 300 Environmental Investigations Quarterly, April–June 1989*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-89-2).
11. Lamarre, A. L. (Ed.) (1989), *LLNL Site 300 Environmental Investigations Quarterly, July–September 1989*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10194-89-3).

Ground Water Monitoring Quarterly Reports

1. Armstrong, D. H., and M. G. Brown (1987), *LLNL Site 300 Ground Water Monitoring Program, Quarterly Report, January–March 1987*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10191-87-1).
2. Buddemeier, R. W., D. H. Armstrong, and M. G. Brown (1987), *LLNL Site 300 Ground Water Monitoring Program, Quarterly Report, April–June 1987*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10191-87-2).
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 2. Raber, E. (1983), *Chemical and Hydrogeological Evaluation of High-Explosive Process Wastewater Discharges at Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCID-19753).
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 4. Crow, N. B., R. Elwood, and P. Webster-Scholten (1986), *Distribution of High Explosives Compounds in Soil and Water at the 806/807 Lagoons, HE Process Area, LLNL Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10169).
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 7. Webster-Scholten, P., and N. B. Crow (1989), *Remedial Investigation of the High Explosives Burn Pit Facility, Building 829 Complex, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCID-21692).
 8. Lamarre, A. L. (1989), *Site 300 Environmental Restoration Work Plan*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10247, Rev. 2).

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9. Lamarre, A. L., and M. J. Taffet (1989), *Firing Table Gravel Cleanup at Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCAR-10282).
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OVERVIEW OF DOCUMENT PRESENTED IN DOE SUGGESTED FORMAT

Introduction

This synopsis presents an overview of the 1989 monitoring information organized in the format suggested by DOE Order 5400.1. It is presented to facilitate compilation of the information about LLNL with information about other DOE facilities. Each year, the Environmental Protection Department makes significant effort toward monitoring the environment near the Livermore site and Site 300. In 1989, over 30 000 analyses of environmental samples were performed. This effort, which is conducted in accordance with DOE Orders 5400.1 and 5484.1, has three purposes: (1) to assess the effectiveness of effluent control programs, (2) to assess compliance with applicable environmental laws and regulations, and (3) to estimate the impact of operations on the environment. Data are produced from sampling of air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and environmental radiation; the type of samples taken at a specific location depends on the site and the potential pollutants to be monitored. Both monitoring and compliance activities are summarized in this document.

LLNL—LIVERMORE SITE

Compliance Self-Assessment

The activities undertaken at the Livermore site in response to legal requirements are described in the Livermore-site section of the main text of this report in the chapter entitled "Summary of Environmental Compliance Activities." These environmental activities were performed by the Regulatory Affairs Division, the Environmental Restoration Division, the Environmental Guidance Division, and the Hazardous Waste Management Division of the Environmental Protection Department.

Table L-44 provides, for 1989, a list of permits issued to LLNL for the Livermore site by various regulatory agencies and a list of inspections conducted by such agencies. (The table numbers reflect the numbering in the body of the text and are not consecutive.)

Resource Conservation and Recovery Act (RCRA)—Hazardous Waste. In February 1989, LLNL submitted a reformatted RCRA Part B permit application for the storage, treatment, and incineration of hazardous waste and performed

the second liquid waste trial burn. In September, the EPA proposed to deny the Part B permit for the Livermore site. In response to this notice, LLNL announced that the permit application would be withdrawn. In addition, LLNL completed physical upgrades to several hazardous and mixed waste management units, and completed the incinerator risk assessment.

The Part A and Part B permit applications were then significantly revised to describe more specifically the individual waste management units, to reflect physical or operational changes, to add mixed-waste management units, and to address documentation issues. The revised permit application was submitted to the regulatory agencies in December 1989.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks. Personnel in the Tank Integrity Testing Program conducted tests of 30 underground diesel fuel and gasoline systems in 1989; all but one was leak tight. In addition, 33 underground wastewater retention systems were tested; 10 systems were identified that could not meet the minimum leak-rate criterion. Leak sites for two of these

Table L-44. Compliance summary—Livermore site.

Type of regulatory action	Regulatory agency
Public hearing (date)	
RCRA Treatment and Storage of Hazardous Waste (Nov. 16)	EPA
Permits (number)	
Underground Hazardous Waste Retention Tanks (22)	ACHD
Underground Hazardous Product Retention Tanks (43)	ACHD
Gasoline Recovery System (1)	BAAQMD
Paint Spray Booth (3)	BAAQMD
Particulate Capture Devices (cyclones/baghouses) (12)	BAAQMD
Solvent Cleaners (51)	BAAQMD
Boilers (192)	BAAQMD
Cleaning/Refurbishment Devices (6)	BAAQMD
Printing Presses (4)	BAAQMD
Paint Spray Booths (3)	BAAQMD
Vapor Recovery Systems (2)	BAAQMD
Groundwater Stripping Systems (2)	BAAQMD
Ovens (2)	BAAQMD
Fire Test Cell (1)	BAAQMD
Wet Scrubber (1)	BAAQMD
Miscellaneous sources (7)	BAAQMD
Interim Status Document No. CA 2890012584 for Hazardous Waste Storage and Treatment (1)	DHS/EPA
Discharge Permit to Sanitary Sewer Permit No. 1250	LWRP
NPDES Permit CA 0029829 Monitoring Well Discharges (1)	RWQCB
WDR 88-075 Groundwater Remediation Activities (1)	RWQCB

...(continued).

Table L-44. Compliance summary—Livermore site (concluded).

Type of regulatory action	Regulatory agency
Inspections (date)	
Building 611 Waste Accumulation Area (Jan. 10)	ACHD
Building 391 vapor recovery system, Building 403 groundwater treatment facility and system (Feb. 8)	BAAQMD
Annual Inspection of Permitted Sources (Feb. 28, Mar. 2, Apr. 11, May 2, July 11, July 14)	BAAQMD
Source test of air pollution control device at Building 403 (June 13)	BAAQMD
Inspected asbestos removal in Building 115 (Oct. 6)	BAAQMD
Inspected 26 boilers, Facility A (Oct. 17)	BAAQMD
Follow-up visit for 1988 Visual Site Inspection (Jan. 27)	EPA (contractor)
RCRA Compliance Evaluation Inspection of WAAs, plus Area 612, Area 514 and Building 419 Hazardous Waste Management Facilities (Mar. 30-31)	EPA (contractor)
Observed second liquid waste trial burn (Feb. 9-17)	EPA/DHS
Review of Hazardous Waste Management facilities and units (May 22)	DHS
Review areas being considered for hazardous waste storage and treatment (July 5)	DHS
Hazardous Waste Management Inspection (Sept. 29)	DHS
Sampling of Building 196 and Building 322 effluent (May 16, 19, 23, 25)	LWRP
Inspection of Building 196 (July 6)	LWRP
Inspection of 2020 Research Drive (Nov. 17)	LWRP

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were identified and repaired. A program for necessary repairs or closure of the remaining eight systems is under way.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I.

