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Environmental Surveillance at Los Alamos During 1989

Environmental Protection Group

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FOREWORD

Suggestions on How to Read This Report

This report addresses both the lay person and the scientist. Each reader may have limited or comprehensive interest in this report. We have tried to make it accessible to all without compromising its scientific integrity. Following are directions advising each audience on how best to use this document.

1. **Lay Person with Limited Interest.** Read Part I, the Executive Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for this year. Emphasis is on the significance of findings and environmental regulatory compliance. A glossary is in the back.

2. **Lay Person with Comprehensive Interest.** Follow directions for the "Lay Person with Limited Interest" given above. Also, summaries of each section of the report are in boldface type and precede the technical text. Read summaries of those sections that interest you. Further details are in the text following each summary. Appendix A, Standards for Environmental Contaminants, and Appendix F, Description of Technical Areas and Their Associated Programs, may also be helpful.

3. **Scientists with Limited Interest.** Read Part I, the Executive Summary, to determine the parts of the Laboratory's environmental program that interest you. You may then read summaries and technical details of these parts in the body of the report. Detailed data tables are in Appendix G.

4. **Scientists with Comprehensive Interest.** Read Part I, the Executive Summary, which describes the Laboratory's environmental programs and summarizes environmental data for this year. Read the boldface summaries that head each major subdivision of this report. Further details are in the text and appendixes.

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ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1989

by

ENVIRONMENTAL PROTECTION GROUP

ABSTRACT

This report describes the environmental surveillance program conducted by Los Alamos National Laboratory during 1989. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in the surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of data for 1989 cover external penetrating radiation; quantities of airborne emissions and effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are small and do not pose a threat to the public, Laboratory employees, or the environment.

I. EXECUTIVE SUMMARY

A. Monitoring Operations

The Laboratory supports an ongoing environmental surveillance program as required by U.S. Department of Energy (DOE) Orders 5400.1 ("General Environmental Protection Program," November 1988) and 5484.1 ("Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 1981) (DOE 1988, 1981). The surveillance program maintains routine monitoring for radiation, radioactive materials, and hazardous chemical substances on the Laboratory site and in the surrounding region. These activities document compliance with appropriate standards, identify trends, provide information for the public, and contribute to general environmental knowledge. Detailed, supplemental environmental studies also are carried out to determine the extent of potential problems, to provide a basis for any remedial actions, and to gather further information on surrounding environments. The monitoring program supports the Laboratory's policy to protect the public, employees, and environment from harm that could be caused by Laboratory activities and to reduce environmental impacts to the greatest degree practicable. Environmental monitoring information complements data on specific releases, such as those from radioactive liquid-waste treatment plants and stacks at nuclear research facilities, as well as airborne releases of nonradioactive compounds from many Laboratory operations.

Monitoring and sampling locations for various types of environmental measurements are organized into three groups:

1. Regional stations are located within the five counties surrounding Los Alamos County (Fig. 1) at distances up to 80 km (50 mi) from the Laboratory. They provide a basis for determining conditions beyond the range of potential influence from normal Laboratory operations.
2. Perimeter stations are located within about 4 km (2.5 mi) of the Laboratory boundary, and many are in residential and community areas. They document conditions in areas regularly occupied by the public and potentially affected by Laboratory operations.
3. On-site stations are within the Laboratory boundary, and most are in areas accessible only to employees during normal working hours. They document environmental conditions at the Laboratory where the public has limited access.

Samples of air particles and gases, waters, soils, sediments, and foodstuffs are routinely collected at these stations for subsequent analyses (Table 1). External penetrating radiation from cosmic, terrestrial, and Laboratory sources is also measured.

Additional samples are collected and analyzed to gain information about particular events, such as major surface run-off events, nonroutine releases, or special studies. More than 25 000 analyses for chemical and radiochemical constituents were carried out for environmental surveillance during 1989. Resulting data were used for dose calculations, for comparisons with standards and background levels, and for interpretation of the relative risks associated with Laboratory operations.

Comprehensive information about monitoring activities, environmental regulatory standards, and methods and procedures for acquiring, analyzing, and recording data is presented in Appendixes A–F; detailed environmental data tables are given in Appendix G.

B. Estimated Doses and Risks from Radiation Exposure

1. Radiation Doses. In this report, estimated individual radiation doses to the public attributable to Laboratory operations are compared with applicable standards. Doses are expressed as percentages of DOE's Radiation Protection Standard (RPS). The RPS is for doses from exposures excluding contributions from natural background, fallout, and radioactive consumer products. Estimated doses are believed to be potential doses to individuals under realistic conditions of exposure.

Historically, estimated doses from Laboratory operations have been less than 7% of the 500-mrem/yr standard that was in effect before 1985 (Fig. 2). These doses have principally resulted from external radiation from the Laboratory's airborne releases. In 1985, DOE issued interim guidelines that lowered its RPS to 100 mrem/yr

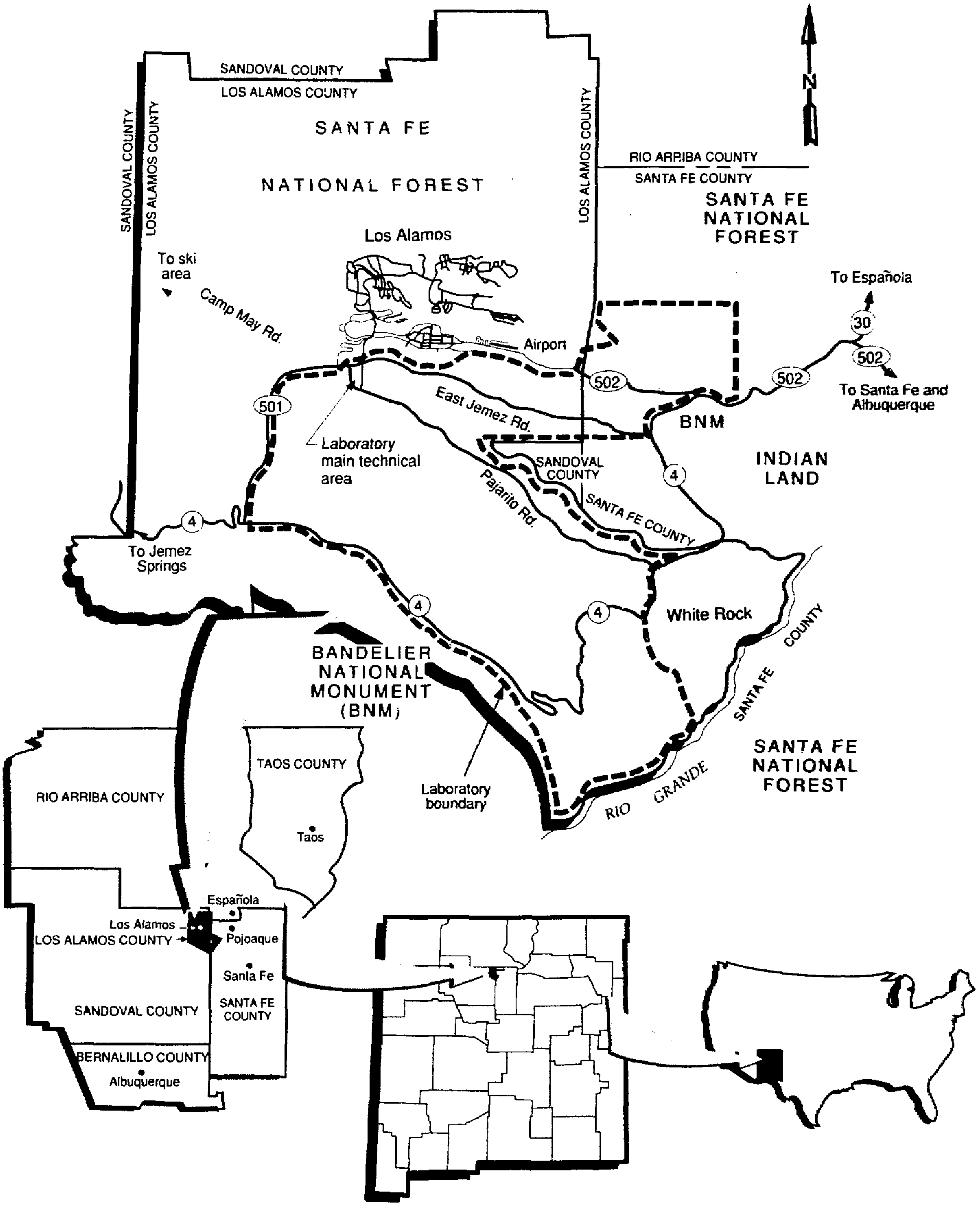

Fig. 1. Regional location of Los Alamos.

Table 1. Number of Sampling Locations for Routine Monitoring of the Ambient Environment

Type of Monitoring	Regional	Perimeter	On Site
External radiation	4	12	139
Air	3	12	12
Surface and ground waters[a]	6	32	37
Soils and sediments	16	16	34
Foodstuffs	10	8	11

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[a] Samples from an additional 22 stations for the water supply and 33 special surface- and ground-water stations related to the Fenton Hill Geothermal Program were also collected and analyzed as part of the monitoring program.

(effective dose equivalent) from all exposure pathways. In addition, exposure via the air pathway was further limited to 25 mrem/yr (whole body) and 75 mrem/yr (any organ) in accordance with requirements of the U.S. Environmental Protection Agency (EPA) (Appendix A).

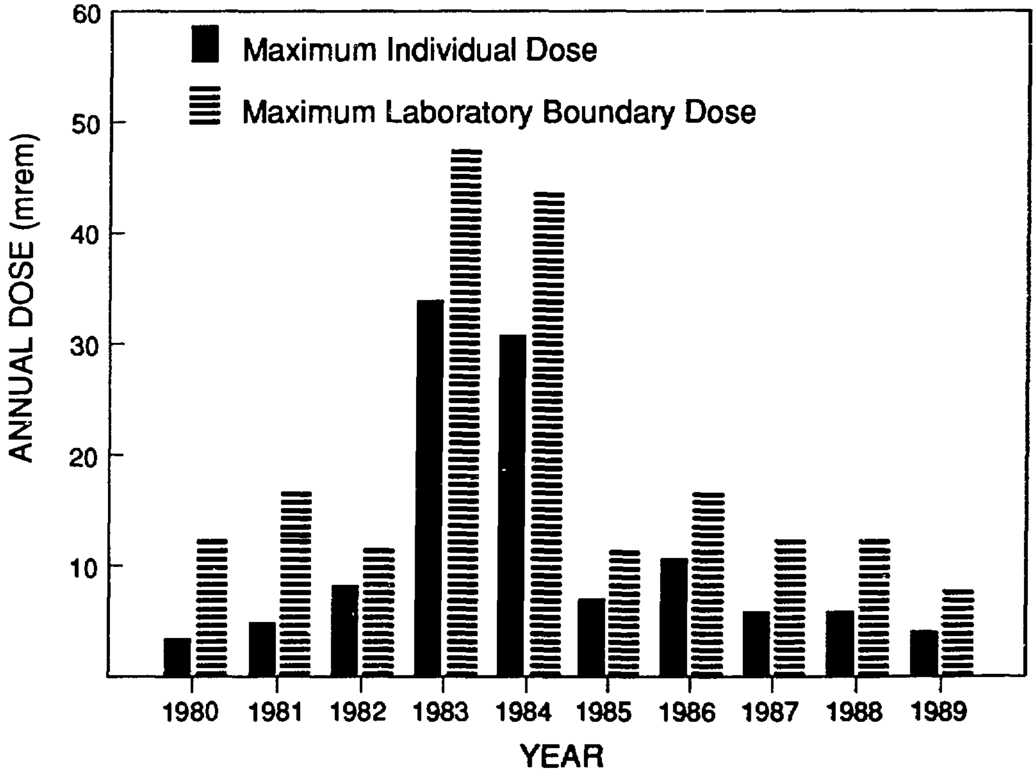

Fig. 2. Summary of estimated maximum individual and maximum Laboratory boundary doses from Laboratory operations (excluding contributions from cosmic, terrestrial, and medical diagnostic sources).

In 1989, the estimated maximum individual effective dose was 3.9 mrem, or 3.9% of DOE's 100-mrem/yr standard for all pathways. Because this dose is principally due to external radiation from airborne activation products, it is equal to the whole-body dose as well and is 16% of EPA's 25-mrem/yr standard for the air pathway alone (Table G-1). This dose resulted mostly from external radiation from short-lived, airborne emissions from a linear particle accelerator, the Los Alamos Meson Physics Facility (LAMPF).

Another perspective is gained by comparing these estimated doses with the estimated effective dose attributable to background radiation. The highest estimated dose caused from Laboratory operations was about 1% of the 327 mrem received from background radioactivity in Los Alamos during 1989.

2. Risk Estimates. Estimates of the added risk of cancer were calculated to provide a perspective for comparing the significance of radiation exposures. Incremental cancer risk to residents of Los Alamos townsite caused by 1989 Laboratory operations was estimated to be 1 chance in 15 000 000 (Table 2). This risk is <0.5% of the 1 chance in 8000 for cancer from natural background radiation and the 1 chance in 43 000 for cancer from medical radiation.

The Laboratory's potential contribution to cancer risk is small when compared with overall cancer risks. The overall lifetime risk in the United States of contracting some form of cancer is 1 chance in 4. The lifetime risk of cancer mortality is 1 chance in 5.

C. External Penetrating Radiation

Levels of external penetrating radiation (including x and gamma rays and charged-particle contributions from cosmic, terrestrial, and manmade sources) in the Los Alamos area are monitored with thermoluminescent dosimeters (TLDs) at 147 locations.

Table 2. Added Individual Lifetime Cancer Mortality Risks Attributable to 1989 Radiation Exposure

Exposure Source	Incremental Effective Dose Equivalent Used in Risk Estimate (mrem)	Added Risk to an Individual of Cancer Mortality (chance)
Average Exposure from Laboratory Operations		
Los Alamos townsite	0.15	1 in 15 000 000
White Rock area	0.14	1 in 16 000 000
Natural Radiation		
Cosmic, terrestrial, self-irradiation, and radon exposure[a]		
Los Alamos	327	1 in 8 000[b]
White Rock	327	1 in 8 000
Medical X Rays (Diagnostic Procedures)		
Average whole-body exposure	53	1 in 43 000

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[a] An effective dose equivalent of 200 mrem was used to estimate the risk from inhaling ^{222}Rn and its transformation products.

[b] The risks from natural radiation from nonradon sources were estimated to be 1 chance in 18 000 in Los Alamos and White Rock. The risk of lung cancer from radon exposure was estimated to be 1 chance in 14 000 for both locations. Risk estimates are derived from the National Research Council (NRC) BEIR IV and BEIR V reports and the National Council on Radiation Protection (NCRP) Report 93 (BEIR IV 1988, BEIR V 1990, NCRP 1987a).

The TLD network for monitoring radiation from airborne activation products released by LAMPF measured about 8 ± 3 mrem for 1989 (excluding background radiation from cosmic and terrestrial sources). This value is less than that measured in 1988, despite a 30% increase in the release of airborne radioactivity from LAMPF. This is probably due to the variations in the micropatterns of winds between the two years.

Radiation levels (including natural background radiation from cosmic and terrestrial sources) are also measured at regional, perimeter, and on-site locations in the environmental TLD network. Some measurements at on-site stations were above background levels, as expected, reflecting ongoing research activities at, or historical releases from, Laboratory facilities.

D. Air Monitoring

Airborne radioactive emissions were monitored at 87 release points at the Laboratory. Total airborne emissions increased from those in 1988 (Table 3). This was principally due to the 30% increase in releases of airborne activation products from LAMPF.

Table 3. Comparison of 1988 and 1989 Releases of Radionuclides from Laboratory Operations[a]

Airborne Emissions

Radionuclide	Activity Released (Ci) 1988	Activity Released (Ci) 1989	Ratio 1989:1988
^{3}H	11 000	14 400	1.3
^{32}P	0.000 057	0.000 018	0.3
^{41}Ar	264	222	0.8
Uranium	0.000 559	0.000 394	0.7
Plutonium	0.000 072	0.000 045	0.6
Gaseous mixed activation products	121 000	156 000	1.3
Mixed fission products	0.001 150	0.435	380
Particulate/vapor activation products	0.1	0.1	1
Rounded total	130 000	170 000	1.3

Liquid Effluents

Radionuclide	Activity Released (Ci) 1988	Activity Released (Ci) 1989	Ratio 1989:1988
^{3}H	26	41	1.6
$^{85,89,90}Sr$	0.081	0.1191	0.2
^{137}Cs	0.031	0.039	1.3
^{234}U	0.0008	0.0005	0.6
$^{238,239,240}Pu$	0.0043	0.0026	0.6
^{241}Am	0.0037	0.0041	1.1
Other	0.048	0.8286	17
Rounded total	26	42	1.6

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[a] Detailed data are presented in Table G-2 for airborne emissions and Tables G-13 and G-14 for liquid effluents.

Ambient air is routinely sampled for tritium, uranium, plutonium, americium, and gross beta activity. Measurements of radioactivity in the air are compared with DOE's Derived Air Concentration Guides. These guides are concentrations of radioactivity in air that, if breathed continuously throughout the year, would result in effective doses equal to DOE's RPS of 100 mrem/yr for persons in off-site areas (Derived Concentration Guides for Uncontrolled Areas) and to the occupational RPS (see Appendix A) for persons in on-site areas (Derived Air Concentrations for Controlled Areas). Hereafter, they are called guides for on- and off-site areas.

Only tritium air concentrations showed levels indicating any measurable impact from radionuclide releases caused by Laboratory operations. Annual average concentrations of tritium continued to be much less than 0.1% of DOE's guides at all stations and posed no environmental or health problems in 1989. Annual average concentrations of longer-lived radionuclides in air during 1989 were also less than 0.1% of the guides.

E. Water, Soil, and Sediment Monitoring

Liquid effluents containing low levels of radioactivity are routinely released from one waste treatment plant and one sanitary sewage lagoon system. The dominant change from 1988 was an increase in tritium discharges (Table 3). The LAMPF lagoons were modified during 1989, requiring the discharge of higher concentrations of radionuclides.

Surface and ground waters are monitored to detect potential dispersion of radionuclides from Laboratory operations. Only the surface and shallow ground waters in on-site liquid effluent release areas contained radioactivity in concentrations that were above natural terrestrial and worldwide fallout levels. These waters are not a source of industrial, agricultural, or municipal water supplies. The quality of water from regional, perimeter, and on-site areas that have received no direct discharge showed no significant effects from Laboratory releases. Samples from test wells and water supply wells continued to show no radioactive or chemical contamination in the deep aquifer that occurs 180 to 360 m (600 to 1200 ft) beneath the Pajarito Plateau.