The efforts of the Environmental Restoration Program are directed mainly toward the Ground Water Project, which addresses contamination at and near the Livermore site resulting from past releases of hazardous substances. Currently, efforts are ongoing to monitor the extent of VOCs and gasoline in soil and groundwater. Pilot remediation has been initiated in two areas.

In November 1989, a draft of the Remedial Investigation Report for the Livermore site was prepared for agency review. The objectives of the report were to characterize the site and lay a foundation for the development of remediation strategies. Screening of groundwater, surface water, soil, sediments, and air for toxic materials has led to the conclusion that the primary medium of concern is groundwater and that the principal compounds found to be of potential concern are volatile organic compounds (VOCs) and fuel hydrocarbons.

Toxic Substances Control Act. In 1989, LLNL removed and disposed of a large number of capacitors containing PCBs. These capacitors were associated with the Tandem Mirror Experiment (TMX). Until 1989, DOE had required LLNL to keep TMX in a mothballed state so that it could be used again, if necessary. In 1989, DOE relaxed this requirement.

National Environmental Policy Act (NEPA). In 1989, over forty projects were evaluated under the applicable policies and procedures for DOE compliance with NEPA. Two of these were determined by DOE to require an Environmental Assessment; four were the subjects of Action Description Memoranda. **Table L-46** provides a list of major NEPA documents filed in 1989.

Air Quality Management Activities. The Bay Area Air Quality Management District issued 192 permits to LLNL in

1989. No deficiencies were noted in the report of the annual inspection of permitted sources.

Nonradiological Monitoring Information

National Pollutant Discharge Elimination System. The NPDES permit CA 0029289 applies to discharges to the ground from monitoring wells used in the groundwater investigation. LLNL also complies with NPDES regulations through its sewer discharge permit. The Biological Oxygen Demand (BOD) and pH limits were the only parameters exceeded in the LLNL sanitary sewer effluent in 1989. The pH excursions were identified by the continuous on-line monitoring system, and the BOD value over the limit was noted during a routine 24-hour monitoring sample collected during the first quarter of the year. None of these releases resulted in any adverse impact on the operation of the LWRP.

Exceedances of permit limits by sewer effluent are minimal; nonetheless, improved monitoring and retention systems are being added to the sanitary sewer system. A detailed discussion of sewer effluents is presented in the Sewer Monitoring Chapter in the body of the report.

Groundwater Monitoring Information. The Environmental Restoration Program (ERP) is a DOE program aimed at the cleanup of environmental contamination caused by past waste practices at DOE facilities. A general budget category was created for this program at the request of the House Armed Services Committee. Funding began in 1988; however, LLNL's environmental investigations have been ongoing since 1979. ERP efforts at the Livermore site are directed mainly toward the Ground Water Project.

The Ground Water Project addresses contamination resulting from past releases of hazardous substances at and near the Livermore site. In 1979, an inventory discrepancy led to the discovery that approximately 17 000 gallons of gasoline had been lost from an underground fuel tank in the former-Building 403 area. In December 1983, additional investigations

Table L-46. NEPA-related documents submitted to DOE during 1989.

Document Type	Subject
EA	High Explosives Applications Facility (HEAF) Nuclear Directed Energy Research Facility (NDERF)
ADM	Sewer Diversion Facility BER Laboratory Modular Complex (Building 361 Addition) Proposed Building 153 Building 166 Laboratory Addition
Memorandum	Building 153 Advanced Implementation Technology Trailer Complex Building 332 SAS Office Expansion (SSEII) Westside Drainage Project Building 185 Light Lab Project NTTC Temporary Parking Lot Project Parking Lots A-8 and D-1 Project Disaster Planning Triage Complex Building 165 Advanced Optical Laboratory High Explosive Rinse-Water Lagoons Closure Building 281 Chemistry and Materials Trailer 2632 Light Laboratory Tritium Evaporator at Well 8 Spring, Site 300 Waste Accumulation Area, Building 495
Categorical Exclusion	12kV Replacement Project Trailer 4675 Central Cafeteria Expansion 15kV Sectional Switch Modifications to Building 197 LLNL Polymer Group Relocation, Building 227 South Cafeteria Ventilation Hood Installation Technical Information Facility (TIF) Liquid Nitrogen Storage Tank Replacement Modifications to Building 323, a fire station at LLNL Exhaust Manifold in Building 131 Earth Science Division, Trailer 1409 Trailers 5927/5906 Building 490 Standby Power

were initiated after volatile organic compounds (VOCs) were detected in offsite and onsite monitoring wells. Currently, efforts are ongoing to monitor the extent of VOCs and gasoline in soil and groundwater. In so doing, pilot remediation has been initiated at the west perimeter of the Livermore site and in the gasoline leak area. In addition, various groundwater computer models are being worked on as

part of the EPA Remedial Investigation/Feasibility Study process.

In November 1989, a draft of the Remedial Investigation Report for the Livermore site was prepared for agency review. The objectives of the report were to characterize the site and lay a foundation for the development of remediation strategies. Screening of groundwater, surface water, soil, sediments, and air for

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toxic materials has led to the conclusion that the primary medium of concern is groundwater. The principal compounds found to be of potential concern are volatile organic compounds (VOCs) and fuel hydrocarbons. Eight chlorinated solvents, trichloroethylene (TCE), tetrachloroethylene (also termed perchloroethylene, PCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethylene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethane (1,1-DCA), carbon tetrachloride (CCl_4), and chloroform have been detected in groundwater in the study area in concentrations exceeding Federal or State maximum contaminant levels (MCLs) or State Recommended Drinking Water Action Levels. TCE and PCE are the predominant VOCs and are locally present in concentrations up to about 5.1 and 1.6 ppm, respectively. Maximum concentrations of other VOCs are typically below several tens to several hundred ppb. Total VOC concentrations exceed 1 ppm in only 8 of 270 sampled wells. The fuel hydrocarbons occur almost exclusively in the area of the leaking underground fuel tank. These hydrocarbons are currently being extracted in a pilot study using vacuum-induced venting. Due to the very low groundwater velocity in the area, the fuel hydrocarbons have not migrated more than about 500 ft from the leak point. No groundwater in the study area has gross alpha or gross beta activities above MCLs. Tritium occurs in a concentration slightly above the MCL in one onsite well. Natural decay will reduce the concentration to below the MCL in a few years, long before the affected waters could migrate off site.

Details of these activities and investigations during 1989 can be found in the following documents: the LLNL *Ground Water Project Monthly Progress Reports* and *Annual Report* (Dresen et al. 1990; Dresen et al. 1989a-f; Devany et al. 1989; Iovenitti et al. 1989; Lawson et al. 1989 a-d) and other special topical reports (Layton 1989; Thorpe et al. 1990).

Superfund Amendments Reauthorization Act (SARA)—Title III. A physical inventory of all chemicals subject to reporting under SARA Title III was

conducted in 1988. In early 1989, the data were entered into a computerized database system, and were used to generate reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site. The inventory itself is three volumes long.

Other Emissions Monitoring Data.

LLNL does not have major air or water nonradioactive point-source emissions (other than emissions to the sewer discussed above). Emissions to the air from small point sources such as boilers and paint spray booths are calculated and are presented in **Table L-2**.

Other Monitoring Data. Other monitoring data that are collected include air beryllium content and EPA-priority-pollutant content in surface water and arroyo sediments. The highest monthly average concentration of beryllium measured was $<26 \times 10^{-5} \mu\text{g}/\text{m}^3$. This is the level of detection of the analysis method and represents $<2.6\%$ of the regulatory limit established by the Bay Area Air Quality Management District. These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium. Most potential pollutants in the storm runoff were not present at detectable levels. For the first time, acetone was detected in one sample at the northwest corner of the Livermore site at $140 \mu\text{g}/\text{L}$. No other organic compounds were detected. Metals were not detected above normal background levels expected for water that has been in contact with soil.

During 1989, sediment samples from the arroyos near the Livermore site were also collected. This was the second year that samples of this type were collected. The level of lead (Pb) in one sample ($79 \text{ mg}/\text{L}$) was above STLC limits ($5 \text{ mg}/\text{L}$). Two samples showed detectable levels of the PCB Aroclor 1260 ($0.07 \text{ mg}/\text{kg}$ and $0.05 \text{ mg}/\text{kg}$). However, the levels detected were close to detection limits ($0.03 \text{ mg}/\text{kg}$) and were below regulatory guidelines (50 ppm ; 40 *Code of Federal Regulations* 761). None of the levels detected for other organic compounds were above regulatory standards. Many of these compounds are

Table L-2. Nonradioactive airborne emissions, Livermore site.

Pollutant	Estimated release (tons/day)	Percent of total Bay Area emissions ^a
Particulates	0.0014	0.0002
Organic compounds	0.0852	0.0070
Oxides of sulfur	0.00033	0.0003
Oxides of nitrogen	0.0549	0.0118
Carbon monoxide	0.0110	0.0005
Chlorofluorocarbons	0.0705	0.0136

^a See BAAQMD 1989.

typical of fuel constituents and are expected in locations that concentrate stormwater runoff. Others are typical laboratory solvents that may indicate contamination of samples. Investigations have been initiated to determine the origin of these contaminants.

These data are not "emission" data as described in the suggested DOE format, and are presented in detail in the body of the report in chapters on Air Monitoring, Routine Water Monitoring, and Soil Monitoring.

Radiological Monitoring Information

Potential Radiological Dose from the Livermore Site. The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 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 definition of "effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway.

The EPA standard is based on the

AIRDOS-EPA Clean Air Act Code (CAAC) model code, while LLNL historically has used the Continuous-Point-Source Code (CPS Code) to determine compliance with DOE standards; this results in somewhat different calculated individual doses because of the differences in model assumptions and calculations.

Small amounts of radioactive materials from operations at the Livermore site were discharged to the environment in air and sewer effluents. The total amount of tritium released to the atmosphere by LLNL in 1989 was 2951.8 Ci, approximately 1554.4 Ci in the form of tritiated water. An additional 834 Ci of tritium was released by Sandia National Laboratories, Livermore (SNLL), with approximately 656 Ci in the form of tritiated water. The total quantity of ¹³N (half-life of 10 minutes) and ¹⁵O (half-life of 2 minutes) released in 1989 was 42 Ci at the Livermore site. The amount of radioactivity released from LLNL during 1989 was lower than 1988 and well within the range of previous years.

The CAAC was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and dose at the maximum offsite exposure location for each emission source. The CPS Code was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, maximum offsite dose, and also the collective person-rem dose to the population residing within 80 km of the Livermore site. Both of these methods are based on

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conservative assumptions, and any actual dose received by an individual would be much less.

The air pathway doses calculated using the Clean Air Act Code included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The Clean Air Act Code was run using specific meteorology for the Livermore site. The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Livermore-site operations in 1989 was 0.53 mrem; the dose to the nearest resident was 0.33 mrem; and the dose at the point of maximum offsite

exposure was 0.53 mrem. These doses represent only 2% or less of the EPA limit. Doses for emissions from specific facilities were also calculated. (See Table L-37.)

Air pathway doses were also calculated for each facility considered to have a measurable airborne discharge to the atmosphere using CPS Code. The maximum combined inhalation dose (i.e., the total from all facility discharges) from airborne emissions at the Livermore-site perimeter was 0.31 mrem. The maximum combined inhalation dose from airborne emissions to the nearest resident was 0.21 mrem. The dose from tritium was entirely due to tritiated water (HTO). Elemental tritium (HT)

Table L-37. Radiation dose from the air pathway, all Livermore facilities, during 1989 (Clean Air Act Code).^a

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Tritium facility	³ H/2949.4 ^c	0.52	0.32	0.52
Insulating core accelerator	0	0	0	0
Rotating target neutron source	³ H/2.18 ^d	0.0019	0.0007	0.0019
Incinerator	0	0	0	0
Laser complex	³ H/0.25 ^e	0.0002	0.00008	0.0002
Linear accelerator	¹³ N/21 ¹⁵ O/21	0.0094	0.0044	0.0094
Total	2993.8	0.53	0.33	0.53
Percent of Federal Emission Standard ^f		2%	1%	2%

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations* Part 61, Subpart H.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose. The doses are calculated using the most conservative exposure assumption and are not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^c Doses are based on 1554.4 Ci of HTO and 1395.0 HT released by LLNL.

^d Doses are based on 2.18 Ci of HTO.

^e Doses are based on 0.25 Ci of HTO.

^f The Federal Emission Standards for radionuclides (contained in 40 *Code of Federal Regulations* 61, Subpart H) limit doses to the public to 25 mrem/y to the whole body and 75 mrem/y to any critical organ. On December 15, 1989, a new standard of 10 mrem/y effective dose equivalent took effect; the percentage of this standard for dose at site perimeter, dose to nearest resident, and dose at maximum offsite exposure are 5.3%, 3.8%, and 5.3%, respectively.

did not present a measurable contribution to the dose.