Measurements of radioactivity in samples of soils and sediments provide data on less-direct pathways of exposure. These measurements are useful for understanding hydrological transport of radioactivity in intermittent stream channels near low-level radioactive waste management areas. On-site areas within Pueblo, Los Alamos, and Mortandad canyons all had concentrations of radioactivity in sediments at levels higher than those attributable to natural terrestrial sources or worldwide fallout. Cesium, plutonium, and strontium in Mortandad Canyon are due to effluents from a liquid-waste treatment plant. No run-off or sediment transport has occurred beyond the Laboratory boundary in Mortandad Canyon since effluent release into the canyon started. However, some radioactivity in sediments in Pueblo Canyon (from pre-1964 effluents) and Los Alamos Canyon (from post-1952 treated effluents) has been transported to the Rio Grande. Theoretical estimates, confirmed by measurements, show that the incremental effect on Rio Grande sediments is a small percentage of the background concentrations attributable to worldwide fallout in soils and sediments.

Surface run-off has transported some low-level contamination from the active waste disposal area and several of the inactive areas into controlled-access canyons. Analyses for extraction procedure toxic metals from surface sediments indicate that no constituents in excess of EPA criteria for determining hazardous waste are present in these canyons.

F. Foodstuffs Monitoring

Most fruit, vegetable, fish, bee, and honey samples from regional and perimeter locations showed no radioactivity distinguishable from that attributable to natural sources or worldwide fallout. Some produce samples from on-site locations had slightly elevated tritium concentrations at levels <1% of DOE's guides for tritium in water (there are no concentration guides for produce).

G. Unplanned Releases

1. Airborne Radionuclide Releases. Four unplanned releases occurred during 1989. Three of these involved the release of tritium from technical area (TA)-41. The fourth was a release of fission products from TA-48. In all cases, the resulting radiation dose to a member of the public was estimated to be less than 0.1% of DOE's RPS. None of these releases exceeded EPA's thresholds for reportable quantities of radionuclides.

On May 31, 1989, 1000 Ci of tritium were released from TA-41. The release was in the form of elemental tritium gas, and 1% was assumed to be subsequently oxidized to tritiated water (Brown 1990). Potential doses were calculated using an atmospheric dispersion model that included wind speed and direction characteristics at the time of the release. The maximum effective dose equivalent from the release is calculated to be 0.02 mrem, which is 0.02% of DOE's RPS of 100-mrem/yr effective dose equivalent from all pathways. The maximum whole-body dose is also 0.02 mrem, which is 0.08% of the EPA's radiation limit of 25 mrem/yr to the whole body from the air pathway.

On June 2, 1989, an additional 400 Ci of tritium gas were released from TA-41. Potential radiation doses resulting from the release were calculated in the same manner as discussed above, using the measured release rate, assuming 1% oxidation to tritiated water (Brown 1990) and taking into account local meteorological conditions. The maximum effective dose equivalent and whole-body dose were calculated to be less than 0.01 mrem, which is less than 0.01% of DOE's RPS of 100-mrem/yr effective dose equivalent from all pathways and less than 0.04% of the EPA's radiation limit of 25 mrem/yr to the whole body from the air pathway.

From October 20, 1989, to November 9, 1989, approximately 0.4 Ci of mixed fission products was released from a stack at TA-48. The radioisotopes ^{68}Ga and ^{68}Ge accounted for more than 92% of the release. Air samplers were placed downwind to measure any impact from the release. Potential doses were estimated using the sample results and atmospheric dispersion calculations. Both the effective dose equivalent and the whole-body dose from the release were calculated to be less than 0.01 mrem, or less than 0.01% of DOE's RPS of 100 mrem/yr (effective dose equivalent) from all pathways and 0.04% of EPA's radiation limit of 25 mrem/yr (whole body) from the air pathway.

On December 7, 1200 Ci of elemental tritium gas were released from TA-41. In this release, 1% of the tritium was assumed to be subsequently oxidized to tritiated water. Potential radiation doses resulting from this release were calculated using an atmospheric dispersion model with wind speed, wind direction, and stability class at the time of the release. The effective dose equivalent and the whole-body dose were both calculated to be less than 0.01 mrem, which is less than 0.01% of the DOE RPS of 100 mrem/yr (effective dose equivalent) from all pathways and less than 0.04% of the EPA radiation limit of 25 mrem/yr (whole body) from the air pathway.

2. Liquid Spills. During 1989, three spill reports were transmitted to the New Mexico Environmental Improvement Division (NMEID) regarding nonradioactive liquid spills. A report was submitted in February regarding improvements designed to prevent the accidental discharge of dielectric oil containing parts-per-billion levels of organic solvent at TA-35, buildings 125 and 85. Spills from previous years were cleaned up and closure plans were submitted to NMEID for remediation of the sites. On March 13, a spill report was submitted to NMEID regarding about 1900 L (500 gal.) of raw sewage discharge from a damaged sanitary lift station, a water line rupture at the pesticide storage building, and a small hydraulic oil spill from a compressor storage tank. On December 9, the spillage of approximately 90 L (20 gal.) of automatic transmission fluid was reported to NMEID. Each spill report detailed an account of the spill and the specific actions taken to clean it up. The spills reported in February and March were inspected by NMEID staff, and all of the spill reports issued in 1989 were reviewed and approved by NMEID. All spills in 1989 were contained within Laboratory boundaries.

H. Environmental Compliance Activities

1. Resource Conservation and Recovery Act (RCRA). This act regulates hazardous wastes, from generation to ultimate disposal. The EPA has given full authority for administering RCRA (with the exception of the Hazardous and Solid Waste Amendments [HSWA] of 1984) to the NMEID. In 1989, the Laboratory had numerous interactions with NMEID and prepared the necessary documentation to comply with RCRA requirements. NMEID conducted one compliance inspection during 1989 and issued one Notice of Violation. The draft hazardous waste permit went to public hearing in July 1989, and the permit was issued on November 8, 1989. The Laboratory and DOE, through the Department of Justice, appealed one provision of the permit. Results are pending. The HSWA portion of the permit was written by EPA and went to public hearing in August. The HSWA permit was issued on March 8, 1990. After the state receives authorization from EPA for regulating mixed waste, a permit modification will be requested.

2. Clean Water Act. Regulations under the Clean Water Act set water quality standards and effluent limitations. The two primary programs at the Laboratory established to comply with the Clean Water Act are the National Pollutant Discharge Elimination System (NPDES) and the Spill Prevention Control and Countermeasure (SPCC) program.

The NPDES requires permits for nonradioactive constituents at all point-source discharges. A single NPDES permit for the Laboratory authorizes effluent discharges from 102 industrial outfalls and 10 sanitary sewage treatment outfalls; the permit expires in March 1991. The Laboratory was in compliance with the NPDES permit in about 98.2% and 99.8%, respectively, of the analyses done on samples collected for monitoring compliance at sanitary and industrial waste discharges. Chronically noncompliant discharges are being addressed under an EPA/DOE Federal Facility Compliance Agreement. In addition, NPDES corrective activities are listed in DOE's "Environmental Restoration and Waste Management Five-Year Plan" (DOE 1989).

Another NPDES permit authorizes liquid effluent discharge from the Fenton Hill Geothermal Project. The permit is for a single outfall and was issued to regulate the discharge of mineral-laden water from the recycle loop of the geothermal wells. No discharges occurred from this outfall in 1989.

The Laboratory has an SPCC Plan, as required by the Code of Federal Regulations (40 CFR 112). The plan is implemented by providing secondary containment for large tanks and other containers to control accidental spills and prevent them from entering a watercourse. The plan also provides for spill control training and cleanup. During 1989, major secondary containment construction was done at 11 sites.

3. National Environmental Policy Act (NEPA). This act requires that environmental impacts be considered during the planning of major federal actions. At the Laboratory, plans for new construction projects receive a comprehensive review for general environmental, safety, and health concerns. Each project that may adversely affect the environment is described briefly in an Action Description Memorandum (ADM) that is prepared by the Health, Environment, and Safety (HSE)-Division staff and submitted to DOE. The DOE (Albuquerque Operations Office or Headquarters) determines the level of NEPA documentation appropriate to each project.

During 1989, more than 300 proposed projects were reviewed to determine potential environmental impacts. Of these, 53 were identified as requiring ADMs.

4. Federal Clean Air Act and New Mexico Air Quality Control Act. Regulations under these acts set ambient air quality standards, require the permitting of new sources, and set acceptable emission limits. The air quality and meteorological program at the Laboratory includes monitoring to ensure that ambient air quality standards are met, reviewing of all new and modified sources to determine whether air permits are required, and air modeling support for permit applications and other programs. During 1989, all of the Laboratory's existing operations remained in compliance with all federal and state air quality regulations:

- Monitoring showed no violations of ambient air quality standards.
- All construction projects at the Laboratory were reviewed and air emissions were estimated to determine whether air permits were required.
- Air quality impacts were modeled for Environmental Assessments, Safety Analysis Reports, air quality permit applications, and unplanned releases.

5. Safe Drinking Water Act (SDWA). Municipal and industrial water supply for the Laboratory and community is from 16 deep wells and 1 gallery (collection system fed by springs). The wells range in depth from 265 to 942 m (869 to 3090 ft). In 1989, the chemical quality of the water met federal and state Primary and Secondary Drinking Water Standards (NMEIB 1988, EPA 1989).

6. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This act requires registration of all pesticides, restricts use of certain pesticides, recommends standards for pesticide applicators, and regulates disposal and transportation of pesticides. The Laboratory stores, uses, and discards pesticides in compliance with this act.

7. National Historic Preservation Act. As required by Sec. 106 of the National Historic Preservation Act of 1966, which was implemented by 36 CFR 800, Laboratory undertakings are evaluated in consultation with the State Historic Preservation Officer (SHPO) for possible effects on historic resources. During 1989, Laboratory archaeologists evaluated 462 undertakings, conducted 42 field surveys, recorded 14 new archaeological sites, and submitted 15 survey reports and 2 mitigation plans for SHPO review. As a result of Laboratory activities, one project was monitored and one site was test excavated.

8. Endangered/Threatened/Protected Species and Floodplains/Wetlands Protection. The DOE and Laboratory must comply with the Endangered Species Act of 1973, as amended, and with Executive Orders 11988, "Floodplain Management," and 11990, "Protection of Wetlands." Compliance under NEPA requires review of projects for potential environmental impact on critical habitats, floodplains, and wetlands. Laboratory activities during 1989 to comply with these requirements were in three categories: (1) 12 endangered species surveys were completed; (2) bird censuses were continued and sensitive habitats were monitored to provide base line monitoring of sensitive or potentially sensitive species; and (3) 1 construction site was monitored to prevent habitat destruction of a sensitive raptor species.

9. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA of 1980 mandated cleanup of toxic and hazardous contaminants at closed and abandoned hazardous waste sites. The Superfund Amendments and Reauthorization Act (SARA) of 1986 extensively amended CERCLA. Investigations and any required remedial actions at Los Alamos will be carried out as part of DOE's Environmental Restoration Program, which requires evaluation of all areas at the Laboratory for possible contamination.

10. Toxic Substances Control Act (TSCA). This act regulates the manufacture, processing, distribution, use, storage, and labeling of chemical substances, including polychlorinated biphenyls (PCBs). The Laboratory has EPA authorization to dispose of PCBs at its radioactive waste landfill (Area G), and some contaminated soil has been disposed of there. However, most PCB-containing or -contaminated materials have been sent off site to EPA-approved disposal facilities.

11. Emergency Planning and Community Right-to-Know Act. Requirements for reporting toxic chemical releases under SARA, Title III Sec. 313 of 1986, became effective in March 1988. The basic purpose of this regulation is to make available to the public environmental information about releases of certain toxic chemicals that are used in operations at facilities covered under this regulation. Reports must be submitted annually to the EPA and to the state in which the facility is located. This rule is in addition to other reporting requirements under SARA Title III, which went into effect in May 1987.

For the 1988 reporting period, approximately 385 kg (850 lb) of nitric acid were reported as airborne releases from stacks. All remaining amounts of nitric acid were either consumed in chemical reactions or were completely neutralized by sodium hydroxide in waste-water treatment operations and thus were not reportable. Reporting of sodium hydroxide is required. However, no environmental releases for this compound were reported because all sodium hydroxide at the Laboratory is completely neutralized in reactions with nitric, sulfuric, or hydrochloric acids during waste-water treatment operations.

The dramatic reduction in reported nitric acid releases to the environment from calendar years 1987 to 1988 was not due to any major change in process or chemical use but rather to more-accurate data. A detailed Laboratory-wide air emissions study was made in 1988, which consisted of a room-by-room chemical-use inventory and selective testing of air emissions from stacks. As a result, air emissions were more accurately estimated.

12. Underground Storage Tanks. The majority of underground storage tanks at the Laboratory were installed in the 1940s. In 1989, two of these were removed. Further investigation after removal of the tanks revealed that neither tank had ever leaked. Laboratory policy is to remove underground storage tanks when user groups determine that the tanks are no longer needed. The tanks will be removed as funding permits.

II. INTRODUCTION TO THE LOS ALAMOS AREA

A. Geographic Setting

Los Alamos National Laboratory and the associated residential areas of Los Alamos and White Rock are located in Los Alamos County, north-central New Mexico, approximately 100 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe (Fig. 1). The 111-km^2 (43-mi^2) Laboratory site and adjacent communities are situated on Pajarito Plateau, which consists of a series of fingerlike mesas separated by deep east-to-west oriented canyons cut by intermittent streams (Fig. 3). Mesa tops range in elevation from approximately 2400 m (7800 ft) on the flank of the Jemez Mountains to about 1900 m (6200 ft) at their eastern termination above the Rio Grande Valley.

All Los Alamos County and vicinity locations referenced in this report are identified by the Laboratory Cartesian coordinate system, which is based on U.S. customary units of measurement. This system is standard throughout the Laboratory, but is independent of the U.S. Geological Survey and the New Mexico State Survey coordinate systems. The major coordinate markers shown on the maps are at 3-km (10 000-ft) intervals. For the purpose of this report, locations are reported to the nearest 0.03 km (100 ft).

The DOE controls the area within Laboratory boundaries and has the option to completely restrict access.

B. Land Use

Most Laboratory and community developments are confined to mesa tops (see the inside front cover). The surrounding land is largely undeveloped, with large tracts of land north, west, and south of the Laboratory site being held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, General Services Administration, and Los Alamos County (see the inside back cover). The San Ildefonso Pueblo borders the Laboratory to the east.

Laboratory land is used for building sites, experimental areas, waste disposal locations, roads, and utility rights-of-way (see Laboratory technical areas, Fig. 4 and

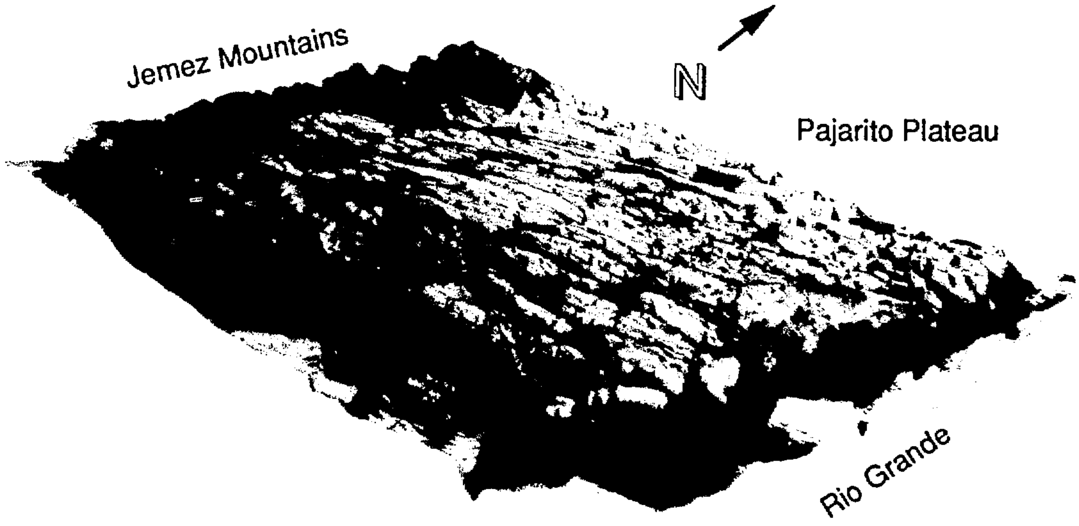

Fig. 3. Topography of the Los Alamos area.

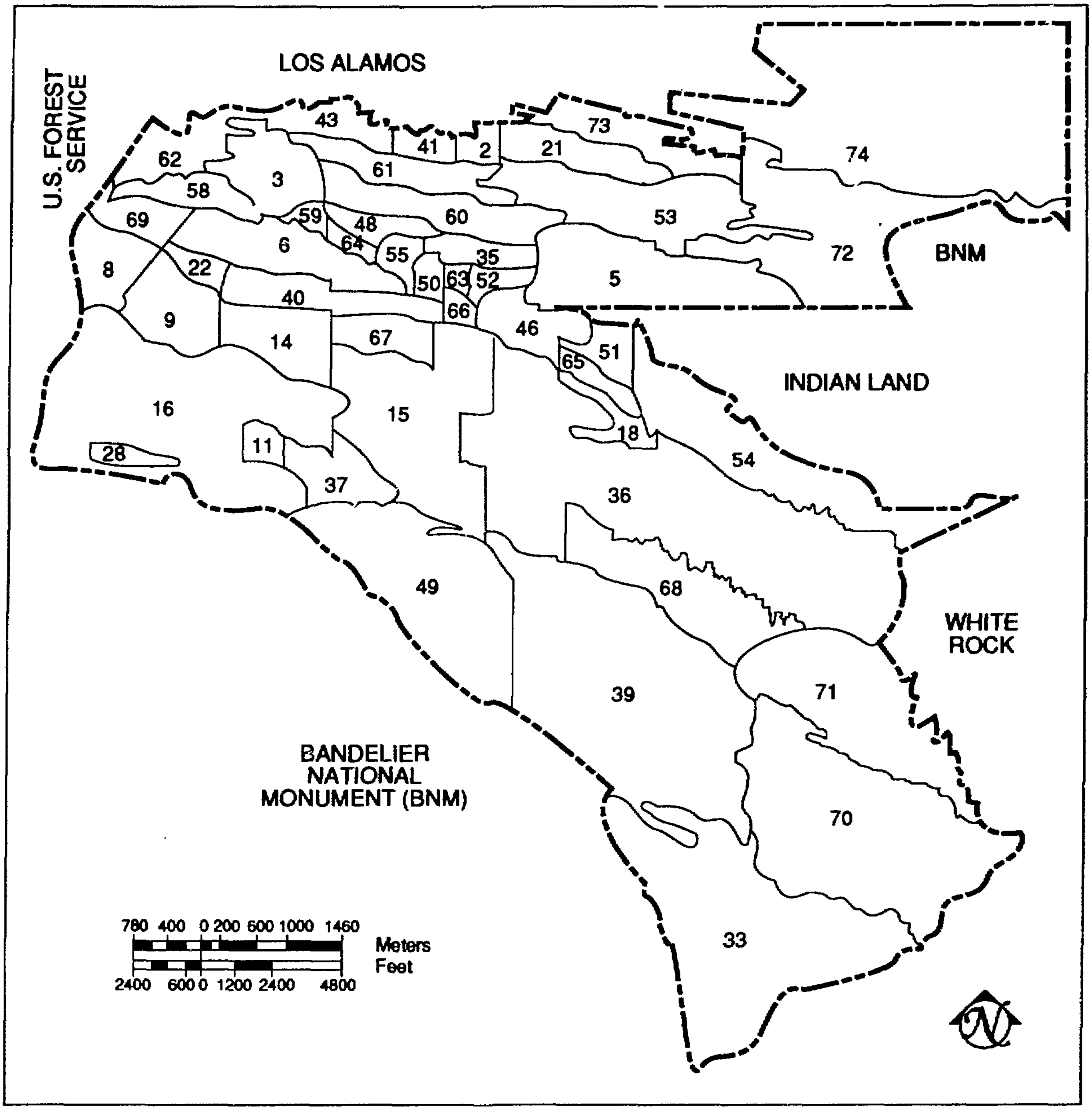

Fig. 4. Technical areas (TAs) of Los Alamos National Laboratory in relation to surrounding landholdings.