The current DOE radiation protection limit for the public is 100 mrem during a one-year period. Prior to 1986, this limit was 500 mrem per year. The total offsite dose has decreased significantly over past years. Fluctuation in dose from year to year is due to changes in operations, operating schedules, and site meteorology. Since 1984, the offsite doses have remained very low, all less than 0.4% of the DOE limit.

The CPS Code was also used to calculate the dose to the maximally exposed individual, a hypothetical person who lives at a location and has a lifestyle that results in receiving the maximum possible calculated radiation dose from Livermore-site operations. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1989 was 0.43 mrem. (See **Table L-38.**) For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation (including radon) during this same period.

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated

collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 0.64 person-rem during 1989. This dose is based on a population of 6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources, during the same period of time was estimated to be 1.9×10^6 person-rem.

Overall, all measured and calculated radiation doses were negligible: the doses were well below the applicable standards for radiation protection of the public and substantially less than the dose normally received from natural sources of background radiation. (See **Tables L-39** and **L-40.**)

Radiological Monitoring Program.

LLNL conducts a substantial environmental radiation monitoring program. Data are collected for radioactivity in air, sewage, surface water and groundwater, soils and sediments, and vegetation and foodstuff. In addition, penetrating radiation is measured. The sample data and the methods used to analyze the samples are presented in detail in the Air Monitoring, Sewage Monitoring, Routine Water Monitoring, Soil Monitoring, Vegetation and Foodstuff Monitoring, and Environmental Radiation Monitoring chapters in the body of the report.

Table L-38. Estimated radiation dose to the public from Livermore-site airborne effluents during 1989 (Continuous-Point-Source Code).

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Tritium facility	³ H/2949.4 ^b	0.26	0.18	0.26	0.64
Insulating core accelerator	0	0	0	0	0
Rotating target neutron source	³ H/2.18 ^c	0.0006	0.0004	0.0006	0.001
Incinerator	0	0	0	0	0
Laser complex	³ H/0.25 ^d	0.00007	0.00004	0.00007	0.00012
Linear accelerator	¹³ N/21 ¹⁵ O/21	0.05 ^e	0.03 ^e	0.05 ^e	0.00001 ^e
Total (Livermore site)	2993.8	0.31	0.21	0.31	0.64

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b Doses are based on 1554.4 Ci of HTO and 1395.0 HT released by LLNL.

^c Doses are based on 2.18 Ci of HTO.

^d Doses are based on 0.25 Ci of HTO.

^e Submersion dose. The short half-life of ¹³N and ¹⁵O preclude calculation of air inhalation dose.

Table L-39. Summary of radiological dose assessment for 1989 for the Livermore site.

Effective dose equivalent to the maximally exposed individual in the public						
Nuclide	Pathways			Total		Percent of DOE primary radiation protection standard for the public ^b
	Inhalation/ submersion ^a (mrem)	Ingestion- foodstuffs (mrem)	Ingestion- water (mrem)	(mrem)	(mSv)	
³ H	0.25	0.07	0.06	0.38	0.0038	0.38
¹³ N, ¹⁵ O	0.05	N/A ^c	N/A ^c	0.05	0.0005	0.05
Livermore-site Total ^d				0.43	0.0043	0.43

^a The inhalation/submersion dose was derived using the Continuous-Point-Source code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c There is no ingestion dose from short half-life air activation products.

^d This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table L-40. Comparison of radiation doses—Livermore site, 1989.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
LLNL Sources		
Atmospheric emissions	0.43 ^b	0.64
Liquid emissions	0 ^b	0 ^c
Other Sources		
Natural radioactivity ^d		
Cosmic radiation	40	240 000
Terrestrial radiation	50	300 000
Internal (food consumption)	28	168 000
Radon	200	1 200 000
Medical radiation ^{e,f} (Diagnostic procedures)	55	330 000
Weapons test fallout ^{e,g}	5	550 000
Nuclear power production ^{e,g}	5.5	33 000

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of the Livermore site (approximately 6 000 000).

^b These doses represent the maximum committed effective dose equivalent from all LLNL emissions. It is calculated using the most conservative exposure assumptions and is not a dose actually received by any member of the public. Therefore, it is not used to calculate LLNL population dose.

^c Populations dose from Livermore-site emissions.

^d These values vary with location and represent approximate averages in the vicinity of LLNL.

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

^f From Mettler et al. (1990).

^g From Glasstone and Jordan (1980).

LLNL—SITE 300

Compliance Self-Assessment

The activities undertaken at the Site 300 in response to legal requirements are described in the Site 300 section of the body of this report in the chapter entitled "Summary of Environmental Compliance Activities." These environmental activities were performed by the Regulatory Affairs Division, the Environmental Restoration Division, the Environmental Guidance Division, and the Hazardous Waste Management Division of the Environmental Protection Department. Table S-27 provides, for 1989, a list of permits issued to LLNL for Site 300 by various regulatory agencies and a list of inspections conducted by such agencies.

Resource Conservation and Recovery Act (RCRA)—Hazardous Waste. Landfill Pits 1 and 7 were operated at Site 300 under provisions of the Interim Status Document CA 2890090002 and WDR

Order 80-184 until November 1988 when their use ceased. They had been used for disposal of firing table gravel and debris. Plans for final closure of Pits 1 and 7 were submitted to DHS, EPA, and the Regional Water Quality Control Board. The RCRA Part A permit application was revised to show the change in landfill status. A RCRA Part B permit application was submitted to EPA and DHS in January 1989 for the hazardous waste container storage facility. The final Part B permits were issued by EPA and DHS in November 1989.

Resource Conservation and Recovery Act (RCRA) and Other Federal, State, and Local Regulation of Storage Tanks.

Personnel in the Tank Integrity Testing Program conducted tests of two underground hazardous product retention systems; one system was identified that could not meet the minimum leak-rate criterion. The leak sites were identified and repaired.

Air Quality Management Activities. The San Joaquin Air Pollution Control

Table S-27. Compliance summary—Site 300.