Appendix F). However, these uses account for only a small part of the total land area. Most land provides isolation for security and safety and is a reserve for future structure locations. The Laboratory's Long-Range Site-Development Plan (Engineering 1990) assures adequate planning for the best possible future uses of available Laboratory lands.

Limited access by the public is allowed in certain areas of the Laboratory reservation. An area north of Ancho Canyon between the Rio Grande and State Road 4 is open to hikers, rafters, and hunters, but woodcutting and vehicles are prohibited. Portions of Mortandad and Pueblo canyons are also open to the public. An archaeological site (Otowi Tract), northwest of State Road 502 near the White Rock Y, is open to the public subject to restrictions of cultural resource protection regulations.

C. Geology-Hydrology

Most of the fingerlike mesas in the Laboratory area are found in Bandelier Tuff (Fig. 5). Ash fall, ash fall pumice, and rhyolite tuff form the surface of Pajarito Plateau. The tuff, ranging from nonwelded to welded, is over 300 m (1000 ft) thick in the western part of the plateau and thins to about 80 m (260 ft) eastward above the Rio Grande. It was deposited as a result of a major eruption of a volcano in the Jemez Mountains about 1.1 to 1.4 million years ago.

The tuffs overlap onto the Tschicoma Formation, which consists of older volcanics that form the Jemez Mountains. The tuff is underlain by the conglomerate of the Puye Formation (Fig. 5) in the central and eastern edge along the Rio Grande. Chino Mesa basalts (Fig. 5) interfinger with the conglomerate along the river. These formations overlay the sediments of the Tesuque Formation (Fig. 5), which extends across the Rio Grande Valley and is in excess of 1000 m (3300 ft) thick.

Los Alamos area surface water occurs primarily as intermittent streams. Springs on the flanks of the Jemez Mountains supply base flow into upper reaches of some canyons, but the amount is insufficient to maintain surface flows across the Laboratory site before it is depleted by evaporation, transpiration, and infiltration. Run-off from heavy thunderstorms or heavy snowmelt reaches the Rio Grande several times a year in some drainages. Effluents from sanitary sewage, industrial waste treatment plants, and cooling-tower blowdown are released into some canyons at rates sufficient to maintain surface flows for varying distances.

Ground water occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in canyons, (2) perched water (a ground-water body above an impermeable layer that separates it from the underlying main body of ground

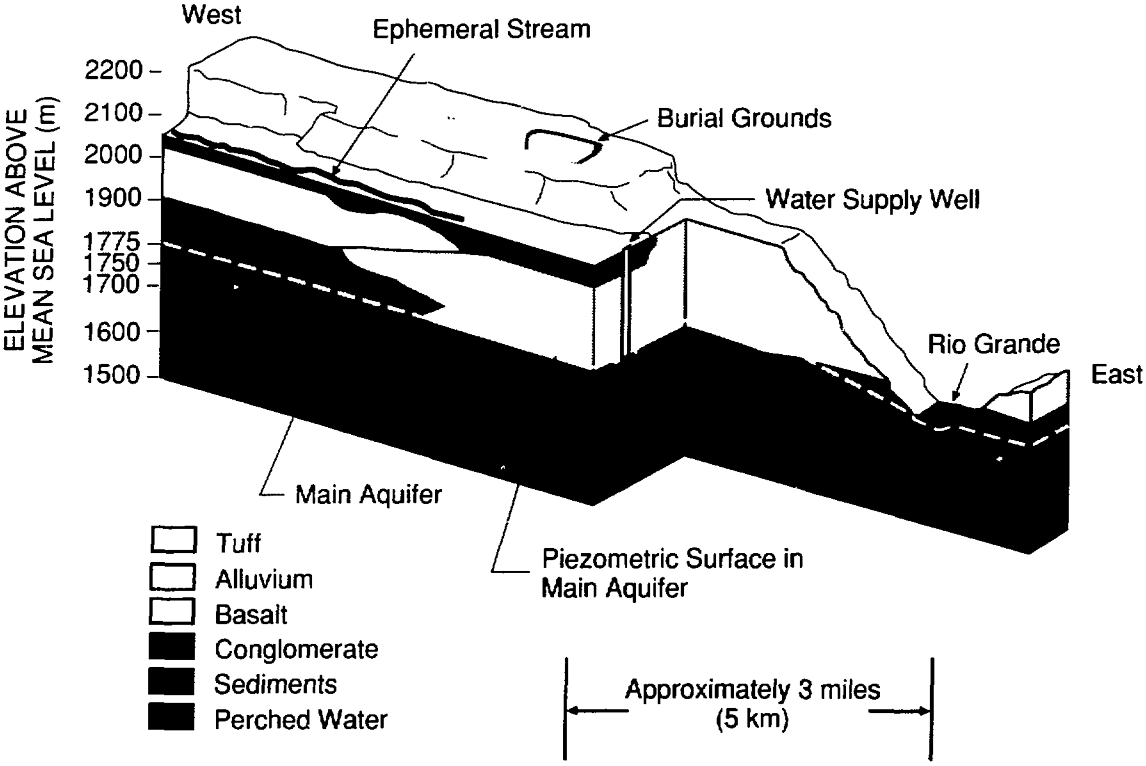

Fig. 5. Conceptual illustration of geologic-hydrologic relationships in the Los Alamos area.

water by an unsaturated zone), and (3) the main aquifer of the Los Alamos area (Fig. 5).

Intermittent stream flows in canyons of the plateau have deposited alluvium that ranges from less than 1 m (3 ft) to as much as 30 m (100 ft) in thickness. The alluvium is permeable, in contrast to the underlying volcanic tuff and sediments. Intermittent run-off in canyons infiltrates the alluvium until its downward movement is impeded by the less permeable tuff and volcanic sediment. This results in a shallow alluvial ground-water body that moves down gradient within the alluvium. As water in the alluvium moves down gradient, it is depleted by evapotranspiration and movement into underlying volcanics (Purtymun 1977).

Perched water occurs in conglomerate and basalts beneath the alluvium in a limited area about 37 m (120 ft) deep in the midreach of Pueblo Canyon and in a second area about 45 to 60 m (150 to 200 ft) beneath the surface in lower Pueblo and Los Alamos canyons near their confluence. The second area is mainly in basalts (Fig. 5) and has one discharge point at Basalt Spring in Los Alamos Canyon.

The main aquifer of the Los Alamos area is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the plateau. Depth of the aquifer decreases from 360 m (1200 ft) along the western margin of the plateau to about 180 m (600 ft) at the eastern margin. The main aquifer is isolated from alluvial and perched waters by about 110 to 190 m (350 to 620 ft) of dry tuff and volcanic sediments. Thus, there is little hydrologic connection or potential for recharge to the main aquifer from alluvial or perched water.

Water in the main aquifer is under water-table conditions in the western and central part of the plateau and under artesian conditions in the eastern part and along the Rio Grande (Purtymun 1974b). Major recharge to the main aquifer is from the intermountain basin of the Valles Caldera in the Jemez Mountains west of Los Alamos. The water table in the caldera is near land surface. The underlying lake sediment and volcanics are highly permeable and contribute to the recharge of the aquifer through the Tschicoma Formation interflow breccias (rock consisting of sharp fragments embedded in a fine-grained matrix) and the Tesuque Formation. The Rio Grande receives ground-water discharge from springs fed by the main aquifer. The 18.5-km (11.5-mi) reach of the river in White Rock Canyon between Otowi Bridge and the mouth of Rito de Frijoles receives an estimated 5.3 to 6.8×10^6 m^3 (4300 to 5500 acre-ft) annually from the aquifer.

D. Climatology

Los Alamos has a semiarid, temperate mountain climate. Average annual precipitation is nearly 45 cm (18 in.). Precipitation was slightly below normal during 1989, totaling 41 cm (16.2 in.). The year 1989 had the least yearly precipitation since 1980 and was the first year with below-normal precipitation since 1983. Precipitation was especially light during April, November, and December. Forty per cent of the annual precipitation normally occurs during July and August from thundershowers. Winter precipitation falls primarily as snow, with accumulations of about 130 cm (51 in.) annually. Snowfall was near normal during 1989.

Summers are generally sunny with moderate, warm days and cool nights. Maximum daily temperatures are usually below 32°C (90°F). The temperature reached or exceeded 32°C (90°F) nine times during the summer of 1989, second only to 1980 when there were 22 days of ≥32°C (≥90°F) temperatures. Brief afternoon and evening thundershowers are common, especially in July and August. High altitude, light winds, clear skies, and dry atmosphere allow night temperatures to drop below 15°C (59°F) after even the warmest day. Winter temperatures typically range from about −9°C to −4°C (15°F to 25°F) during the night and from −1°C to 10°C (30°F to 50°F) during the day. Occasionally, temperatures drop to −18°C (0°F) or below. Many winter days are clear with light winds, so strong sunshine can make conditions comfortable even when air temperatures are cold. In 1989, abnormally warm weather in March, April, and May gave Los Alamos its warmest spring on record.

Snowstorms with accumulations exceeding 10 cm (4 in.) are common in Los Alamos. Some storms can be associated with strong winds, frigid air, and dangerous wind chills. A snowstorm closed the Laboratory and county businesses and schools on January 27 when 29.2 cm (11.5 in.) of snow fell. The year's largest storm struck February 4–6, when 38.1 cm (15.0 in.) of snow fell, accompanied by cold arctic air. Temperatures dipped to between −15°C and −20°C (5°F and −4°F) during the 5th and 6th before the storm ended.

Because of complex terrain, surface winds in Los Alamos often vary greatly with time of day and location. With light, large-scale winds and clear skies, a distinct daily wind cycle often exists: a light southeasterly to southerly upslope wind during the day and a light westerly to northwesterly drainage wind during the night. However, several miles to the east toward the edge of Pajarito Plateau near the Rio Grande Valley, a different daily wind cycle is common: a moderate southwesterly up-valley wind during the day and either a light northwesterly to northerly drainage wind or moderate southwesterly wind at night. On the whole, the predominant winds are southerly to northwesterly over western Los Alamos County and southwesterly and northeasterly toward the Rio Grande Valley. The year 1989 followed normal patterns in wind.

Historically, no tornadoes have been reported to have touched down in Los Alamos County. Strong dust devils can produce winds up to 34 m/s (75 mph) at isolated spots in the county, especially at lower elevations. A dust devil struck the Royal Crest Trailer Court on April 20, lifting and damaging a boat. Strong winds with gusts exceeding 27 m/s (60 mph) are common and widespread during the spring. Thunderstorms produced peak wind gusts of 34 m/s (76 mph) at East Gate and Area G on April 9 and 27.

Lightning is common over Pajarito Plateau. There are 58 thunderstorm days during an average year, with most occurring during the summer. There were, in fact, 58 thunderstorm days reported during 1989. Lightning protection is an important design factor for most facilities at the Laboratory. Hail damage can also occur. Hailstones with diameters up to 0.64 cm (0.25 in.) are common; 1.3-cm (0.5-in.)-diameter hailstones are rare. A hailstorm on May 9 dropped large hail on White Rock, causing traffic accidents and some damage to roofs and cars. Also, up to 5 cm (2 in.) of hail accumulated in North Community.

The irregular terrain at Los Alamos affects the atmospheric turbulence and dispersion, sometimes favorably and sometimes unfavorably. Enhanced dispersion promotes greater dilution of contaminants released into the atmosphere. The complex terrain and forests create an aerodynamically rough surface, forcing increased horizontal and vertical dispersion. Dispersion generally decreases at lower elevations where the terrain becomes smoother and less vegetated. The frequent clear skies and light, large-scale winds cause good vertical, daytime dispersion, especially during the warm season. Strong daytime heating during the summer can force vertical mixing up to 1–2 km (3000–6000 ft) above ground level (AGL), but the generally light winds are limited in diluting contaminants horizontally.

Clear skies and light winds have a negative effect on nighttime dispersion, causing strong, shallow surface inversions to form. These inversions can severely restrict near-surface vertical and horizontal dispersion. Inversions are especially strong during the winter. Shallow drainage winds can fill lower areas with cold air, thereby creating deeper inversions, common toward the valley (White Rock) on clear nights with light winds. Canyons can also limit dispersion by channeling air flow. Strong, large-scale inversions during the winter can limit vertical mixing to under 1 km (3000 ft) AGL.

Dispersion is generally greatest during the spring when winds are strongest. However, deep vertical mixing is greatest during the summer. Low-level dispersion is generally the least during summer and autumn when winds are light. Even though low-level, winter dispersion is generally greater, intense surface inversions can cause least-dispersive conditions during the night and early morning.

The frequencies of atmospheric dispersive capability are 52% unstable (stability classes *A–C*), 21% neutral (*D*), and 27% stable (*E–F*) during the winter at TA-59. The frequencies are 44%, 22%, and 34%, respectively, during the summer. These stability category frequencies are based on measured vertical wind variations. Stability generally increases (becomes less dispersive) toward the valley.

E. Population Distribution

Los Alamos County has an estimated 1989 population of approximately 19 300 (based on the 1980 census, adjusted for 1989). Two residential and related commercial areas exist in the county (Fig. 1). The Los Alamos townsite (the original area of development, now including residential areas known as Eastern Area, Western Area, North Community, Barranca Mesa, and North Mesa) has an estimated population of 12 100. The White Rock area (including the residential areas of White Rock, La Senda, and Pajarito Acres) has about 7200 residents. About one-third of the people employed in Los Alamos commute from other counties. Population estimates for 1989 place about 208 000 persons within an 80-km (50-mi) radius of Los Alamos (Table 4).

F. Programs at Los Alamos National Laboratory

The Laboratory is administered by the University of California for the DOE. The Laboratory's environmental program, conducted by the Environmental Protection Group, is part of a continuing investigation and documentation program.

Since its inception in 1943, the Laboratory's primary mission has been nuclear weapons research and development. Programs include weapons development, magnetic and inertial fusion, nuclear fission, nuclear safeguards and security, and laser isotope separation. There is also basic research in the areas of physics, chemistry, and engineering that supports such programs. Research on peaceful uses of nuclear energy has included space applications, power reactor programs, radiobiology, and medicine. Major research programs in elementary particle physics are carried out at the Laboratory's linear proton accelerator. Other programs include applied photochemistry, astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, computer sciences, solar energy, geothermal energy, biomedical and environmental research, and nuclear waste management research. Appendix F summarizes activities at the Laboratory's 32 active technical areas (TAs).

In August 1977, the Laboratory site, encompassing 111 km^2 (43 mi^2), was dedicated as a National Environmental Research Park. The ultimate goal of programs

Table 4. 1989 Population within 80 km of Los Alamos[a,b]

	Distance from TA-53 (km)								
Direction	**1–2**	**2–4**	**4–8**	**8–15**	**15–20**	**20–30**	**30–40**	**40–60**	**60–80**
N	1	0	0	0	0	0	1 090	0	352
NNE	0	0	0	541	0	518	1 660	1 720	211
NE	1	0	0	0	303	14 700	966	1 080	3 650
ENE	0	0	0	1 860	1 500	2 610	2 610	1 140	2 140
E	0	0	80	24	534	1 100	668	0	1 390
ESE	0	0	0	0	0	281	22 230	1 040	1 450
SE	0	0	7 190	0	0	0	51 400	2 350	8
SSE	0	0	0	0	0	0	409	4 180	91
S	0	0	0	50	0	315	607	6 680	0
SSW	0	0	0	20	0	808	199	8 150	33 110
SW	0	0	0	0	0	0	311	4 110	0
WSW	0	0	0	0	0	311	309	2 520	204
W	0	0	0	0	0	0	0	162	131
WNW	0	1 530	6 950	0	0	0	0	0	3 050
NW	0	557	1 830	0	0	0	0	1 380	0
NNW	0	615	616	0	0	0	0	61	60

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[a] This distribution represents the resident, non-work-force population with respect to the Los Alamos Meson Physics Facility's stack (LAMPF, TA-53). A slightly different distribution for Los Alamos County townsites was used to model releases from the TA-2 stack, which is closer to Los Alamos.

[b] Total population within 80 km of Los Alamos is 208 000.

associated with this regional facility is to encourage environmental research that will contribute understanding of how people can best live in balance with nature while enjoying the benefits of technology. Park resources are available to individuals and organizations outside of the Laboratory to facilitate self-supported research on these subjects deemed compatible with the Laboratory programmatic mission (DOE 1979).

A final Environmental Impact Statement (DOE 1979) that assesses potential cumulative environmental impacts associated with current, known future, and continuing activities at the Laboratory was completed in 1979. The report provides environmental input for decisions regarding continuing activities at the Laboratory. It also provides more detailed information on the environment of the Los Alamos area.

III. RADIATION DOSES

Some incremental radiation doses (above those received from natural background, resuspended fallout, and medical and dental diagnostic procedures) are received by Los Alamos County residents as a result of Laboratory operations. The largest estimated effective dose equivalent to a member of the public was about 4 mrem from all pathways, which is 4% of the DOE's Radiation Protection Standard of 100 mrem/yr (all pathways). This dose is principally due to airborne emissions from the linear particle accelerator at the Los Alamos Meson Physics Facility.

No significant exposure pathways are believed to exist for radioactivity released in treated liquid-waste discharges. Most released radionuclides are retained in alluvial sediments within Laboratory boundaries. A small fraction is transported off site in stream-channel sediments during heavy run-off. Radionuclide concentrations in these sediments, however, are only slightly above background levels. Other minor pathways include direct radiation and ingestion of foodstuffs.

The collective effective dose equivalent attributable to Laboratory operations received by the population living within 80 km (50 mi) of the Laboratory was conservatively estimated to be 3.1 person-rem during 1989. This is <0.01% of the 65 000 person-rem collective effective dose equivalent received by the same population from natural radiation sources and 0.03% of the 11 000 person-rem collective effective dose equivalent received from diagnostic medical procedures. Nearly 90% of the dose contributed by Laboratory operations, 2.7 person-rem, was received by persons living in Los Alamos County. This dose is 0.04% of the 6300 person-rem received by the population of Los Alamos County from background radiation and 0.3% of the 1000 person-rem from diagnostic medical and dental procedures.

In 1989, the average added risk of cancer mortality to Los Alamos townsite residents was 1 chance in 15 000 000 from radiation released by this year's Laboratory operations; this is much less than the 1 chance in 8000 from background radiation. The EPA has estimated average lifetime risk for overall cancer incidence as 1 chance in 4; for cancer mortality, 1 chance in 5.

To evaluate compliance with EPA's regulation 40 CFR Part 61, Subpart H, the maximum doses from airborne emissions from 1989 Laboratory operations were calculated by the computer modeling program AIRDOS-EPA/RADRISK. The maximum individual whole-body and organ doses were 11 mrem (whole body) and 14 mrem (testes). These doses were 44% and 18%, respectively, of EPA's radiation limit of 25 mrem/yr (whole body) and 75 mrem/yr (any organ) from the air pathway. The whole-body dose is slightly higher than the maximum effective dose equivalent cited above because exposure was modeled rather than based on thermoluminescent dosimeter measurements taken in the area of maximum exposure. AIRDOS-EPA tends to overestimate radiation doses in the complex terrain around Los Alamos because it does not take into account dilution of airborne radionuclides by terrain-induced turbulence.

A. Background

The impact of environmental releases of radioactivity is evaluated by estimating doses received by the public from exposure to these releases. These doses are then compared with applicable standards and with doses from background radiation and medical and dental radiation.

The DOE's Radiation Protection Standard (RPS) limits the effective dose equivalent for a member of the public to 100 mrem/yr for all pathways of exposure (DOE 1985, 1990). The effective dose equivalent is the hypothetical whole-body dose that carries the same risk of cancer or genetic disorders as a given dose to a particular organ (see Glossary). Using this dose, which was introduced by the International Commission on Radiological Protection (ICRP 1977), allows direct comparison of exposures to different organs.

In accordance with EPA regulations (40 CFR 61) governing radiation doses from the air pathway to members of the public, whole-body doses are limited to 25 mrem/yr and individual organ doses are limited to 75 mrem/yr. The principal pathway of exposure at Los Alamos has been through release of radionuclides into the air, resulting in external radiation doses to the whole body. Other pathways contribute finite but negligible doses. A detailed discussion of standards is presented in Appendix A.

The exposure pathways considered for the Los Alamos area are atmospheric transport of airborne radioactive emissions, hydrologic transport of treated liquid effluents, food chains, and direct exposure to external penetrating radiation. Exposure to radioactive materials or radiation in the environment was determined by direct measurements of airborne and waterborne contaminants, of contaminants in foodstuffs, and of external penetrating radiation. Theoretical dose calculations based on atmospheric dispersion modeling were made for other airborne emissions present at levels too low to measure.

Doses were calculated from measured or derived exposures using models based on the recommendations of the ICRP (Appendix D). These doses are summarized in Table 5 for the most important exposure categories:

1. *Maximum Boundary Dose, or "Fence-Post" Dose Rate.* This is the estimated maximum dose to a hypothetical individual present at the point on the Laboratory boundary where the highest dose rate occurs. This dose does not take into account shielding or occupancy and does not mean that an individual actually receives this dose.
2. *Maximum Individual Dose.* This is the estimated maximum dose to an individual actually residing in the off-site location where the highest dose rate occurs. It includes corrections for shielding (for example, for being inside a building) and occupancy (the fraction of the year that the person is in the area).
3. *Average Dose.* This is the estimated average dose to residents of Los Alamos and White Rock.
4. *Collective Effective Dose Equivalent.* This is an estimate of the total effective dose (in person-rem) received by the population within an 80-km (50-mi) radius of the Laboratory.

The maximum boundary dose and the maximum individual dose over the past 10 years are summarized in Fig. 2. Each year, more than 95% of the dose resulted from airborne emissions of activation products from the Los Alamos Meson Physics Facility (LAMPF).

All internal radiation doses (through inhalation or ingestion) are 50-year dose commitments (Appendix D). This is the total dose received from intake of a radionuclide for 50 years following intake.

In addition to compliance with dose standards, which define an upper limit for doses to the public, there is a concurrent commitment to limit radiation exposure to individuals and population groups to levels as low as reasonably achievable (ALARA). This policy is followed at the Laboratory by applying strict controls on airborne emissions, liquid effluents, and operations, not only to minimize doses to the public but also to limit releases of radioactive materials to the environment. Ambient monitoring described in this report documents the effectiveness of these controls.

B. Estimate of Radiation Doses

1. Total Maximum Individual Dose to a Member of the Public from 1989 Laboratory Operations. The maximum individual effective dose equivalent to a member of the public from 1989 Laboratory operations is estimated to be 3.9 mrem/yr. This is the total effective dose equivalent from all pathways. This dose is 3.9% of the DOE's RPS of 100 mrem/yr effective dose equivalent from all pathways.

The dose occurred at East Gate (the Laboratory boundary northeast of LAMPF) and was primarily due to external penetrating radiation from air activation products released by the LAMPF accelerator. The dose is based on

Table 5. Summary of Annual Effective Dose Equivalents Attributable to 1989 Laboratory Operations

	Maximum Dose at Laboratory Boundary[a]	Maximum Dose to an Individual[b]	Average Dose to Nearby Residents		Collective Dose to Population within 80 km of the Laboratory
			Los Alamos	White Rock	
Dose	8 ± 3 mrem	3.9 mrem	0.15 mrem	0.14 mrem	3.1 person-rem
Location	Boundary north of TA-53	Residence north of TA-53	Los Alamos	White Rock	Area within 80 km of Laboratory
DOE Radiation Protection Standard	—	100 mrem	100 mrem	100 mrem	—
Percentage of Radiation Protection Standard	—	3.9%	0.2%	0.1%	—
Background	327 mrem	327 mrem	327 mrem	327 mrem	65 000 person-rem
Percentage of background	2%	1%	0.05%	0.04%	0.005%

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[a] Maximum boundary dose is the dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs, with no correction for shielding. It assumes that the individual is at the Laboratory boundary continuously (24 hours/day, 365 days/year).

[b] Maximum individual dose is the dose to an individual at or outside the Laboratory where the highest dose rate occurs and where there is a person, but where calculations take into account occupancy (the fraction of time a person is actually at that location), self-shielding, and shielding by buildings.

environmental measurement data discussed below. Table 6 summarizes the maximum individual effective dose equivalent and associated organ doses.

2. **Doses from Natural Background Radiation and Medical and Dental Radiation.** Effective dose equivalents from natural background and from medical and dental uses of radiation are estimated in order to provide a comparison with doses resulting from Laboratory operations. Doses from global fallout are only a small fraction of total background doses (<0.3%, NCRP 1987a) and are not considered further here. Exposure to natural background radiation results principally in whole-body doses and in localized doses to the lung and other organs. For convenience, these doses are divided into those resulting from exposure to radon and its decay products that mainly affect the lung and those from nonradon sources that mainly affect the whole body.

As in the environmental surveillance reports for 1987 and 1988 (ESG 1988, 1989), estimates of background radiation are based on a recent comprehensive report by the National Council on Radiation Protection and Measurements (NCRP 1987a). The 1987 NCRP report contains some minor differences from a 1975 NCRP report that had been used in previous environmental surveillance reports. These differences include using 20% (instead of 10%) shielding by structures for high-energy cosmic radiation and 30% (instead of 20%) self-shielding by the body for terrestrial radiation. The 1987 NCRP document also gives an effective dose equivalent for radon exposure. These changes were used to obtain estimates of background radiation based on the most current data. This has resulted in some small differences from the procedure used in surveillance reports before 1987 for determining background doses.

Whole-body external dose is incurred from exposure to cosmic rays and to external terrestrial radiation from naturally occurring radioactivity in the earth's surface and from global fallout. Effective dose equivalents from internal radiation are due to radionuclides deposited in the body through inhalation or ingestion.

Nonradon effective dose equivalents from background radiation vary each year depending on factors such as snow cover and the solar cycle (NCRP 1975b). Estimates of background from nonradon sources are based on measured external radiation background levels of 102 mrem (Los Alamos) and 106 mrem (White Rock) caused by irradiation from charged particles, x rays, and gamma rays. These uncorrected, measured doses were adjusted for shielding by reducing the cosmic-ray component (60 mrem at Los Alamos and 52 mrem at White Rock) by 20% to allow for shielding by structures and by reducing the terrestrial component (42 mrem at Los Alamos and 54 mrem at White Rock) by 30% to allow for self-shielding by the body (NCRP 1987a). To these estimates, based on measurements, were added 10 mrem at Los Alamos

Table 6. Maximum Individual Dose from Laboratory Operations during 1989

	Laboratory Operations (mrem/yr)	DOE Radiation Protection Standard (mrem/yr)	Percentage of Radiation Protection Standard
Effective Dose Equivalent	3.9	100	3.9
Organ			
Breast	4.2	5000	<0.1
Lung	3.4	5000	<0.1
Red marrow	3.5	5000	<0.1
Bone surface	4.1	5000	<0.1
Thyroid	4.2	5000	<0.1
Testes	4.5	5000	<0.1
Ovaries	3.0	5000	<0.1

and 8 mrem at White Rock from neutron cosmic radiation (20% shielding assumed) and 40 mrem from internal radiation (NCRP 1987a). The estimated whole-body dose from background, nonradon radiation is 127 mrem at both Los Alamos and White Rock.

In addition to these nonradon doses, a second component of background radiation is dose to the lung from inhalation of ^{222}Rn and its decay products. The ^{222}Rn is produced by decay of ^{226}Ra, a member of the uranium series, which is naturally present in construction materials in buildings and in the underlying soil. The effective dose equivalent from exposure to background ^{222}Rn and its decay products is taken to be 200 mrem/yr (NCRP 1987a). This background estimate may be revised if a nationwide study of background levels of ^{222}Rn and its decay products in homes is undertaken, as recommended by the NCRP (1984, 1987a).

The total effective dose equivalent to residents is 327 mrem/yr at Los Alamos and White Rock (Table 5), or 127 mrem/yr from nonradon sources and 200 mrem/yr from radon.

Medical and dental radiation in the United States accounts for an average effective dose equivalent, per person, of 53 mrem/yr (NCRP 1987a). This estimate includes doses from both x rays and radiopharmaceuticals.

3. Doses to Individuals from External Penetrating Radiation from Airborne Emissions. The thermoluminescent dosimeter (TLD) network at the Laboratory boundary north of LAMPF indicated an 8-mrem increment above cosmic and terrestrial background radiation during 1989 (Sec. IV). This increment is attributed to emission of air activation products from LAMPF. Based on estimates of 30% shielding inside buildings (NRC 1977, NCRP 1987a), 30% self-shielding (NCRP 1987a), and 100% occupancy, this 8-mrem increment translates to an estimated 3.9-mrem whole-body dose to an individual living along State Road 502, northeast of LAMPF (Table G-1). This location has been the area where the highest boundary and individual doses have been measured since dosimeter monitoring began. The 3.9 mrem is 16% of EPA's air emission standard of 25 mrem/yr for a member of the public (Appendix A).

Because these doses are from external penetrating radiation, all whole-body doses reported in this section are numerically equal to effective dose equivalents. Consequently, the doses are not only less than EPA's air pathway standard of 25 mrem/yr (whole body), but they are also less than DOE's RPS of 100 mrem/yr (effective dose equivalent).

The average dose to residents in Los Alamos townsite attributable to Laboratory operations was 0.15 mrem to the whole body. The corresponding dose to White Rock residents was 0.14 mrem. The doses are 0.6% of EPA's 25-mrem/yr air pathway standard. They were estimated using an in-house simple Gaussian air dispersion model, measured stack releases (Table G-2), and 1989 meteorological data. These doses were dominated by external radiation from airborne releases at LAMPF.

4. Doses to Individuals from Inhalation of Airborne Emissions. The maximum individual doses attributable to inhalation of airborne emissions (Table G-1) are below the EPA air pathway standards for whole-body doses, 25 mrem/yr, and the limit for organ doses, 75 mrem/yr (Appendix A).

Exposure to airborne ^{3}H (as tritiated water vapor), uranium, ^{238}Pu, ^{239,240}Pu, and ^{241}Am were determined by measurement (Sec. V). Correction for background was made by assuming that natural radioactivity and worldwide fallout were represented by data from the three regional sampling stations at Española, Pojoaque, and Santa Fe. Doses were calculated using the procedures described in Appendix D.

The highest effective dose equivalent was 0.03 mrem (total body), or <0.1% of the DOE's RPS of 100 mrem/yr. The inhalation dose that was the highest percentage of the EPA's air pathway standard was 0.52 mrem to the bone surface; this is 0.7% of the 75-mrem/yr standard for dose to any organ from the air pathway.

Emissions of air activation products from LAMPF resulted in negligible inhalation exposures.

Exposure from all other atmospheric releases of radioactivity (Table G-2) was evaluated by theoretical calculations of airborne dispersion. All potential doses from these other releases were less than the smallest ones presented in this section and thus were considered insignificant.

5. Modeled Doses from Airborne Emissions for Compliance with 40 CFR 61, Subpart H. The EPA requires that radiation doses be determined with computer codes AIRDOS-EPA and RADRISK (40 CFR 61). The AIRDOS-EPA code was run with 1989 meteorological data, radioactive emissions data (given in Table G-2), and RADRISK dose conversion factors (70-year commitment). As expected, more than 98% of the maximum individual dose resulted from external exposure to air activation products from LAMPF. The maximum individual whole-body dose, as determined by AIRDOS-EPA, was 11 mrem, corrected to include shielding by buildings (30% reduction). The calculation also took into account the chemical form of the radionuclide, such as whether tritium was present as tritiated water or tritium gas (see Appendix D). The 11-mrem maximum dose, which would occur in the area just northeast of LAMPF, is 44% of the EPA's air pathway standard of 25 mrem/yr (whole body).

The maximum organ dose was calculated by AIRDOS-EPA to be 14 mrem to the testes, or 18% of EPA's air pathway standard of 75 mrem/yr to any organ. This dose would also occur in the area just northeast of LAMPF. Of the 14 mrem, approximately 98% is due to external penetrating radiation from LAMPF air emissions and 2% from other Laboratory emissions.

See Appendix D for additional information on modeling doses under 40 CFR 61.

6. Doses from Direct Penetrating Radiation. No direct penetrating radiation from Laboratory operations was detected by TLD monitoring in off-site areas. The only off-site TLD measurements showing any effect from Laboratory operations were those taken north of LAMPF. These were due to airborne emissions, as discussed above. On-site TLD measurements of external penetrating radiation reflected Laboratory operations and did not represent potential exposure to the public except in the vicinity of TA-18 on Pajarito Road. Members of the public using the DOE-controlled road passing by TA-18 would likely receive no more than 3 mrem/yr of direct gamma and neutron radiation, which is 3% of the DOE's 100-mrem/yr standard for protection from exposure by all pathways (Appendix A). This value was based on 1989 field measurements of gamma plus neutron dose rates using TLDs.

The on-site TLD station (station 24, Fig. 6) near the northeastern Laboratory boundary recorded an above-background dose of about 26 mrem. This dose reflects direct radiation from a localized accumulation of ^{137}Cs on sediments transported from TA-21 before 1964. No one resides near this location at this time.

7. Doses to Individuals from Treated Effluents. At this time, discharged, treated effluents do not flow beyond the Laboratory boundary but are retained in the alluvium of the receiving canyons (Sec. VI). These treated effluents are monitored at their point of discharge, and their behavior in the alluvium of the canyons below outfalls has been studied and is monitored annually (Hakonson 1976a, 1976b; Purtymun 1971, 1974a; Sec. VI).

Small quantities of radioactive contaminants transported during periods of heavy run-off have been measured in canyon sediments beyond the Laboratory boundary in Los Alamos Canyon. Calculations made with radiological data from Acid-Pueblo and Los Alamos canyons (ESG 1981) indicate a minor exposure pathway to man from these canyon sediments (eating liver from a steer that drinks water from and grazes in lower Los Alamos Canyon). This pathway could potentially result in a maximum committed effective dose equivalent of 0.1 mrem.

8. Doses to Individuals from Ingestion of Foodstuffs. Data from sampling of produce, fish, and honey during 1989 (Sec. VII) were used to estimate doses received from eating these foodstuffs. All calculated effective dose equivalents are ≤0.1% of DOE's 100-mrem/yr standard (Appendix A).

Fruit and vegetable samples were analyzed for six radionuclides (^{3}H, ^{90}Sr, total uranium, ^{238}Pu, and ^{239,240}Pu). The maximum committed effective dose equivalent that would result from ingesting one-fourth of an annual consumption of fruits and vegetables (160 kg) from an off-site location was 0.002 mrem. This dose is <<0.1% of the DOE's RPS for protecting members of the public (Appendix A).

Ingestion of produce collected on site is not a significant exposure pathway because of the small amount of edible material, low radionuclide concentrations, and limited access to these foodstuffs.

Fish samples were analyzed for ^{90}Sr, ^{137}Cs, natural uranium, ^{238}Pu, and ^{239,240}Pu. Radionuclide concentrations in fish from Cochiti Reservoir, the sampling location downstream from the Laboratory, are compared with concentrations in fish taken from upstream. The maximum effective dose equivalent to an individual eating 21 kg of fish from Cochiti Reservoir is 0.005 mrem, which is <<0.1% of DOE's 100-mrem/yr standard (DOE 1985). Maximum organ dose is 0.06 mrem to bone surface.