Type of regulatory action	Regulatory agency
Public hearing (date)	
RCRA Waste Disposal Permit (Aug. 3)	DHS/EPA
Permits (number)	
RCRA Hazardous Waste Container Storage Facility Permits (2)	DHS/EPA
Interim Status for HE burn pit (1)	DHS/EPA
WDR 80-184 for Class II-1 Solid Waste Disposal Sites (1)	RWQCB
WDR 82-105 (NPDES Permit CA0081396) for Cooling Tower Wastewater Discharge (1)	RWQCB
WDR 85-188 for Domestic and Industrial Wastewater to Septic Systems and Evaporation Ponds (1)	RWQCB
Gasoline Recovery System (2)	SJCAPCD
Paint Spray Booth (1)	SJCAPCD
Sawdust Collector (cyclone) (1)	SJCAPCD
Boilers (5)	SJCAPCD
Inspections (date)	
Landfill Closure Inspection (Mar. 10)	EPA/DHS/RWQCB
RCRA Annual Inspection (Mar. 26)	EPA
Annual Inspection of Permitted Sources (Apr. 4)	RWQCB
Underground Tank Soil Sampling (June 26)	SJCHD
Annual Inspection of Endangered Wildflower (Mar. 30)	U.S. Fish and Wildlife/ California Fish & Game
Annual Inspection of Permitted Sources (Nov. 28)	SJCAPCD

District issued nine permits to LLNL for Site 300 operations in 1989. No deficiencies were noted in the report of the annual inspection of permitted sources.

Endangered Species Act Activities. Staff from the California Department of Fish and Game and the U.S. Fish and Wildlife Service performed their annual inspection of the endangered wild flower, *Amsinckia grandiflora*, on March 30, 1989. A newly discovered second population located on Site 300 was also inspected.

Nonradiological Monitoring Information

National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements. Clean water is the subject of Federal, State, and local laws and regulations. The National Pollutant Discharge Elimination System (NPDES),

under the Federal Clean Water Act, establishes the permit requirements for discharges into surface waterways. In addition, the State of California requires permits for any discharges that have potential to adversely impact beneficial uses of waters of the State. The Regional Water Quality Control Boards (RWQCBs) are responsible for issuance and enforcement of both types of permits.

Site 300 has three permits issued by the Regional Water Quality Control Board. Waste Discharge Requirement, Order 80-184, for a Class II-1 solid waste disposal site pertains to inactive landfills located at Site 300. Waste Discharge Requirement, Order 82-105, is a permit that applies to the cooling tower discharges at Site 300. This permit is also an NPDES permit because discharges may enter stormwater drainages. Finally, Waste Discharge

Requirement, Order 85-188, is a permit for the sewer lagoons, septic tanks, leach-fields, and the high-explosives rinsewater Class II surface impoundment at Site 300.

On April 4, 1989, RWQCB performed an inspection of permitted discharges. This included review of cooling tower discharges, landfill operations, HE process water discharges to a surface impoundment system, and septic system discharges. No inspection report was received.

Groundwater Monitoring Information.

Groundwater monitoring is conducted under two programs at LLNL. One program is designed to meet regulatory commitments established for specific site investigations; the other program consists of routine compliance monitoring around landfill and wastewater surface impoundment units.

Until recently, investigations under the first program were being conducted under the California Clean Water Act, using CERCLA guidelines and procedures. In March 1989, LLNL received a proposed RCRA cleanup order from EPA. The terms of the cleanup order have not yet been negotiated with EPA.

Accordingly, Remedial Investigations/Feasibility Studies of TCE, tritium, and HE compounds in soil and groundwater continued during 1989. TCE contamination was investigated at the Building 834 complex, at Building 833, the General Services area, Landfill Pit 6, and the HE Process Area. A soil-vapor survey in the General Services area resulted in the detection of TCE in offsite soils east of the southeast corner of Site 300. Subsequent installation of monitoring wells allowed identification of a plume of TCE (concentrations up to 58 ppb) in shallow groundwater extending about 4000 ft from the site boundary beneath private and State of California property. A groundwater treatment system has been designed to begin remediation of these low concentrations of TCE. By year end, the treatment unit was being constructed and applicable permits had been sought.

The investigation of tritium in groundwater at Landfill Pit 7 showed that groundwater in that area is moving at a

maximum of about 15 m/y toward the northern site boundary. Given this flow rate and the radioactive decay half-life for tritium of 12.3 years, by the time the groundwater reaches the site boundary, its tritium concentration will be only slightly above background levels.

In 1989, LLNL continued its investigation of the extent of HE compounds and TCE in groundwater beneath the HE Process Area. Both plumes are small, with concentrations of HE compounds at 350 ppb or less and TCE at 280 ppb or less.

As part of LLNL's environmental remediation efforts, six inactive water-supply wells at Site 300 were sealed and abandoned. These older wells posed a potential threat of cross-contamination of water-bearing zones because of their long well screens or sand packs. The wells were sealed and abandoned.

In addition during 1989, the RWQCB approved LLNL's plan to close the nine decommissioned HE rinsewater lagoons in the HE Process Area. By October 1989, LLNL had filled the lagoons to grade level with native soils, placed a clay cover on each lagoon, and seeded them with native grasses. The lagoons have now been formally closed.

Details of this program are described in the LLNL Site 300 *Environmental Investigations Quarterly Reports* (Lamarre et al. 1989a-c; Taffet et al. 1989a); they are not discussed in this report.

The other groundwater program consists of routine compliance monitoring around landfill and wastewater surface impoundment units, as required by the RWQCB, California Department of Health Services (DHS), and the EPA. In 1989, very low concentrations of Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) continued to be observed in two wells at a maximum concentration of 5.8 µg/L and 9.7 µg/L, respectively. Freon-113 was also detected in another well during the second quarter at a concentration of 0.9 µg/L. These levels are far below the State action level of 1200 µg/L.

Some groundwater monitoring wells near landfills at Site 300 continued to show sharply elevated concentrations of

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tritiated water. These elevated levels have been observed in this area since 1984. The highest value measured was 4.0×10^{-4} $\mu\text{Ci/mL}$. This value exceeds the MCL; however, it was found in an aquifer that is not used for onsite water supplies. Water movement analysis has shown that the tritium will decay to levels below drinking water limits before it reaches the site boundary. Traces of halogenated hydrocarbons were detected in wells downgradient of this area and in groundwater downgradient from another landfill at Site 300. As in 1988, the highest trichloroethylene value observed during routine monitoring in 1989 from a well in the Building 817 area; this year the value was 81 $\mu\text{g/mL}$, in 1988 it was 98 $\mu\text{g/mL}$. This contamination is most likely due to past operations at Building 815. Nitrate levels in a number of monitoring wells were above the MCL. These levels are considered to be naturally occurring.

Superfund Amendments Reauthorization Act (SARA)—Title III. A physical inventory of all chemicals, subject to reporting under SARA Title III was conducted in 1988. In early 1989 the data were entered into a computerized database system, and were used to generate reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site. The inventory itself is three volumes long.

Table S-2. Nonradioactive airborne emissions, Site 300, 1989.

Pollutant	Estimated release (tons/day)
Particulates	0.0003
Organic compounds	0.0062
Oxides of sulfur	0.0001
Oxides of nitrogen	0.0023 ^a
Carbon monoxide	0.0006 ^a
Chlorofluorocarbons	0.0045

^a These values are estimates based on the combustion products from diesel-fuel-fired boilers.

Other Emissions Monitoring Data.

LLNL does not have major air or water nonradioactive point-source emissions (other than emissions to the sewer discussed above). Emissions to the air from small point sources such as boilers and paint spray booths are calculated and are presented in **Table S-2**.

Other Monitoring Data. Other nonradiological monitoring data that is collected includes air beryllium content and noise monitoring. The highest monthly average concentration of beryllium detected was a detection-limit value of $<26 \times 10^{-5}$ $\mu\text{g/m}^3$. This value is less than 3% of the regulatory limit established by the San Joaquin County Air Pollution Control District. These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium.

LLNL conducted 55 high explosives tests at Site 300 during 1989. Microbarograph measurements in the vicinity of Site 300 and the City of Tracy demonstrated that the noise limit of 400 μbar was not exceeded, nor were there any complaints of noise or overpressure from residents in the vicinity of the test site. Furthermore, none of the 55 tests produced sound levels, at any of the six microbarograph stations, above 65 μbar .

These data are not "emission" data as described in the suggested DOE format, and are presented in detail in the body of the report in chapters on Air Monitoring and Noise Monitoring.

Radiological Monitoring Information

Potential Radiological Dose from Site 300. The primary DOE radiation standards for protection of the public are 100 mrem/y effective dose equivalent for prolonged exposure and 500 mrem/y effective dose equivalent for occasional exposure. These limits are based on the dose to the hypothetical maximally exposed individual in an uncontrolled area. The definition of "effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and LLNL also comply with EPA standards for radiation protection. These EPA radiation dose standards are 25 mrem/y dose equivalent for whole-body exposures from the air pathway and 75 mrem/y dose equivalent for exposure of any organ from the air pathway.

The EPA standard is based on the AIRDOS-EPA Clean Air Act Code (CAAC) model code, while LLNL historically has used the Continuous-Point-Source Code (CPS Code) to determine compliance with the DOE standard; this results in somewhat different calculated individual doses because of the differences in model assumptions and calculations.

The total airborne discharge from the Advanced Test Accelerator in 1989 was 0.57 Ci of ^{13}N and 0.57 Ci of ^{15}O . These nuclides are air activation products generated during the interaction of the accelerator beam with air. Nitrogen-13 has a half-life of about 10 minutes, and ^{15}O has a half-life of about 2 minutes.

The CAAC was used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and dose at the maximum offsite exposure location for each emission source. The CPS Code was used to calculate the estimated dose at the site perimeter, dose to the nearest resident,

and maximum offsite dose as well as collective person-rem dose to the population residing within 80 km of the Livermore site. Both of these methods are based on conservative assumptions, and any actual dose received by an individual would be much less.

The air pathway doses calculated using the CAAC included exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The CAAC was run using specific meteorology for Site 300. The EPA limit for airborne emissions is 25 mrem/y whole body dose equivalent. The total fence-line dose from air emissions from Site 300 operations in 1989 was 1.5×10^{-4} mrem; the dose to the nearest resident was 3.7×10^{-7} mrem; and the dose at the point of maximum offsite exposure was 1.5×10^{-4} mrem. These doses represent only 0.006% or less of the EPA limit. (See **Table S-23**.)

Air pathway doses were also calculated using CPS Code. The maximum inhalation dose from airborne emissions at the Site 300 perimeter was 6.3×10^{-4} mrem. The maximum inhalation dose from airborne emissions to the nearest resident was 1.6×10^{-4} mrem. (See **Table S-24**.)

The CPS Code was also used to calculate the dose to the maximally exposed

Table S-23. Radiation dose from the air pathway (Clean Air Act Code^a calculations) for Site 300, 1989.

Facility	Nuclide (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Advanced Test Accelerator	$^{13}\text{N}, ^{15}\text{O}$ (0.57, 0.57)	0.00015	3.7×10^{-7}	0.00015
Total		0.00015	3.7×10^{-7}	0.00015
Percent of Federal Emission Standard ^c		0.006	1×10^{-5}	0.006

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations* Part 61, Subpart H.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose.

^c The Federal Emission Standards for radionuclides (contained in 40 *Code of Federal Regulations* Part 61, Subpart H) limit doses to the public to 25 mrem/y to the whole body and 75 mrem/y to any critical organ. On December 15, 1989, a new standard of 10 mrem/y effective dose equivalent took effect; the percentages of this standard for dose at the site perimeter, dose to nearest resident, and dose at maximum offsite exposure are 0.0015%, $3.7 \times 10^{-6}\%$, and 0.0015%, respectively.

Table S-24. Estimated radiation dose to the public from Site 300 airborne effluents during 1989 (Continuous-Point-Source Code).

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Advanced Test Accelerator (ATA)	¹³ N/0.57 ¹⁵ O/0.57	0.00063	0.00016	0.00063	0.0013
Total		0.00063	0.00016	0.00063	0.0013

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less. It is not used to calculate population dose.

^b The population dose is the collective (combined) dose of all individuals residing within an 80-km radius. These calculations are based on the same population distribution as that around the Livermore site (6 000 000). The population densities within 80 km of Site 300 are actually less. Therefore, the collective person-rem dose is conservative—the actual dose to the public within 80 km around Site 300 is actually lower. The population dose is calculated directly with the Continuous-Point-Source Code.

individual, a hypothetical person who lives at a location and has a lifestyle that results in receiving the maximum possible calculated radiation dose from Site 300 operations. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1989 was 6.3×10^{-4} mrem. For comparison, the average resident of the Livermore Valley received a dose of approximately 318 mrem from natural background radiation (including radon) during this same period. (See **Table S-25** and **S-26**.)

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 miles) of LLNL was 1.3×10^{-3} person-rem during 1989. This dose is based on a population of 6 million within 80 km of LLNL. The collective population dose from natural sources of radiation, using 318 mrem/y as a typical average from natural sources, during the same period of time was estimated to be 1.9×10^6 person-rem.

Overall, all measured and calculated radiation doses were negligible. The doses were well below the applicable standards for radiation protection of the public and substantially less than the dose normally received from natural sources of background radiation.