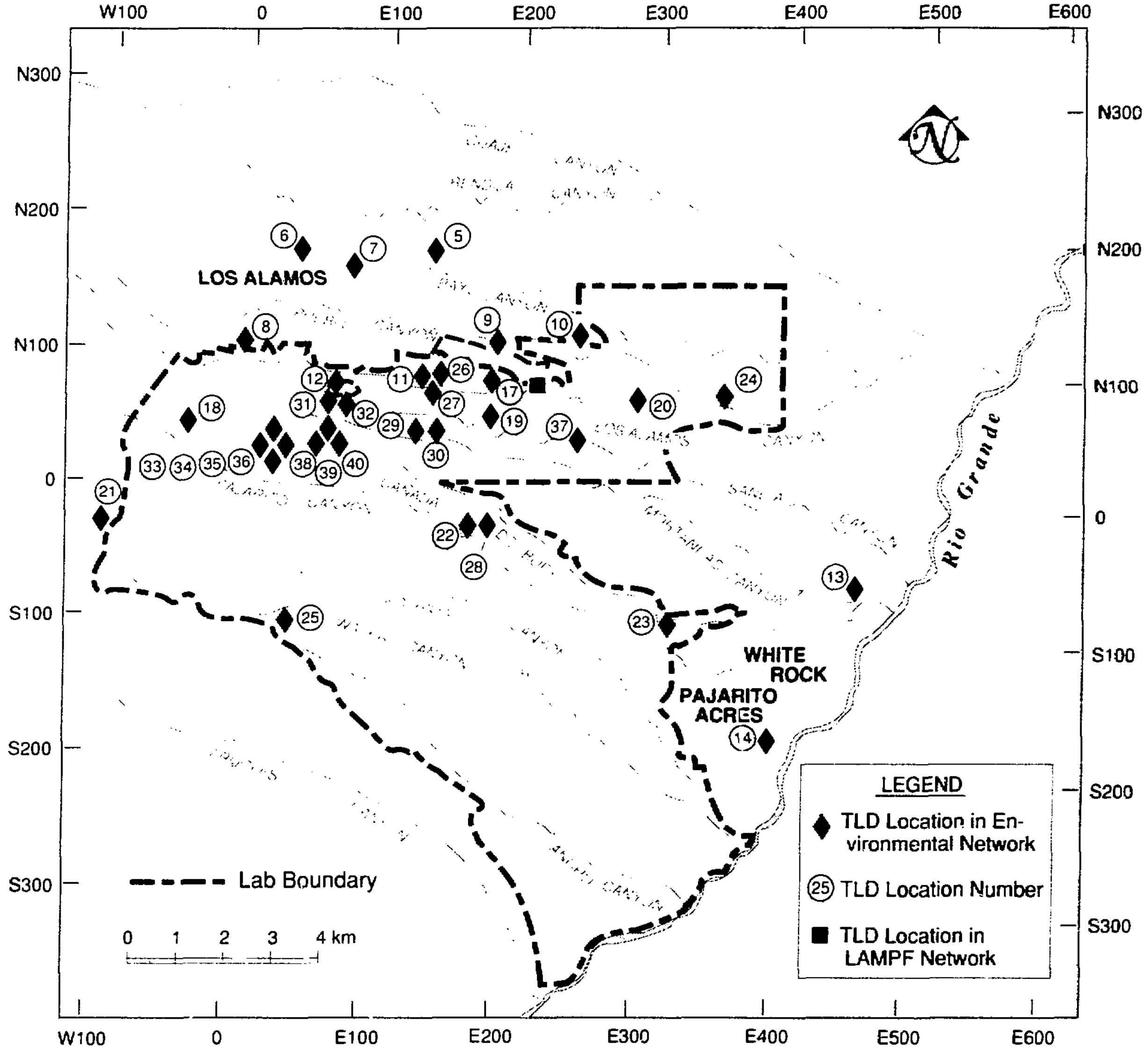

Fig. 6. Thermoluminescent dosimeter (TLD) locations on or near the Laboratory site.

Trace amounts of radionuclides were found on site in honey. The maximum effective dose equivalent one would get from eating 5 kg of this honey, if it were made available for consumption, would be 0.1 mrem, which is 0.1% of DOE's 100-mrem/yr standard.

9. Collective Effective Dose Equivalents. The 1989 population collective effective dose equivalent attributable to Laboratory operations to persons living within 80 km (50 mi) of the Laboratory was calculated to be 3.1 person-rem. This dose is <0.1% of the 65 000 person-rem exposure from natural background radiation and <0.1% of the 11 000 person-rem exposure from medical radiation (Table 7). The 1989 collective whole-body dose equivalent is also 3.1 person-rem. This is because the dose is dominated by external whole-body radiation from LAMPF emissions. Whole-body doses received from external radiation approximately equal total effective doses.

The collective dose from Laboratory operations was calculated from measured radionuclide emission rates

Table 7. Estimated Collective Effective Dose Equivalents during 1989 (person-rem)

Exposure Mechanism	Los Alamos County (19 300 persons)	80-km Region (208 000 persons)[a]
Total caused by Laboratory releases	2.7[b]	3.1
Natural background		
Nonradon	2 500	23 800
Radon	3 900	41 500
Total caused by natural sources of radiation	6 400	65 300
Diagnostic medical exposures (~53 mrem/yr/person)[c]	1 000	11 000

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[a] Includes doses reported for Los Alamos County.

[b] Calculations are based on TLD measurements. They include a 20% reduction in cosmic radiation from shielding by structures and a 30% reduction in terrestrial radiation from self-shielding by the body (NCRP 1987a).

[c] NCRP (1987a).

(Table G-2), atmospheric modeling using measured meteorological data for 1989, and population data based on the 1980 Bureau of Census count, adjusted to 1989 (Table 4 and Appendix D).

The collective dose from natural background radiation was calculated using the background radiation levels given above. For the population living within the 80-km radius of the Laboratory, the dose from medical and dental radiation was calculated using a mean annual dose of 53 mrem per capita. The population distribution in Table 4 was used in both these calculations to obtain the total collective dose.

Also shown in Table 7 is the collective effective dose equivalent in Los Alamos County from Laboratory operations, natural background radiation, and medical and dental radiation. Approximately 90% of the total collective dose from Laboratory operations is to Los Alamos County residents. This dose is <0.1% of the collective effective dose equivalent from background and 0.3% of the collective dose from medical and dental radiation, respectively.

Population centers outside of Los Alamos County are farther away, so dispersion, dilution, and decay in transit (particularly for ^{11}C, ^{13}N, ^{14}O, ^{15}O, and ^{41}Ar) reduce the collective dose to less than 10% of the total. The collective dose to residents outside of Los Alamos County and within 80 km (50 mi) of the Laboratory is <<0.1% of the dose from natural background radiation and <<0.1% of the dose from medical and dental radiation.

C. Risk to an Individual from Laboratory Releases

1. Estimating Risk. Risk estimates of possible health effects from radiation doses to the public resulting from Laboratory operations have been made to provide perspective in interpreting these radiation doses. These calculations, however, may overestimate actual risk for low-LET (linear-energy-transfer) radiation. The NCRP (1975a) has warned that “risk estimates for radiogenic cancers at low doses and low dose rates derived on the basis of linear (proportional) extrapolation from the rising portions of the dose incidence curve at high doses and high dose rates . . . cannot be expected to provide realistic estimates of the actual risks from low-level, low-LET radiation, and have such a high probability of overestimating the actual risk as to be of only marginal value, if any, for purposes of realistic risk-benefit evaluation.”

Low-LET radiation, which includes gamma rays, is the principal type of environmental radiation resulting from Laboratory operations. Estimated doses from high-LET radiation, such as neutron or alpha particle radiation, are less than 3% of estimated low-LET radiation doses. Consequently, risk estimates in this report may overestimate the true risks.

Risk estimates used here are based on two recent reports by the National Research Council's Committee on the Biological Effects of Ionizing Radiation (BEIR IV 1988, BEIR V 1990). These reports incorporate the results of the most current research and update risk estimates in previous surveillance reports that were based on the work of the ICRP. The procedures used in this report for the risk estimates are described in more detail in Appendix D.

2. Risk from Natural Background Radiation and Medical and Dental Radiation. During 1989, persons living in Los Alamos and White Rock received an average effective dose equivalent of 127 mrem of nonradon radiation (principally to the whole body) from natural sources (including cosmic, terrestrial, and self-irradiation sources, with allowances for shielding and cosmic neutron exposure). Thus, the added cancer mortality risk attributable to natural, whole-body radiation in 1989 was 1 chance in 18 000 in Los Alamos and White Rock.

Natural background radiation also includes exposure to the lung from ^{222}Rn and its decay products (see above), in addition to exposure to whole-body radiation. This exposure to the lung also carries a chance of cancer mortality because of natural radiation sources that were not included in the estimate for whole-body radiation. For the background effective dose equivalent of 200 mrem/yr, the added risk because of exposure to natural ^{222}Rn and its decay products is 1 chance in 14 000.

The total cancer mortality risk from natural background radiation is 1 chance in 8000 for Los Alamos and White Rock residents (Table 2). The additional risk of cancer mortality from exposure to medical and dental radiation is 1 chance in 43 000.

3. Risk from Laboratory Operations. The risks calculated above from natural background radiation and medical and dental radiation can be compared with the incremental risk caused by radiation from Laboratory operations. The average doses to individuals in Los Alamos and White Rock because of 1989 Laboratory activities were 0.15 and 0.14 mrem, respectively. These doses are estimated to add lifetime risks of about 1 chance in 15 000 000 in Los Alamos and 1 chance in 16 000 000 in White Rock to an individual's risk of cancer mortality (Table 2). These risks are <0.1% of the risk attributed to exposure to natural background radiation or to medical and dental radiation.

For Americans, the average lifetime risk is a 1-in-4 chance of contracting cancer and a 1-in-5 chance of dying of cancer (EPA 1979a). The Los Alamos incremental risk attributable to Laboratory operations is equivalent to the additional exposure from cosmic rays a person would get from flying in a commercial jet aircraft for 41 minutes at 9100 m (30 000 ft) (NCRP 1987b).

The exposure from Laboratory operations to Los Alamos County residents is well within variations in exposure of these people to natural cosmic and terrestrial sources and global fallout. For example, the amount of snow cover and variability of the solar sunspot cycle can explain a 10-mrem difference from year to year (NCRP 1975b).

IV. MEASUREMENT OF EXTERNAL PENETRATING RADIATION

Levels of external penetrating radiation (including x and gamma rays and charged-particle contributions from cosmic, terrestrial, and manmade sources) are monitored in the Los Alamos area with thermoluminescent dosimeters (TLDs). The only boundary or perimeter measurements showing an effect attributable to Laboratory operations were those from dosimeters located north of the Los Alamos Meson Physics Facility (a linear particle accelerator). These TLDs showed an above-background radiation measurement of about 8 ± 3 mrem in 1989, less than the dose measured in 1988. Some on-site measurements were above background levels, as expected, reflecting research activities and waste management operations at the Laboratory.

A. Background

Natural external penetrating radiation comes from terrestrial and cosmic sources. The natural terrestrial component results from the decay of ^{40}K and of radionuclides in the decay chains of ^{232}Th, ^{235}U, and ^{238}U. Natural terrestrial radiation in the Los Alamos area is highly variable with time and location. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (NCRP 1975b). There is also spatial variation because of different topographies and soil and rock types from area to area (ESG 1978).

The cosmic source of natural ionizing radiation increases with elevation because of reduced shielding by the atmosphere. At sea level, it produces measurements between 25 and 30 mrem/yr. Los Alamos, with a mean elevation of about 2.2 km (1.4 mi), receives about 60 mrem/yr from the cosmic component. However, regional locations range in elevation from about 1.7 km (1.1 mi) at Española to 2.7 km (1.7 mi) at Fenton Hill, resulting in a corresponding range between 45 and 90 mrem/yr for the cosmic component. This component can vary ±5% because of solar modulations (NCRP 1975b).

Fluctuations in natural background ionizing radiation make it difficult to detect an increase in radiation levels from manmade sources. This is especially true when the size of the increase is small relative to the magnitude of natural fluctuations. Therefore, to measure contributions to external radiation from the operation of the Los Alamos Meson Physics Facility (LAMPF), arrays with 48 TLDs for each array have been deployed near LAMPF and in background areas.

Levels of external penetrating radiation (including x and gamma rays and charged-particle contributions from cosmic, terrestrial, and manmade sources) in the Los Alamos area are measured with TLDs in three independent networks. These networks are used to measure radiation levels (1) at the Laboratory and regional areas, (2) at the Laboratory boundary north of LAMPF, and (3) at low-level radioactive waste management areas.

B. Environmental TLD Network

The environmental network consists of 40 stations divided into 3 groups. The regional group consists of four locations, 28 to 44 km (17 to 27 mi) from the Laboratory boundary in the neighboring communities of Española, Pojoaque, and Santa Fe, as well as at the Fenton Hill Site 30 km (19 mi) west of Los Alamos. The off-site perimeter group consists of 12 stations within 4 km (2.5 mi) of the boundary (Fig. 6). Within the Laboratory, the on-site group comprises 24 locations (Fig. 6). Details of the methodology for this network are found in Appendix B.

Annual averages for the groups were generally lower in 1989 than in 1988 (Fig. 7). Regional and perimeter stations showed no statistically discernible increase in radiation levels attributable to Laboratory operations (Table G-3). Annual measurements at off-site stations ranged from 72 to 126 mrem.

Some comparisons provide a useful perspective for evaluating these measurements. For instance, the average

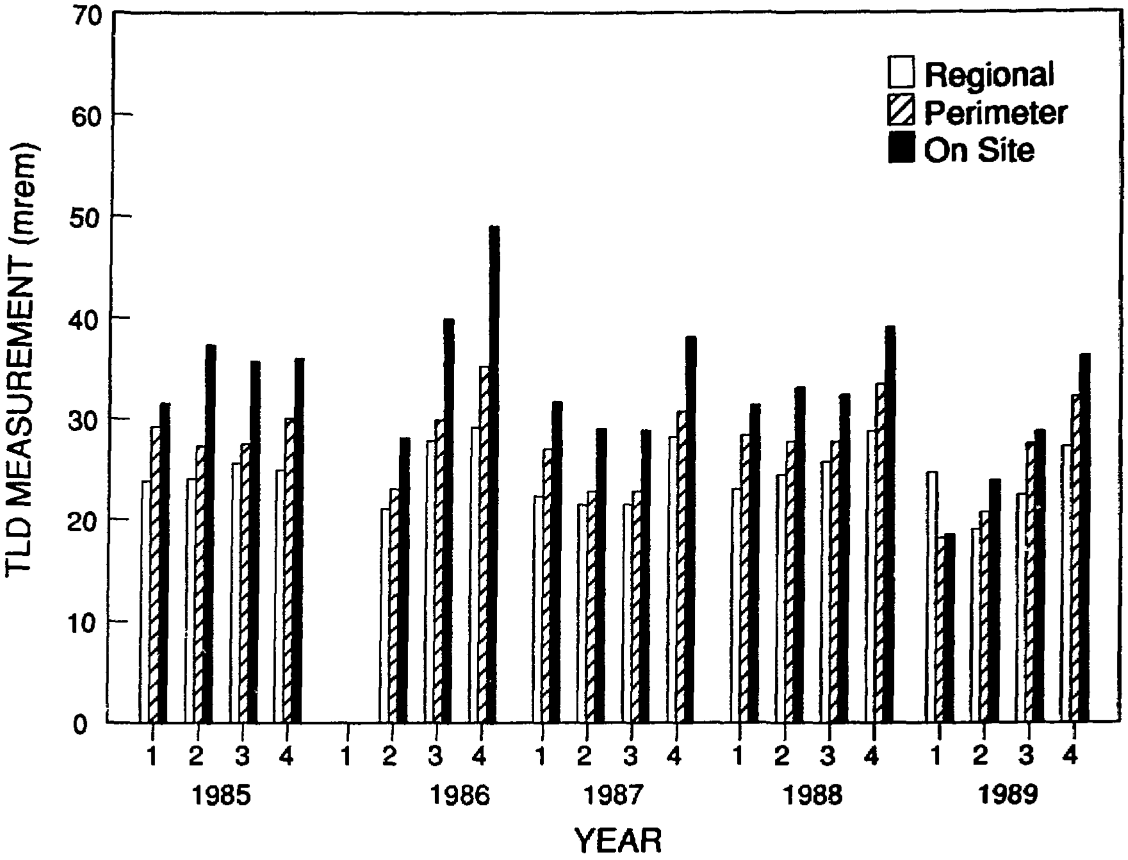

Fig. 7. Thermoluminescent dosimeter (TLD) measurements (including contributions from cosmic, terrestrial, and Laboratory radiation sources).

person in the United States receives about 53 mrem/yr from medical diagnostic procedures (NCRP 1987a). The DOE's Radiation Protection Standard (RPS) is 100-mrem/yr effective dose received from all pathways, and the dose received by air is restricted by EPA's (whole-body) standard of 25 mrem/yr (Appendix A). These values are in addition to those from normal background, consumer products, and medical sources. The standards apply to locations of maximum probable exposure to an individual in an off-site, uncontrolled area.

C. TLD Network at LAMPF

This network monitors external radiation from airborne activation products (gases, particles, and vapors) released by LAMPF, TA-53. The prevailing winds are from the south and southwest (Sec. II). Twelve TLD sites are located downwind at the Laboratory boundary north of LAMPF along 800 m (0.5 mi) of canyon rim. Twelve background TLD sites are about 9 km (5.5 mi) from the facility along a canyon rim near the southern boundary of the Laboratory (Fig. 6). This background location is not influenced by any Laboratory external radiation sources.

The TLDs at the 24 sites are changed each calendar quarter, more often if LAMPF's operating schedule indicates the need (start up or shutdown of the accelerator for extended periods midway in a calendar quarter). The radiation measurement (above background) for this network was about 8 ± 3 mrem for 1989. This value was obtained by subtracting the annual measurement taken at the background sites from the annual measurement taken at the Laboratory's boundary north of LAMPF (Appendix B). The value measured this year is less than that measured in 1988 (Fig. 2), although annual emissions of mixed activation products from LAMPF increased (Table 3). This discrepancy is probably due to varying wind conditions between the two years.

D. TLD Network for Low-Level Radioactive Waste Management Areas

This network of 92 locations monitors radiation levels at 1 active and 11 inactive low-level radioactive waste management areas. These waste management areas are controlled-access areas and thus are not accessible to the general public. Active and inactive waste areas are monitored for external penetrating radiation with arrays of TLDs (Table 8). Averages at all sites were higher than the average for the perimeter network. However, the range of values at most sites largely overlapped those found at perimeter and regional stations (Tables 8 and G-3). The extremes at Area G (the active radioactive waste area) and Area T (an inactive waste area) have been noted in previous years. These data reflect the results of past and present radioactive waste management activities.

Table 8. Doses Measured by TLDs at On-Site Waste Disposal Areas during 1989

Area	Number of TLDs	Doses (mrem)		
		Mean	Minimum	Maximum
A	5	100	96	105
B	14	98	83	109
C	10	105	91	131
E	4	111	103	116
F	4	99	92	102
G	27	129	97	201
T	7	117	92	196
U	4	110	108	114
V	4	101	94	108
W	2	93	77	108
X	1	71	—	—
AB	10	101	92	110

V. AIR MONITORING

Airborne radioactive emissions were monitored at 87 Laboratory release points. The largest airborne release was 156 000 Ci of short-lived (2- to 20-minute half-lives) air activation products from the Los Alamos Meson Physics Facility (LAMPF) during its operation from May 5 through September 29, 1989. Air is routinely sampled at several locations on site, along the Laboratory perimeter, and in distant areas that serve as regional background stations. Atmospheric concentrations of tritium, uranium, plutonium, americium, and gross beta are measured. The highest measured and annual average concentrations of these radioactive materials were much less than the 0.1% of concentrations that would cause DOE's Radiation Protection Standard to be exceeded.