Radiological Monitoring Program. LLNL conducts a substantial environmental radiation monitoring program. Data are collected for radioactivity in air, sewage, surface water and groundwater, soils and sediments, and vegetation and foodstuff. In addition, penetrating radiation is measured. The sample data and the methods used to analyze the samples are presented in the Air Monitoring, Routine Water Monitoring, Compliance Water Monitoring, Soil Monitoring, Vegetation Monitoring, and Environmental Radiation Monitoring chapters in the body of the report.

Conclusion

In sum, the results of the Environmental Monitoring Program for 1989 demonstrate that the environmental impacts of LLNL are minimal and pose no threat to the public or the environment.

Table S-25. Summary of radiological dose assessment for 1989 for Site 300.

Effective dose equivalent to the maximally exposed individual in the public						
Nuclide	Pathways			Total (mrem)	(mSv)	Percent of DOE primary radiation protection standard for the public ^b
	Inhalation/ submersion ^a (mrem)	Ingestion- foodstuffs (mrem)	Ingestion- water (mrem)			
¹³ N, ¹⁵ O	0.00063	N/Ac	N/Ac	0.00063	6×10^{-6}	0.0006
Site 300 Total ^d				0.00063	6×10^{-6}	0.0006

^a The inhalation/submersion dose was derived using the Continuous-Point-Source code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c There is no ingestion dose from short half-life air activation products.

^d This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table S-26. Comparison of radiation doses—Site 300, 1989.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
<u>Site 300 Sources</u>		
Atmospheric Emissions	0.00063 ^b	0.0013 ^c
<u>Other Sources</u>		
<u>Natural radioactivity^d</u>		
Cosmic radiation	40	240 000
Terrestrial radiation	50	300 000
Internal (food consumption)	28	168 000
Radon	200	1 200 000
<u>Medical radiation^{e,f}</u>		
(Diagnostic procedures)	55	330 000
Weapons test fallout ^{e,g}	5	30 000
Nuclear power production ^{e,g}	5.5	33 000

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of LLNL (approximately 6 000 000).

^b This dose represents the maximum committed effective dose equivalent from all Site 300 emissions. It is calculated using the Continuous Point Source Code and the most conservative exposure assumptions and is not a dose actually received by any member of the public. Therefore, it is not used to calculate Site 300 population dose.

^c Population dose from Site 300 emissions is calculated directly with the Continuous-Point-Source Code.

^d These values vary with location and represent approximate averages in the vicinity of Site 300.

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

^f From Mettler et al. (1990).

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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.
	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 (2 protons and 2 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 or parameter that is being analyzed.
	Anion	A negatively charged ion.
	ANOVA	Analysis of variance. A test of whether two or more sample means could have been obtained from the same statistical population.
	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.
	ARB	California Air Resources Board. The State agency responsible for developing control strategies to protect ambient air quality. This agency also regulates mobile sources.

Glossary

	Atom	The smallest particle of an element capable of entering into a chemical reaction.
	Atomic absorption spectrometry	Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor. Abbreviated AA.
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.
C	CAA	Clean Air Act. The Federal law that authorizes the EPA to set air quality standards and to assist State and local governments to develop and execute air pollution prevention and control programs.
	CAM WET	California Assessment Manual, Waste Extraction Test. A DHS procedure for evaluating the leachability of certain metals, pesticides, and other organic compounds from a semi-solid or solid waste. It is used to determine the toxicity of a waste.
	CAAC	Clean Air Act Code (EPA). Computer code required by the EPA for modeling air emissions.

Cation	A positively charged ion.
CEQA	California Environmental Quality Act of 1970. This legislation regulates the issuance of permits for the construction and operation of any facility in California that has potential to cause harm to the environment. Federal facilities are exempt from CEQA. However, the University of California has voluntarily chosen to comply with this legislation.
CERCLA	<p>Comprehensive Environmental Response, Compensation and Liability Act of 1980. Also known as Superfund, this law authorizes the Federal government to respond directly to releases of hazardous substances that may endanger health or the environment. The EPA is responsible for managing Superfund. The major step in the Superfund process is the Remedial Investigation/Feasibility Study (RI/FS).</p> <p>In 1986, the President signed into law the Superfund Amendments and Reauthorization Act (SARA), which amended and reauthorized CERCLA for five years at a total funding level of \$8.5 billion. SARA also strengthened State involvement in the cleanup process, and encouraged the use of treatment technologies and permanent solutions. However, the Superfund cleanup of groundwater at LLNL is funded by DOE.</p>
<i>Code of Federal Regulations</i>	A codification of all regulations developed and finalized by Federal government agencies in the <i>Federal Register</i> . RCRA regulations are contained in Title 40 of the <i>Code of Federal Regulations</i> .
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).

Glossary

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 rem (or sievert).
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 rem (or sievert).
Cosmic radiation	Radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.
CPS Code	Continuous-Point-Source computer code for plume dispersion and deposition calculations.
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	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).
DEIS	Draft Environmental Impact Statement. (See EIS.)
DHS	Department of Health Services (California). The State agency that regulates hazardous waste management and remedial actions.
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 sponsors energy research and regulates 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.
DWS	Drinking water standard. A standard established by the State of California in Title 22 of the <i>California Code of Regulations</i> .

E	EA	Environmental Assessment. A report that identifies potentially significant environmental impacts from any Federally approved or funded project that may change the physical environment. If an EA shows significant impact, an EIS is required.
	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.
	Effluent	A liquid or gaseous waste discharged to the environment.
	EIR	Environmental Impact Report. A detailed report, required by California law, on the significant environmental impacts from any project that is carried out, approved, or funded by a local or State (California) public agency the may change the physical environment.
	EIS	Environmental Impact Statement. A detailed report, required by Federal law, on the significant environmental impacts that a pending structure or development will have on the environment. An EIS must be prepared by a government agency when a "major" Federal action that will have "significant" environmental impacts is planned.

Glossary

	EPA	Environmental Protection Agency. The Federal agency responsible for enforcing 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. EPA administers the Superfund legislation and works with State and local agencies to provide technical oversight for cleanup activities at Federal facilities regulated by the Superfund program.
	EPD	Environmental Protection Department (LLNL).
	EMG	Environmental Monitoring Group in the Regulatory Affairs Division of the Environmental Protection Department (LLNL).
F	Federal Facility	A facility that is owned or operated by the Federal government. With the passage of SARA, Federal facilities became subject to the same requirements that other responsible parties must adhere to once they are placed on the Superfund National Priorities List.
	<i>Federal Register</i>	A document published daily by the Federal government containing notification of government agency actions. The <i>Federal Register</i> contains notification of EPA and DOE actions, including notification of EPA and DOE decisions concerning permit applications and rule making.
	FEIS	Final Environmental Impact Statement. (See EIS.)
	FFA	Federal Facilities Agreement. A document that specifies required actions at a Federal facility as agreed upon by various agencies (e.g., EPA, DHS, RWQCB, and DOE).
	Fissile	Any material fissionable by neutrons of all energies (e.g., ^{235}U and ^{239}Pu).
	Fluvial	Produced by the action of a stream or river.
	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 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.