A. Airborne Radioactivity

1. Introduction. The sampling network for ambient airborne radioactivity consists of 25 continuously operating air sampling stations (see Appendix B for a complete description of sampling procedures). The regional monitoring stations, 28 to 44 km (18 to 28 mi) from the Laboratory, are located at Española, Pojoaque, and Santa Fe (Table G-4). The data from these stations are used as reference points for determining regional background levels of atmospheric radioactivity. The 10 perimeter stations are within 4 km (2.5 mi) of the Laboratory boundary, and 12 on-site stations are within the Laboratory boundary (Fig. 8, Table G-4).

Natural atmospheric and fallout radioactivity levels fluctuate and affect measurements made during the Laboratory's air sampling program. Worldwide background airborne radioactivity is largely composed of fallout from past atmospheric nuclear weapons tests, natural radioactive constituents from the decay chains of thorium and uranium attached to dust particles, and materials resulting from interactions with cosmic radiation (for example, natural tritiated water vapor produced by interactions of cosmic radiation and stable water). Background radioactivity concentrations in the atmosphere are summarized in Table G-5 and are useful in interpreting air sampling data.

Particulate matter in the atmosphere is primarily caused by the resuspension of soil that is dependent on current meteorological conditions. Windy, dry days can increase the soil resuspension, whereas precipitation (rain or snow) can wash out particulate matter in the atmosphere. Consequently, there are often large daily and seasonal fluctuations in airborne radioactivity concentrations caused by changing meteorological conditions.

2. Airborne Emissions. Radioactive airborne emissions are monitored at 87 Laboratory discharge locations. These emissions consist primarily of filtered exhausts from glove boxes, experimental facilities, operational facilities (such as liquid-waste treatment plants), a nuclear research reactor, and a linear particle accelerator at LAMPF. The emissions receive appropriate treatment before discharge, such as filtration for particulate matter and catalytic conversion and adsorption for activation gases. The quantities of airborne radioactivity released depend on the type of research activities and can vary markedly from year to year (Figs. 9–11).

During 1989, the most significant releases were from LAMPF. The amount released for the entire year was 156 000 Ci of air activation products (gases, particles, and vapors) (Tables 3 and G-2). This emission was about one-third higher than that in 1988, but was within the range of variation seen over the last few years (Fig. 11). The principal airborne activation products (half-lives in parentheses) were ^{11}C (20 min), ^{13}N (10 min), ^{14}O (71 s), ^{15}O (123 s), ^{41}Ar (1.83 h), ^{192}Au (4.1 h), and ^{195}Hg (9.5 h). More than 95% of the radioactivity was from the ^{11}C, ^{13}N, ^{14}O, and ^{15}O radioisotopes, whose radioactivity declines very rapidly over time.

Airborne tritium emissions increased by a factor of 1.3, from 11 000 Ci in 1988 to 14 400 Ci in 1989 (Table 3).

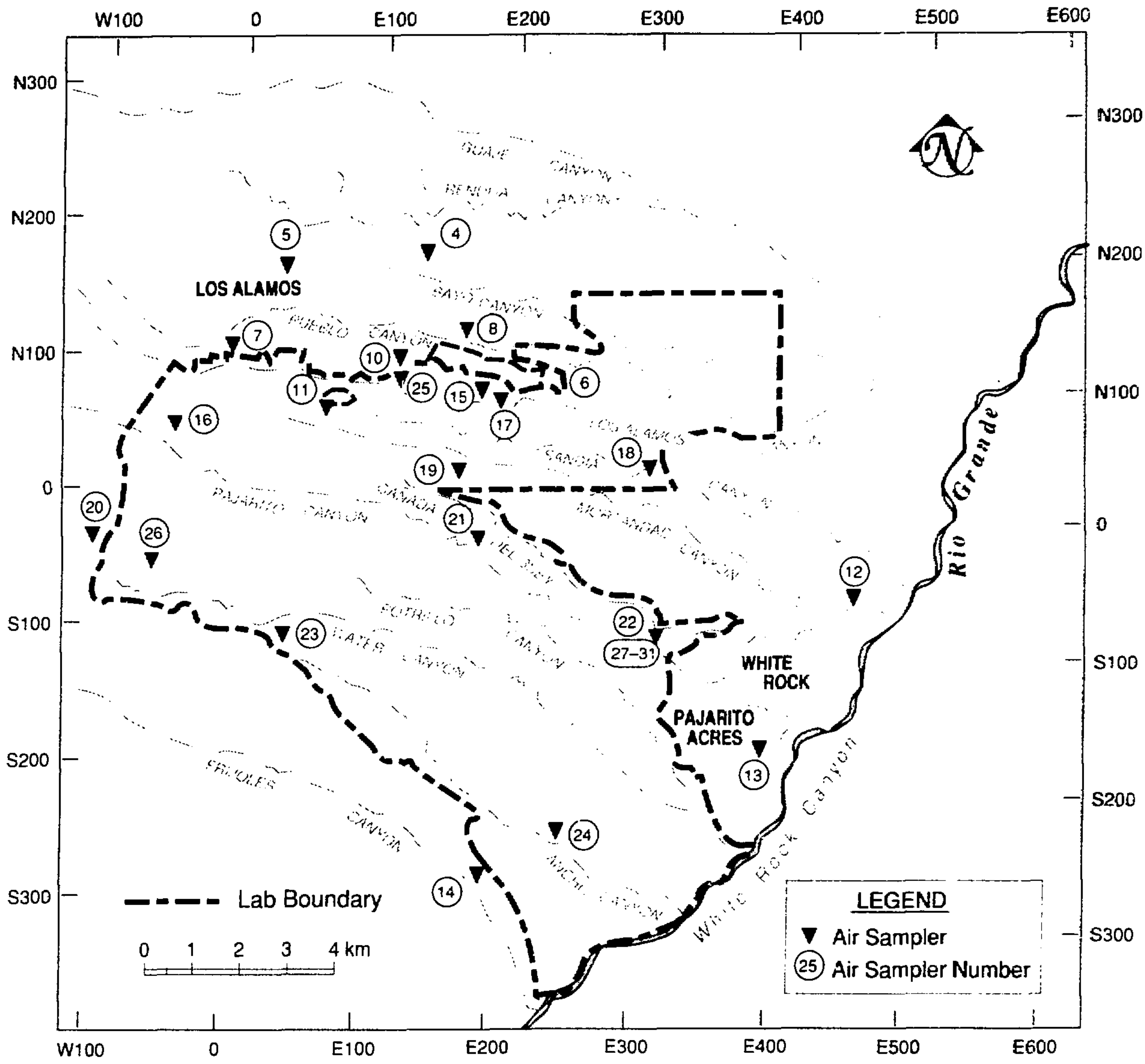

Fig. 8. Locations on or near the Laboratory site for sampling airborne radionuclides.

This rise was principally due to several unplanned releases at TA-41 (Sec. I.G). The sharp increase in mixed fission products from 1988 to 1989 resulted from the October 1989 unplanned release of 0.43 Ci from TA-48 (Sec. I.G).

In addition to releases from facilities, some depleted uranium (uranium consisting primarily of ^{238}U) is dispersed by experiments that use conventional high explosives. About 237 kg (523 lb) of depleted uranium were used in such experiments in 1989 (Table G-6). This mass contains about 0.11 Ci of radioactivity. Most of the debris from these experiments is deposited on the ground in the vicinity of the firing sites. Limited experimental data show that no more than about 10% of the depleted uranium becomes airborne (Dahl 1977). Dispersion calculations indicate that resulting airborne concentrations are in the same range as that for concentrations attributable to the natural abundance of uranium that is resuspended in dust particles originating from the earth's crust.

The EPA limits radiation doses from airborne radioactive emissions to 25 mrem/yr (whole body) and 75 mrem/yr (any single organ), according to regulations under the auspices of NESHAP (National Emission

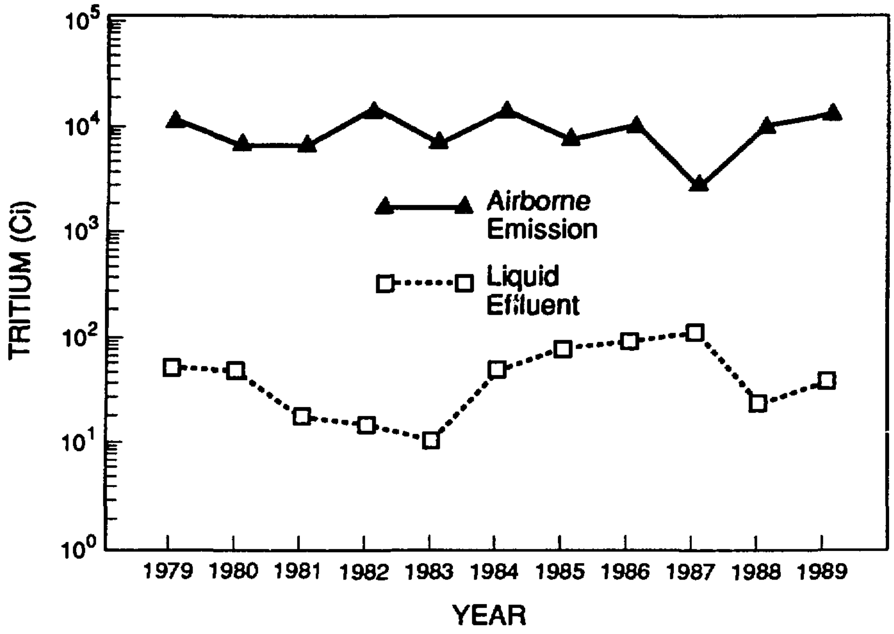

Fig. 9. Summary of tritium releases (airborne emissions and liquid effluents).

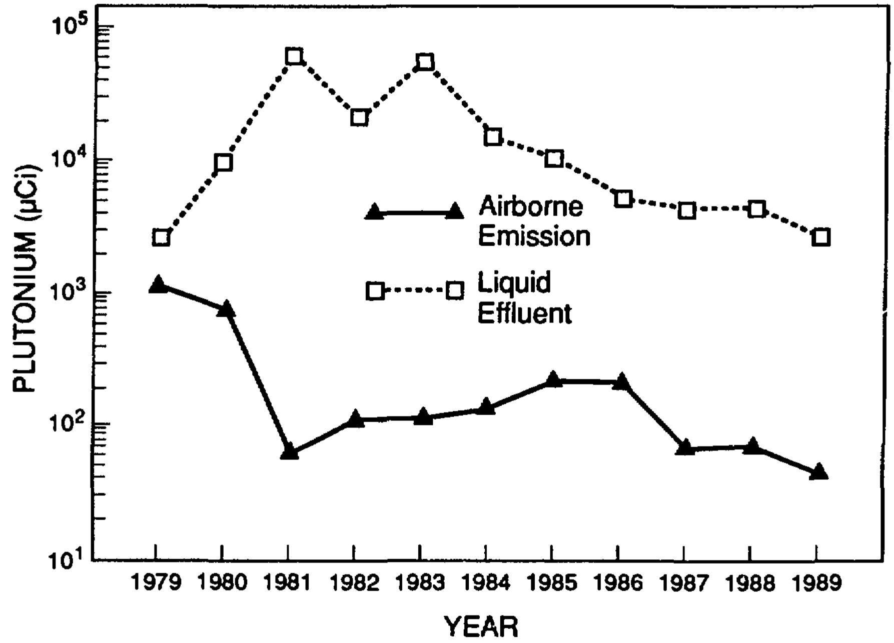

Fig. 10. Summary of plutonium releases (airborne emissions and liquid effluents).

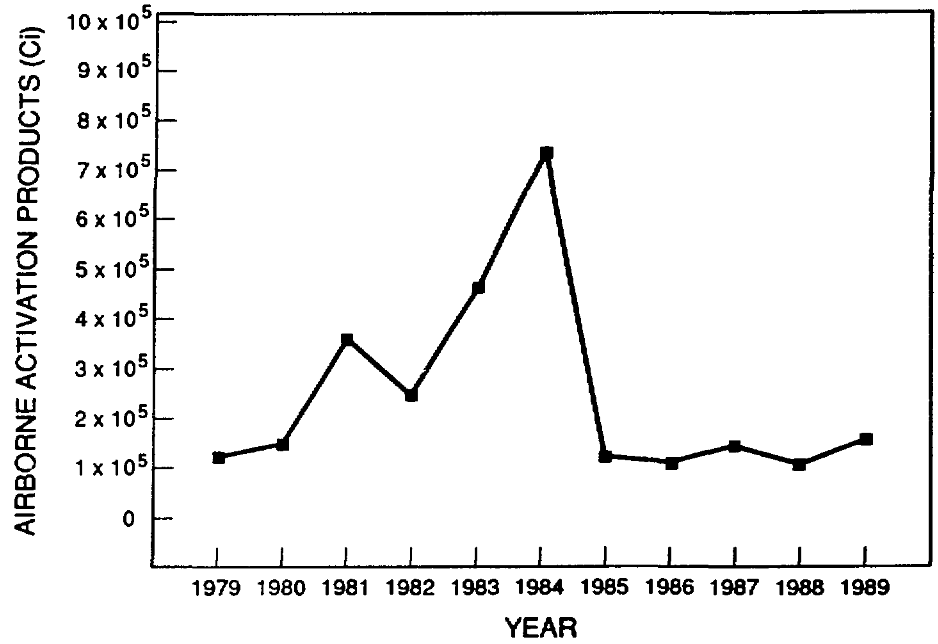

Fig. 11. Airborne activation product emissions (principally, ^{10}C, ^{11}C, ^{13}N, ^{16}N, ^{14}O, ^{15}O, ^{41}Ar) from LAMPF, the Los Alamos Meson Physics Facility (TA-53).

Standards for Hazardous Air Pollutants, EPA 1985). As discussed in Sec. III, the maximum individual doses caused by Laboratory operations during 1989, which resulted from releases of air activation products from LAMPF, were estimated to be 11 mrem to the whole body and 14 mrem to the testes. These doses were 44% of the EPA limit of 25 mrem/yr to the whole body and 18% of the EPA limit of 75 mrem/yr to any organ.

3. **Gross Beta Radioactivity.** Gross beta analyses help in evaluating general radiological air quality. Figure 12 shows gross beta concentrations at a regional sampling location (Española, station 1), about 30 km from the Laboratory, and at an on-site sampling location (TA-59, building OH-1).

4. **Tritium.** In 1989, the regional mean (0.7 × 10^{-12} µCi/mL) was statistically significantly lower than the perimeter annual mean (4.6 × 10^{-12} µCi/mL) and the on-site annual mean (9.3 × 10^{-12} µCi/mL) (Table G-7). This difference reflects the slight impact of Laboratory operations. The TA-2 (station 25) and TA-54 (station 22) annual means of 22.8 × 10^{-12} and 28.8 × 10^{-12} µCi/mL, respectively, were the two highest annual means measured in 1989. Both of these stations are located within the Laboratory boundary near areas where tritium is disposed of or used in operations. These tritium concentrations are <0.1% of the concentration guides for tritium in air, based on DOE's Derived Air Concentrations for controlled areas (Appendix A).

5. **Plutonium and Americium.** Of the 99 air sample analyses performed in 1989 for ^{238}Pu, only 17 were above the minimum detectable limit of 2.0 × 10^{-18} µCi/mL. The highest concentration occurred at 48th Street (36.5 ± 19.1 × 10^{-18} µCi/mL) and represents <0.1% of the DOE's Derived Air Concentration guides for ^{238}Pu in uncontrolled areas, or 2 × 10^{-12} µCi/mL (Appendix A). The results of the ^{238}Pu analyses are not tabulated in this report because of the large number of results below the minimum detectable activity.

The 1989 annual means for ^{239,240}Pu concentrations in air for the regional (2.1 × 10^{-18} µCi/mL), perimeter (1.1 × 10^{-18} µCi/mL), and on-site (2.7 × 10^{-18} µCi/mL)

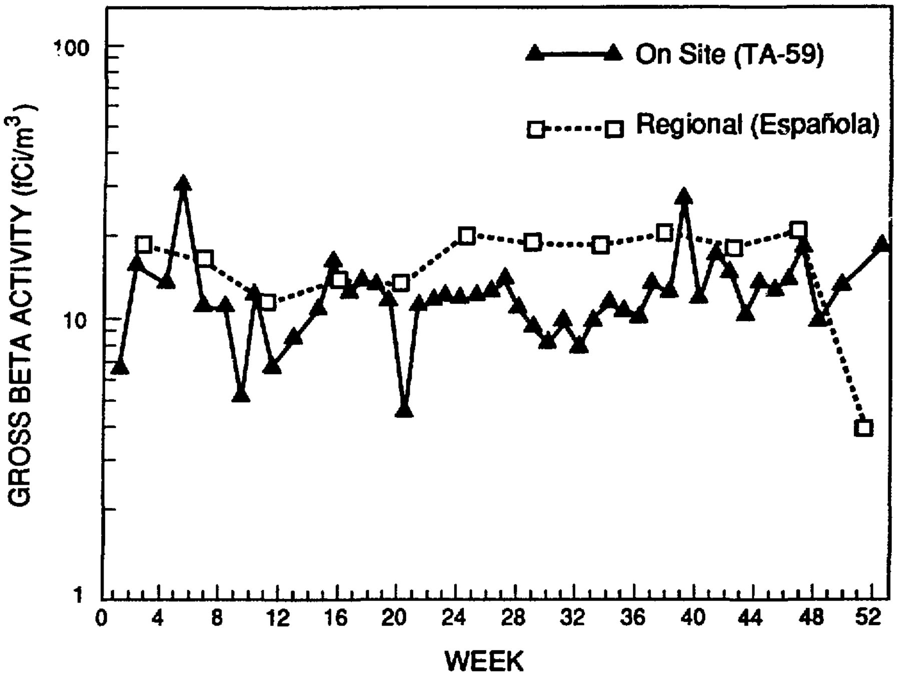

Fig. 12. Atmospheric gross beta activity at a regional (background) station and an on-site station during 1989.

stations were all less than 0.1% of the Derived Air Concentration guides for controlled or uncontrolled areas (Appendix A).

Measured concentrations of ^{241}Am were all less than 0.1% of the Derived Air Concentration guides for controlled and uncontrolled areas (Appendix A).

Detailed results are given in Tables G-8 and G-9.

6. Uranium. Because uranium is a naturally occurring radionuclide in soil, it is found in airborne soil particles that have been resuspended by wind or mechanical forces (for example, vehicle or construction activity). As a result, uranium concentrations in air are heavily dependent on the immediate environment of the air sampling station. Stations with relatively higher annual averages or maximums are in dusty areas, where heavier accumulation of dust on filters results in increased amounts of natural uranium in the samples.