Greek prefixes

Symbol	Name	Scientific notation	Decimal notation
m	milli	10^{-3}	0.001
μ	micro	10^{-6}	0.000001
n	nano	10^{-9}	0.000000001
p	pico	10^{-12}	0.000000000001

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 leach 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. RCRA regulations set strict controls on the management of hazardous wastes.

HE High explosives. Materials that release large amounts of energy when detonated.

HSWA Hazardous and Solid Waste Amendments of 1984 to RCRA. These amendments to RCRA greatly expanded the scope of hazardous waste regulation. In HSWA, Congress directed EPA to take measures to further reduce the risks to human health and the environment caused by hazardous wastes.

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.)

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.

Glossary

I	ICRP	International Commission on Radiological Protection. An international organization that studies radiation, including its measurement and effects.
	Inorganic compounds	Compounds that either do not contain carbon or do not contain hydrogen along with carbon. Inorganic compounds include metals, salts, and various carbon oxides (carbon monoxide, carbon dioxide).
	<i>In situ</i>	A term that can be used to refer to the treatment of contaminated areas without excavation or other removal, as in the <i>in situ</i> treatment of soils through biodegradation of contaminants on site.
	Interim status	A legal classification that applies to hazardous waste incinerators or other hazardous waste management facilities that were under construction or in operation by November 19, 1980, and can meet other interim status requirements. Interim status facilities may operate while EPA considers their permit application.
	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.
J	Isotopes	Forms of an element having the same number of protons in their nuclei but differing numbers of neutrons.
	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.
	LBL	Lawrence Berkeley Laboratory.
	Less than detection limits	A phrase indicating that a chemical constituent was either not identified or not quantified at the lowest level of sensitivity of the analytical method being employed by the laboratory. Therefore, the chemical constituent either is not present in the sample, or it is present in such a small concentration that it cannot be measured by the analytical procedure.

LLNL	Lawrence Livermore National Laboratory.
Lower limit of detection	The smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.
LWRP	Livermore Water Reclamation Plant. The City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.
M	
MATHEW/ ADPIC codes	Transport and diffusion computer codes used to determine the concentration of pollutants at a distance from the source.
MCL	Maximum contaminant levels in drinking water established by EPA or DHS.
N	
NAAQS	National Ambient Air Quality Standards. Air standards established by EPA to protect human health and the environment.
NEPA	National Environmental Policy Act. This Federal legislation, passed in 1969, regulates the issuance of permits for the construction and operation of facilities that have the potential to impact the environment or public health. One provision of NEPA requires the preparation of an EIS by Federal agencies when "major" actions are taken. The agency responsible for assuring NEPA compliance at LLNL is DOE, with EPA oversight.
NESHAP	National Emission Standards for Hazardous Air Pollutants. These standards are found in the Clean Air Act; they set limits for such pollutants as beryllium and radionuclides.
NIST	National Institute for Standards and Technology. The Federal agency responsible for reference materials against which laboratory materials are calibrated, formerly known as the National Bureau of Standards.
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).
NPDES	National Pollutant Discharge Elimination System. This Federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways. LLNL holds NPDES permits at the Livermore site for groundwater discharges to the arroyos and for cooling-tower discharges at Site 300.
NPL	National Priorities List. EPA's list of the top-priority hazardous waste sites in the country that are subject to the Superfund program.

Glossary

	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.
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.
	PCE	Tetrachloroethylene, also known as perchloroethylene. A volatile organic contaminant found in groundwater.
	Performance standards	Specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in emissions from incinerators. Permit applicants must show that the incinerator can meet the performance standards under the operating conditions specified in the RCRA permit. EPA also established performance standards for concentrations of metals and organic compounds in wastewater.
	Piezometer	Generally, a small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface.
	pH	A measure of hydrogen-ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.
	Point source	Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack).

Porter-Cologne Act	The California law that established a two-tier administrative organization to enforce its water-quality legislation: Regional Water Quality Control Boards and the State Water Resources Control Board.
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.
ppb	Parts per billion. A unit of measure for the concentration of a substance in its surrounding medium. For example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion.
ppm	Parts per million. A unit of measure for the concentration of a substance in its surrounding medium. For example, one million grams of water containing one gram of salt has a salt concentration of one part per million.
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 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.

Glossary

	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.
	RCRA	Resource Conservation and Recovery Act of 1976. RCRA is an amendment to the first Federal solid waste legislation, the Solid Waste Disposal Act of 1965. In RCRA, Congress established initial directives and guidelines for EPA to regulate hazardous wastes.
	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.
	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).
	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.
	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.
	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.
	RWQCB	Regional Water Quality Control Board. The 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, the level of a contaminant in drinking water recommended by DHS for remediation.
	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.
	SI	Système International d'Unités. An international system of physical units. Units of measure in this system include meters (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).

Glossary

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.)
SJCAPCD	San Joaquin County Air Pollution Control District. The local agency responsible for regulating stationary air emission sources (including Site 300) in the San Joaquin County.
SJCHD	San Joaquin County Health District. The local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.
SNLL	Sandia National Laboratories, Livermore. SNLL discharges its sanitary sewage from a common monitored outfall with the Livermore site.
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). CERCLA is a Federal statute that gives the Federal government the ability to respond to hazardous waste releases that pose a potential threat to human health and the environment. 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 pertaining to property rights to use water, and acts as an appellate agency for actions of the Regional Water Quality Control Boards.

T	TCA	Trichloroethane. A volatile organic contaminant found in groundwater.
	TCE	Trichloroethylene. A volatile organic contaminant found in groundwater.
	TCLP	Toxicity Characteristic Leaching Procedure. An analytical method designed to determine the mobility of both organic and inorganic compounds present in liquid, solid, and multi-phase 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.
	TLD	Thermoluminescent dosimeter. A device used to measure external gamma radiation levels.
	TTO	Total toxic organic compounds. A list of organic compounds for which EPA has established discharge limits for specific processes or industries.
	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.
	T-test	A type of ANOVA that determines the significance of the difference between two sample means.
U	Turbidity	A measure of the concentration of sediment or suspended particles in solution.
	^{238}U	Uranium-238, also known as D-38 or DU (depleted uranium), a radionuclide.
	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; it 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 non-earthen 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.

Glossary

	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.
	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	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.
	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.
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.
Y	y	The SI abbreviation for year.
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.

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