The 1989 annual means for uranium concentrations in air for regional, perimeter, and on-site stations were 241, 74, and 68 pg/m³, respectively (Table G-10). All measured annual means were <0.1% of the concentration guides for uranium in controlled and uncontrolled areas (Appendix A). No effects attributable to Laboratory operations were observed.

B. Nonradioactive Chemicals in Ambient Air

1. Air Quality

a. Acid Precipitation. The Laboratory operates a wet-deposition monitoring station located at Bandelier National Monument. This station is part of the National Atmospheric Deposition Program (NADP) network. The NADP is an independently operated network of monitoring stations located throughout the United States that are designed to measure regional deposition rates. The samples, which are collected following standardized procedures, are chemically characterized by the NADP Central Analytical Laboratory. Sampling results are presented in Sec. IX.

b. Ambient Air Monitoring. Because the Los Alamos area is remote from large metropolitan areas and major sources of air pollution, extensive monitoring for nonradioactive air pollutants has not been conducted. In 1989, total suspended particulate (TSP) matter was measured at two sites in the vicinity of the Laboratory by the New Mexico Air Quality Bureau. Measurements were made once every 6 days at a site on West Road in Los Alamos and at the sewage treatment plant in White Rock. Measurements of TSP matter levels at these sites and applicable standards are reported in Table 9.

These data show that the TSP levels are well below federal and state ambient air quality standards. The state is in the process of converting from measuring TSP matter to measuring particles that are less than 10 µm effective diameter (PM_{10}) in response to changes in federal regulations. Because the levels of TSP matter are so low in Los Alamos County, state authorities have decided to discontinue the sampling rather than convert to PM_{10} sampling. In their judgment, there is very little likelihood that the area exceeds the PM_{10} standard.

During 1989, nine stations in the radioactive air sampling network had their filters composited quarterly and analyzed for stable beryllium. The 1989 means for stable beryllium concentrations were 0.03 ng/m^3 for the regional station, 0.02 ng/m^3 for the four perimeter stations, and 0.02 ng/m^3 for the four on-site stations (Table G-11). These concentrations are well below the state standard of 10 ng/m^3.

In 1989, the Laboratory operated an ambient air monitoring station south of TA-49 and adjacent to Bandelier National Monument. Data have been collected for ozone, PM_{10}, and nitrogen dioxide. Carbon monoxide and sulfur dioxide will be added to the network in 1990.

2. Airborne Emissions. Several sources at the Laboratory emit air pollutants that are regulated under ambient air quality standards or state-imposed emission limits. The emissions from these sources are described below.

a. Beryllium Operations. Beryllium machining operations are located in shop 4 at TA-3-39, in shop 13 at TA-3-102, the beryllium shop at TA-35-213, and the beryllium processing facility at TA-3-141. Exhaust air from each of these operations passes through air pollution control equipment before exiting from a stack. A fabric filter controls emissions from shop 4. The other operations use HEPA (high-efficiency particle-attenuation) filters to control emissions, with a removal efficiency of more than 99.95%. Source tests have demonstrated that all beryllium operations meet the emission limits established by NESHAP. Emissions from the facility are so low that there is negligible impact on ambient air quality; emissions are well below the New Mexico State standard for beryllium. The Laboratory has obtained a permit for an additional beryllium processing operation at TA-3-35, but this source has not yet been constructed.

b. Steam Plants and Power Plant. Fuel consumption and emission estimates for the steam plants and the TA-3 power plant are reported in Table G-12. These plants are sources of particulate matter, oxides of nitrogen (NO_x), carbon monoxide, and hydrocarbons. The NO_x emissions from the TA-3 power plant were estimated on the basis of boiler exhaust gas measurements. Exhaust gas measurements also indicated that sulfur oxides (SO_x) in the exhaust gases are below minimum detectable levels. EPA emission factors were used in making the other emission estimates (EPA 1986a). Both the fuel consumption and the emissions, which are proportionate to fuel usage, dropped 19% between 1988 and 1989. The

Table 9. Particulate Matter Air Quality in 1989
(µg/m^3)

Type	State Ambient Air Quality Standards Maximum Allowed	Measurements	
		Los Alamos	White Rock
24-hour average	150	88 (51)[a]	83 (80)[a]
Annual geometric mean	60	25	27

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[a] Highest (second highest).

Table 10. Asphalt Plant Particulate Matter Emissions

Year	Production (ton/yr)	Emissions (lb/yr)	Change from 1988 (%)
1988	7389	246	
1989	9769	325	32.1

Western Area steam plant, used as a standby plant, was not operated during 1989. The emissions from these plants are low, posing no threat of violating ambient air quality standards.

c. Asphalt Plant. Annual production figures and estimates of the particulate matter emissions from the asphalt concrete plant are found in Table 10. The particulate matter emission estimate was based on stack testing data (Kramer 1977) and production data. A multicyclone and a wet scrubber are used to clean the exhaust gas stream before it is released into the atmosphere. Asphalt production has substantially decreased since 1986 because most of the asphalt used at Los Alamos has been purchased from outside vendors. However, emissions increased slightly between 1988 and 1989, associated with an increase in the amount of asphalt produced.

d. Burning and Detonation of Explosives. Emissions from high explosives occur from two sources: (1) burning of waste high explosives and (2) detonation of explosives for research purposes.

During 1989, approximately 18 000 kg (40 000 lb) of high-explosive wastes were disposed of by open burning at the TA-16 burn ground. Burning the explosives resulted in emissions of oxides of nitrogen, particulate matter, carbon monoxide, and hydrocarbons. Estimates of these emissions are reported in Table 11. The estimates were made using data from experimental work carried out by Mason and Hanger Silas Co., Inc. (MHSM 1976). Because high explosives burn at very high temperatures, their destruction is nearly complete, and only small amounts of pollutants are generated.

Experimental detonation of conventional explosives is routinely conducted in certain test areas at the Laboratory. In some experiments, these explosives contain small amounts of metals, including uranium, beryllium, lead, and other heavy metals. Estimates of emissions from this activity are given in Table G-6. Estimated ambient air impacts are also shown in the table. The emissions and impacts are based on a study performed by the Laboratory (Dahl 1977) that measured airborne uranium and beryllium in the dispersion cloud from detonation experiments. These measurements showed that approximately 10% of the uranium and 2% of the beryllium detonated were aerosolized. No measurements were made for the other heavy metals; therefore, it was assumed that 100% is aerosolized. This is an extremely conservative assumption. The percentage aerosolized is probably similar to that for uranium and beryllium. The study also calculated impacts downwind of the detonation site using air dispersion models. The impacts shown in Table G-6 were

Table 11. Estimated Air Pollutant Emissions during 1989 from the Open Burning of Waste Explosives

Pollutant	Emissions (kg)
Oxides of nitrogen	518
Particulate matter	509
Carbon monoxide	172
Hydrocarbons	2.7

estimated using Dahl's modeling results, the total amount of metals detonated, and the assumptions described above regarding aerosolization. As the table shows, the average concentrations of these toxic metals off site are <0.03% of the applicable standards.

e. Lead-Pouring Facility. A lead-pouring facility for casting lead is located at TA-3-38. This facility emits particulate matter containing lead. Both federal and state ambient air quality standards for lead are 1.5 µg/m^3, averaged over a calendar quarter. Approximately 1600 kg (3500 lb) of lead were poured during 1989. The maximum amount of lead poured in a single quarter was about 950 kg (2100 lb). The EPA (1986a) provides emission factors for lead casting for both primary and secondary processing. Primary facilities recover lead from ore, and secondary facilities recover lead from manufactured items such as batteries. Neither of these is identical to the process at TA-3-38, which melts and casts pure lead ingots. The EPA factors for TSP emissions are 0.87 lb of TSP matter per ton of lead poured from primary facilities and 0.04 lb of TSP matter and 0.01 lb of lead per ton of lead poured from secondary facilities. There are considerable differences between the two, so both were used to provide a range of possible emissions, as shown in Table 12.

The maximum quarterly ambient air quality concentrations for 1989 are also shown in the table. Air dispersion procedures recommended by the EPA (1986b) were used to estimate these concentrations on the basis of quarterly emissions from the lead-pouring facility. Because no lead emission factor is provided for primary lead processing, which has the higher emission factors, impacts were estimated by assuming that all of the TSP matter was lead. This approach provides a worst-case estimate of ambient lead concentration of 0.028 µg/m^3, or about 2% of the standard. If the lower lead emission factors for secondary lead processing were used, the estimated emissions would be only 0.0003 µg/m^3, or about 0.02% of the standard.

Table 12. Maximum Lead Emissions from the Lead-Pouring Facility per Quarter in 1989

	Maximum Quarterly Emissions	
Pollutant	Emissions (kg)	Concentrations (µg/m^3)
TSP matter	0.02–0.4	0.001–0.03
Lead	0.04	0.0003

VI. WATER, SOIL, AND SEDIMENT MONITORING

Surface and ground waters, soils, and sediments were sampled and analyzed to monitor dispersion of radionuclides and chemicals from Laboratory operations. Radionuclide and chemical concentrations of water from areas where there has been no direct release of treated effluents evidenced no observable effects caused by Laboratory operations. The chemical quality of surface waters from areas with no effluent release varied with seasonal fluctuations. The quality of water in the release areas reflected some impact from Laboratory operations, but these waters are confined within the Laboratory boundary and are not a source of municipal, industrial, or agricultural water supply. All concentrations in water sampled outside the Laboratory boundary were <10% of DOE's guides.

Most regional and perimeter soil and sediment stations contained radioactivity at, or near, background levels. Concentrations that did exceed background were low and were principally associated with sediments from areas where, historically, untreated and treated discharges have been released. Concentrations of plutonium in sediments from regional reservoirs on the Rio Chama and Rio Grande reflected worldwide fallout.

A. Effluent Quality

In recent years, treated effluents containing low levels of radioactivity have been released from the central liquid-waste treatment plant (TA-50), a smaller plant serving laboratories at TA-21, and a sanitary sewage lagoon system serving LAMPF (Los Alamos Meson Physics Facility, TA-53) (Tables 3, G-13, G-14, and Figs. 9, 10, 13). In 1989, there were no releases from TA-21.

Total activity released in 1989 (about 42 Ci) was greater by a factor of 1.6 than that released in 1988 (about 26 Ci, Table 3). The increase was due to an increase in tritium discharged from the TA-53 lagoons (Table G-14). These increased discharges were the result of modifications to the TA-53 lagoons to separate sanitary and industrial waste waters. This required discharge of more highly concentrated radionuclides into the effluent during the early spring. No discharges occurred from the lagoons after March. Effluents from TA-50 are discharged into the normally dry stream channel in Mortandad Canyon, where surface flow has not passed beyond the Laboratory's boundary since the plant began operation in 1963. Discharge from the TA-53 lagoons sinks into the alluvium of Los Alamos Canyon within the Laboratory's boundary.

As discussed in subsequent sections, concentrations of radionuclides in water generally decrease from the point of discharge. Effluent radionuclides do occur off site in Los Alamos Canyon. The concentrations of radionuclides in all off-site waters are <10% of DOE's guides. Thus, these effluent discharges do not pose a threat to the general public or the environment.

B. Radiochemical and Chemical Quality of Surface and Ground Waters

1. Background. Surface and ground waters from regional, perimeter, and on-site stations are monitored to provide routine surveillance of Laboratory operations (Figs. 14 and 15, Table G-15). If a sample from a particular station was not taken this year, it was because the station was dry, a water pump was broken, or the wells were down for repairs. Concentrations of radionuclides in water samples are compared with guides derived from DOE's Radiation Protection Standard (RPS) (Appendix A). Concentration guides do not account for concentrating mechanisms that may exist in environmental media. Consequently, other media, such as sediments, soils, and foodstuffs, are also monitored (see subsequent sections).

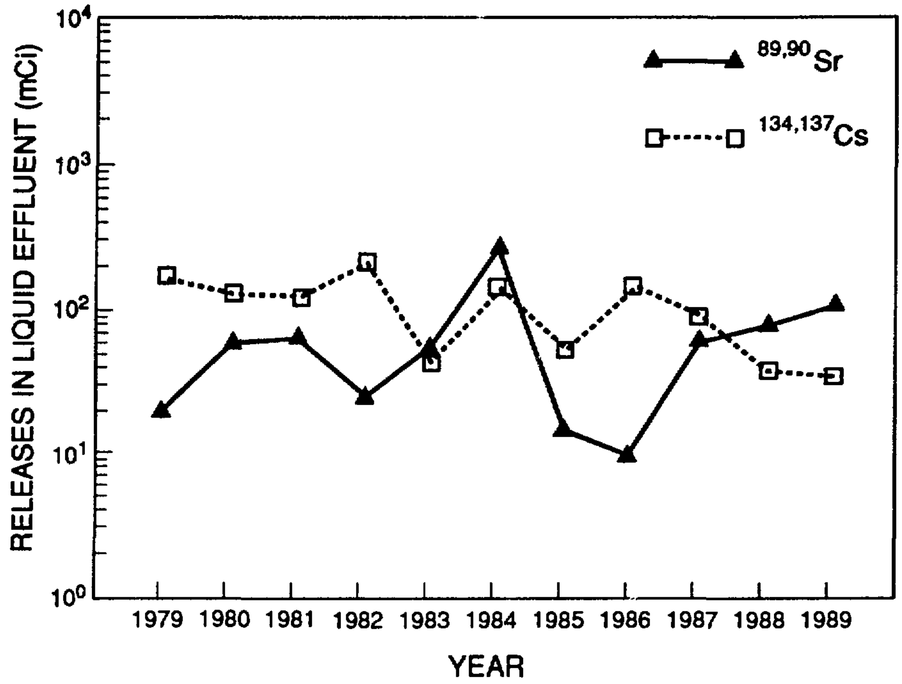

Fig. 13. Summary of strontium and cesium liquid effluent releases.

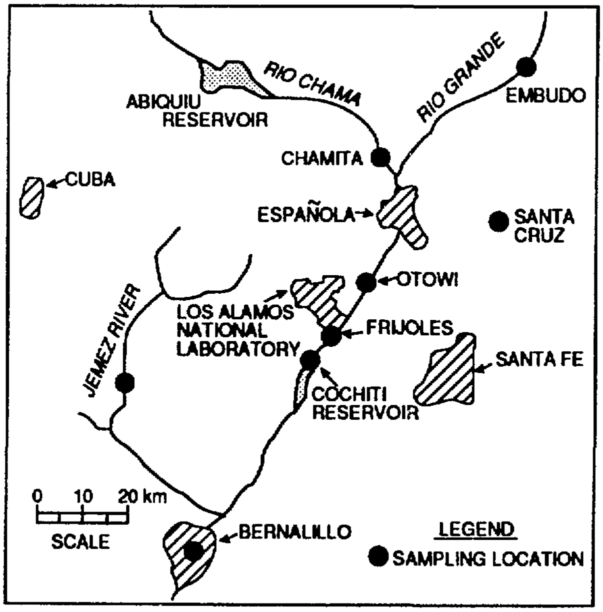

Fig. 14. Regional sampling locations for surface water, sediment, and soil.

Routine chemical analyses of water samples have been carried out for many constituents over a number of years. Although surface and shallow ground waters are not a source of municipal or industrial water supply, results of these analyses are compared with EPA drinking water standards, as these are the most restrictive related to water use.

2. Regional Stations. Regional surface-water samples were collected within 75 km (47 mi) of the Laboratory from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 14). The six water-sampling stations were located at U.S. Geological Survey (USGS) gaging stations. These waters provided base line data for radiochemical and chemical analyses in areas beyond the Laboratory boundary. Stations on the Rio Grande were at Embudo, Otowi, Cochiti, and Bernalillo.

The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 37 000 km^2 (14 300 mi^2) in southern Colorado and northern New Mexico. Discharge for the periods of record (1895–1905 and 1909–1988) has ranged from a minimum of 1.7 m^3/s (60 ft^3/s) in 1902 to

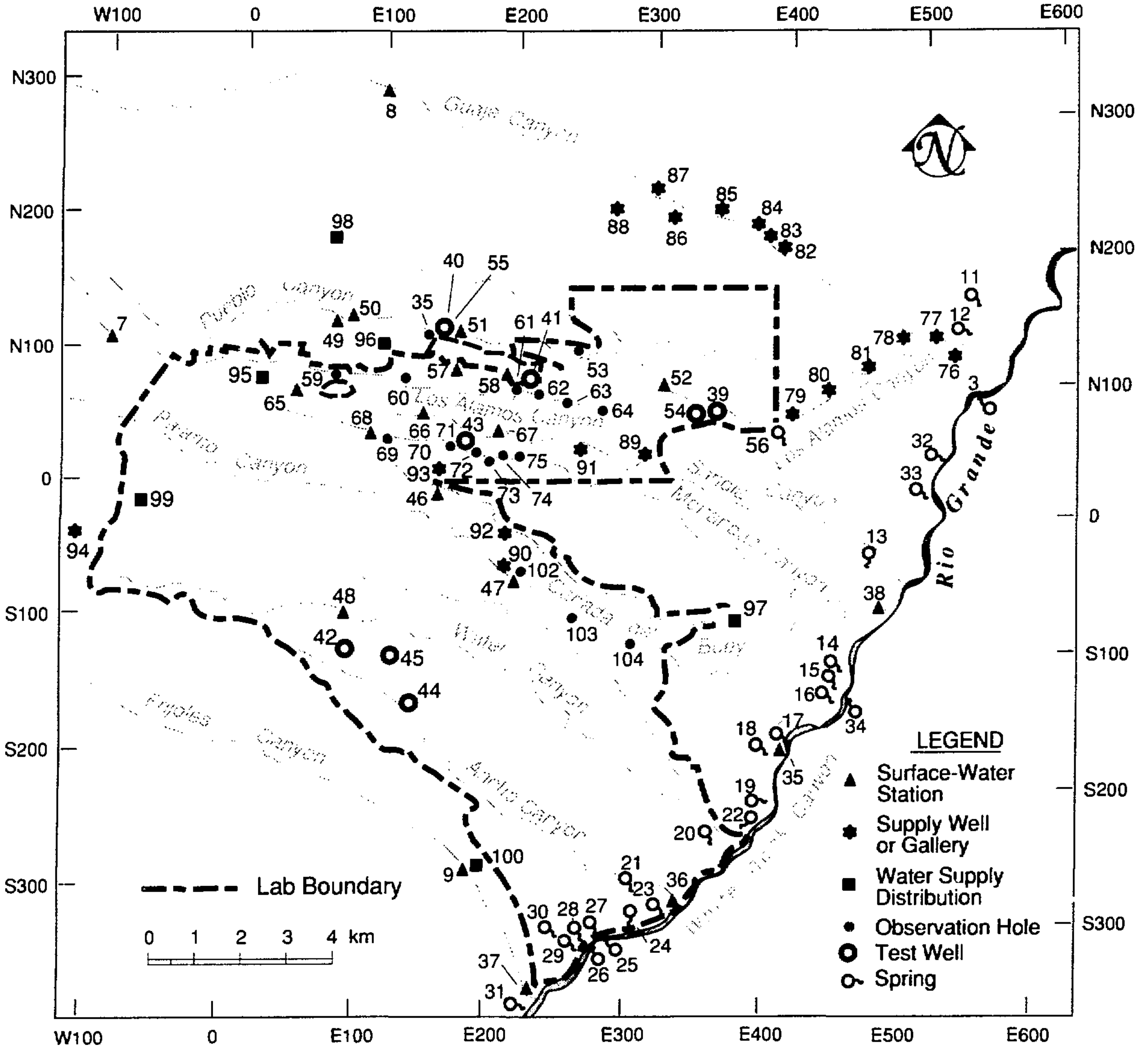

Fig. 15. Surface- and ground-water sampling locations on and near the Laboratory site.

691 m^3/s (24 400 ft^3/s) in 1920. The discharge for water year 1988 (October 1987 through September 1988) ranged from 10 m^3/s (360 ft^3/s) in September to 105 m^3/s (3720 ft^3/s) in May (USGS 1989).

The Rio Chama is a tributary to the Rio Grande upstream from Los Alamos (Fig. 14). At Chamita on the Rio Chama, the drainage area above the station is 8143 km^2 (3143 mi^2) in northern New Mexico, together with a small area in southern Colorado. Since 1971, some flow has resulted from transmountain diversion water from the San Juan drainage. Flow at the Chamita gage is governed by release from several reservoirs. Discharge at Chamita during water year 1988 ranged from 1.5 m^3/s (54 ft^3/s) in July to 64 m^3/s (2270 ft^3/s) in November.

The station at Jemez on the Jemez River drains an area of the Jemez Mountains west of Los Alamos. The Fenton Hill Hot Dry Rock Geothermal Facility (TA-57) is located within this drainage. The drainage area is small, about 1220 km^2 (471 mi^2). During water year 1988, discharge ranged from 0.34 m^3/s (12 ft^3/s) in September to 26 m^3/s

($925\ ft^3/s$) in April. The river is a tributary to the Rio Grande downstream from Los Alamos.

Surface waters from the Rio Grande, Rio Chama, and Jemez River are used for irrigation of crops in the valleys, both upstream and downstream from Los Alamos. These rivers run through recreational areas on state and federal lands.

a. Radiochemical Analyses. Surface-water samples from regional stations were collected in March 1989. Tritium, cesium, plutonium, and total uranium activity levels in these waters were low (Tables 13 and G-16). Samples collected down gradient from the Laboratory showed no effect from the Laboratory's operation. Sampling results in 1989 exhibited no major differences from those in 1988. Maximum concentrations of radioactivity in regional surface-water samples were well below DOE's concentration guides for off-site areas.

b. Chemical Analyses. Surface-water samples from regional stations were collected in March 1989. Maximum concentrations in regional water samples were well below drinking water standards (Tables 14 and G-17). There were some variations from previous years' results. These fluctuations are caused by chemical changes that occur with variations in discharges at the sampling stations. This is normal, and no inference can be made that the water quality at these stations is deteriorating.

3. **Perimeter Stations.** Perimeter stations within 4 km (2.5 mi) of Los Alamos included surface-water stations at Los Alamos Reservoir, Guaje Canyon, Frijoles Canyon, and three springs (La Mesita, Indian, and Sacred springs). Other perimeter stations were in White Rock Canyon along the Rio Grande just east of the Laboratory. Included in this group were stations at 22 springs, 3 streams, and a sanitary effluent release area (Fig. 15 and Table G-15).

Los Alamos Reservoir, in upper Los Alamos Canyon on the flanks of the mountains west of Los Alamos, has a capacity of 51 000 m^3 (41 acre-ft) and a drainage area of 17 km^2 (6.4 mi^2) above the intake. The reservoir is used for storage and recreation. Water flows by gravity through about 10 km (6.4 mi) of water lines for irrigation of lawns and shrubs at the Laboratory's Health Research Laboratory (TA-43), the Los Alamos High School, and the University of New Mexico's Los Alamos Branch.

The station in Guaje Canyon is below Guaje Reservoir, which is located in upper Guaje Canyon and has a capacity of 900 m^3 (0.7 acre-ft) and a drainage area above the intake of about 14 km^2 (5.6 mi^2). The reservoir is used for diversion rather than storage, as flow in the canyon is maintained by perennial springs. Water flows by gravity through 9.0 km (5.6 mi) of water lines for irrigation of lawns and shrubs at Los Alamos Middle School and Guaje Pines Cemetery. The stream and reservoir are also used for recreation.

Water lines from Guaje and Los Alamos reservoirs are not a part of the municipal or industrial water supply at Los Alamos. They are owned by DOE and operated by Pan Am World Services. Diversion for irrigation is usually from May through October.

Surface-water flow in Frijoles Canyon was sampled at Bandelier National Monument Headquarters. Flow in the canyon is from spring discharge in the upper reach of the canyon. Flow decreases as the stream crosses Pajarito Plateau because of seepage and evapotranspiration losses. The drainage area above the monument headquarters is about 45 km^2 (17 mi^2) (Purtymun 1980a).

La Mesita Spring is east of the Rio Grande, whereas Indian and Sacred springs are west of the river in lower Los Alamos Canyon. These springs discharge from faults in the siltstones and sandstones of the Tesuque Formation and from small seepage areas. Total discharge at each spring is probably less than 1 L/s (0.3 gal./s).

Perimeter stations in White Rock Canyon are composed of four groups of springs. The springs discharge from the main aquifer. Three groups (I, II, and III) have similar, aquifer-related chemical quality. Water from these springs is from the main aquifer beneath the Pajarito Plateau (Purtymun 1980b). Chemical quality of spring 3B (group IV) reflects local conditions in the aquifer discharging through a fault in volcanics.

Three streams that flow into the Rio Grande were also sampled. Streams in Pajarito and Ancho canyons are fed from group I springs. The stream in Frijoles Canyon at the Rio Grande is fed by a spring on the flanks of the mountains west of Pajarito Plateau and flows through Bandelier National Monument to the Rio Grande.

Treated sanitary effluent from the community of White Rock was sampled in Mortandad Canyon at its confluence with the Rio Grande.

Detailed results of radiochemical and chemical analyses of samples collected from the perimeter stations are shown in Tables G-18 through G-21.

Table 13. Maximum Concentrations of Radioactivity in Surface and Ground Waters from Off- and On-Site Stations

	Number of Stations Sampled	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	$^{239,240}Pu$ (10^{-9} µCi/mL)
Analytical Limits of Detection		0.7	40	1.0	0.009	0.03
Off-Site Stations (Uncontrolled Areas)						
Derived concentration guide (DCG)[a]		2000	3000	800	400	300
Regional	6	0.2 (0.3)[b]	88 (48)	4.0 (0.1)	0.021 (0.015)	0.013 (0.007)
Perimeter						
Adjacent	6	0.4 (0.3)	188 (92)	10 (1.0)	0.012 (0.012)	0.025 (0.012)
White Rock	24	0.3 (0.3)	186 (65)	23 (4.7)	0.026 (0.013)	0.025 (0.012)
Off-Site Stations Group Summary						
Maximum concentration		0.4 (0.3)	188 (92)	23 (4.7)	0.026 (0.013)	0.025 (0.012)
Maximum concentration as a percentage of DCG		0.02	6.3	2.9	<0.01	<0.01
On-Site Stations (Controlled Areas)						
Noneffluent Release Areas						
Ground water (main aquifer)	5	0.1 (0.3)	40 (38)	2.7 (0.3)	0.019 (0.011)	0.028 (0.011)
Surface water	3	0.6 (0.3)	105 (70)	5.9 (0.6)	0.014 (0.016)	0.010 (0.017)
Observation wells (Pajarito Canyon)	3	0.6 (0.3)	100 (48)	2.0 (1.0)	0.006 (0.015)	0.011 (0.008)
Effluent Release Areas						
Acid-Pueblo canyons	8	0.6 (0.3)	716 (119)	2.8 (1.0)	0.012 (0.010)	0.082 (0.021)
DP–Los Alamos canyons	7	3.8 (0.5)	96 (88)	2.0 (1.0)	0.028 (0.013)	0.018 (0.014)
Sandia Canyon	3	0.7 (0.3)	72 (73)	3.0 (1.0)	0.000 (0.010)	0.005 (0.011)
Mortandad Canyon	7	150 (20)	3130[c] (470)	4.0 (1.0)	7.82 (0.318)	29.9 (1.05)
On-Site Stations Group Summary						
Maximum concentration		150 (20)	3130 (470)	5.9 (0.6)	7.82 (0.318)	29.9 (1.05)
Maximum concentration as a percentage of DCG		7.5	104	0.7	2.0	10

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[a] See Appendix A.

[b] Counting uncertainties are in parentheses.

[c] This concentration was measured in water on site. The water is confined within the Laboratory boundary.

Table 14. Maximum Chemical Concentrations in Surface and Ground Waters from Regional and Perimeter Stations (mg/L)

	Number of Stations	Ca	Na	Cl	F	NO_3-N	TDS[a]
Regional Stations							
Rio Chama	1	47	24	3	0.2	<0.1	158
Rio Grande	4	35	27	11	0.3	0.2	222
Jemez River	1	18	29	23	0.4	<0.1	162
Perimeter Stations							
Surface water	3	8	9	7	0.2	0.1	119
Springs	3	34	34	25	0.5	2.2	199
White Rock Canyon							
Group I	7	20	15	6	0.8	1.2	216
Group II	10	23	23	4	0.8	<5.0	202
Group III	3	20	32	3	1.3	0.6	372
Group IV	1	22	35	3	0.6	2.0	446
Streams	2	21	14	4	0.5	0.7	158
Sanitary effluent	1	29	97	48	1.2	9.0	452
Drinking Water Standard[b]							
(for comparison)		—	—	250	4.0	10	500

[a] Total dissolved solids.

[b] NMEIB (1988) and EPA (1989).

a. Radiochemical Analyses. Measurements of activity in tritium, cesium, plutonium, and total uranium samples collected at perimeter stations were low, to well below, DOE's concentration guides for off-site areas (Tables 13, G-18, and G-20).

b. Chemical Analyses. Maximum chemical concentrations in samples from the perimeter stations are shown in Tables 14, G-19, and G-21. Chemical concentrations in water samples from 21 springs and 3 streams in White Rock Canyon varied slightly but showed no major changes from concentrations recorded for the previous year. Even though none of these waters are used for water supply, maximum concentrations were below standards that apply to drinking water.

4. On-Site Stations. On-site sampling stations are grouped by location in (1) noneffluent release areas and (2) effluent release areas (areas that receive, or have received, treated industrial or sanitary effluents) (Fig. 15, Table G-15).

a. Noneffluent Release Areas. On-site, noneffluent sampling stations consist of seven deep test wells, three surface water sources, and three shallow observation wells. The deep test wells are completed into the main aquifer.

Test wells 1 and 2 are in the lower and middle reaches of Pueblo Canyon. Depths to the top of the main aquifer are 181 and 231 m (594 and 758 ft), respectively. The pumps in test wells 1 and 2 were down for repairs in 1989, and water from the wells was not sampled. Test well 3 in the midreach of Los Alamos Canyon has a depth of 228 m (748 ft) to the top of the main aquifer. Test wells DT-5A, DT-9, and DT-10 are at the southern edge of the Laboratory. Depths to the top of the main aquifer are 359, 306, and 332 m (1180, 1006, and 1090 ft), respectively. Test well 8 is in the midreach of Mortandad Canyon. The top of the main aquifer here lies about 295 m (968 ft) below the surface.

These test wells are constructed to seal out all water above the main aquifer. The wells are used to monitor for potential effects that the Laboratory's operation may have on water quality in the main aquifer.

Surface-water samples are collected in Cañada del Buey and in Pajarito and Water canyons downstream from technical areas to monitor the quality of run-off from these sites.

Three shallow observation wells were drilled in 1985 and cased through the alluvium (thickness about 4 m [12 ft]) in Pajarito Canyon (Fig. 15 and Table G-15). Water in the alluvium is perched on the underlying tuff and is recharged through storm run-off. The observation wells were constructed to determine if technical areas in the canyon or adjacent mesas were affecting the quality of shallow ground water.

Radiochemical concentrations from surface- and ground-water sources showed no effects from Laboratory operations (Tables 13 and G-22). Concentrations of tritium, cesium, and plutonium were at, or below, limits of detection.

Chemical quality of ground water from the test wells into the main aquifer reflected local conditions of the aquifer around the well (Tables 15 and G-23). Quality of surface water and water in observation wells in Pajarito Canyon varied slightly. The effect, if any, was small, and probably was the result of natural seasonal fluctuations.

b. *Effluent Release Areas.* On-site effluent release areas are in canyons that receive, or have received, treated industrial or sanitary effluents. These include DP–Los Alamos, Sandia, and Mortandad canyons. Also included is Acid-Pueblo Canyon, which is a former release area for industrial effluents. Acid-Pueblo Canyon received untreated and treated industrial effluents, which contained residual radionuclides, from 1944 to 1964 (ESG 1981). The canyon also receives treated sanitary effluents from Los Alamos County treatment plants in the upper and middle reaches of Pueblo Canyon. Sanitary effluents form some perennial flow in the canyon but generally have not reached the confluence with Los Alamos Canyon except during storm or snowmelt run-off.

Water occurs seasonally in the alluvium, depending on the volume of surface flow from sanitary effluents and storm run-off. Hamilton Bend Spring, which discharges from alluvium in the lower reach of Pueblo Canyon, is dry part of the year. The primary sampling stations are surface-water stations at Acid Weir, Pueblo 1, Pueblo 2, and Pueblo 3 (Table G-15). Two other sampling stations are located in the middle reach (test well 2A) and lower reach (test well 1A) of Pueblo Canyon. Test well 2A (drilled to a depth of 40.5 m [133 ft]) penetrates the alluvium and Bandelier Tuff and is completed into the Puye Conglomerate. Aquifer tests indicate that the perched aquifer is of limited extent. Measurements of water levels over a period of time indicate that the perched aquifer is hydrologically connected to the stream in Pueblo Canyon. Perched water in the basaltic rocks is sampled from test well 1A and Basalt Spring, further eastward in lower Los Alamos Canyon. Recharge to the perched aquifer in the basalt occurs near Hamilton Bend Spring. Travel time for water from the recharge area near Hamilton Bend Spring

Table 15. Maximum Chemical Concentrations in Surface and Ground Waters from On-Site Stations (mg/L)

	Number of Stations Sampled	Ca	Na	Cl	F	NO_3-N	TDS
Ground Water							
(main aquifer)	5	17	17	3	0.4	0.6	179
Surface Water	3	77	113	194	0.4	0.3	579
Observation Wells							
(Pajarito Canyon)	3	18	23	25	0.2	0.1	144
Drinking Water Standard[a]							
(for comparison)		—	—	250	4.0	10	500

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[a] NMEIB (1988) and EPA (1989).

to test well 1A is estimated to be 1 to 2 months, with another 2 to 3 months required to reach Basalt Spring.

DP–Los Alamos Canyon has received treated industrial effluents, which contain some radionuclides and some sanitary effluents from treatment plants at TA-21. Treated industrial effluents have been released into the canyon since 1952. During 1989, no liquid discharges were released from TA-21. In the upper reaches of Los Alamos Canyon (above station LAO-1), there were occasional releases of cooling water from the research reactor at TA-2. Los Alamos Canyon also receives discharge from the lagoons at LAMPF (TA-53). On the flanks of the mountains, Los Alamos Reservoir impounds run-off from snowmelt and rainfall. Stream flow from this impoundment into the canyon is intermittent, dependent on precipitation to cause run-off to reach the Laboratory boundary at State Road 4.

Infiltration of treated effluents and natural run-off from the stream channel maintains a shallow body of water in the alluvium of Los Alamos Canyon. Water levels are highest in late spring from snowmelt run-off and in late summer from thundershowers. Water levels decline during the winter and early summer, when storm run-off is at a minimum. Sampling stations consist of two surface-water stations in DP Canyon and six observation wells completed into the alluvium in Los Alamos Canyon (Table G-15).

Sandia Canyon has a small drainage area that heads on Pajarito Plateau at TA-3. The canyon receives cooling tower blowdown from the TA-3 power plant and treated sanitary effluents from TA-3. Treated effluents from a sanitary treatment plant form a perennial stream in a short reach of the upper canyon. Only during heavy summer thundershowers in the drainage area does stream flow reach the Laboratory boundary at State Road 4. Two monitoring wells in the lower canyon just west of State Road 4 indicate that no perched water is in the alluvium in this area. Three surface-water sampling stations in the reach of the canyon contain perennial flow (Table G-15).

Mortandad Canyon has a small drainage area that also heads at TA-3. Industrial liquid wastes containing radionuclides are collected and processed at the industrial waste treatment plant at TA-50. After treatment that removes most of the radioactivity, the effluents are released into Mortandad Canyon. Velocity of water movement in the perched aquifer ranges from 18 m/day (59 ft/day) in the upper reach to about 2 m/day (7 ft/day) in the lower reach (Purtymun 1974c, 1983). The top of the main aquifer is about 290 m (950 ft) below the perched aquifer. Hydrologic studies in the canyon began in 1960. Since that time, there has been no surface-water flow beyond the Laboratory's boundary because the small drainage area in the upper part of the canyon results in limited run-off and because a thick section of unsaturated alluvium in the lower canyon allows rapid infiltration and storage of run-off when it does occur. Monitoring stations that were sampled in the canyon this year consist of one surface-water station (gaging station 1, GS-1) and six observation wells completed into the shallow alluvial aquifer. At times, wells in the lower reach of the canyon are dry.

Acid-Pueblo, DP-Los Alamos, Sandia, and Mortandad canyons all contain surface and shallow ground waters with measurable amounts of radioactivity (Tables 13 and G-24). Radionuclide concentrations from treated effluents decreased down gradient in the canyon because of dilution and adsorption of radionuclides on alluvial sediments. Surface and shallow ground waters in these canyons are not a source of municipal, industrial, or agricultural water supply. Only during periods of heavy precipitation or snowmelt would waters from Acid-Pueblo, DP–Los Alamos, or Sandia canyons extend beyond Laboratory boundaries and reach the Rio Grande. In Mortandad Canyon, there has been no surface run-off to the Laboratory's boundary since hydrologic studies were initiated in 1960. This was 3 years before the treatment plant at TA-50 began releasing treated effluents into the canyon (Purtymun 1983).

Maximum chemical concentrations occurred in water samples taken near treated effluent outfalls (Tables 16 and G-25). Chemical quality of the water improved down gradient from the outfalls. Relatively high nitrate concentrations were found in waters from Mortandad Canyon, which receives the largest volume of industrial effluents (Purtymun 1977). Although the concentrations of some chemical constituents in the waters of these canyons were elevated above natural background (because of industrial and sanitary effluents), the concentrations do not cause concern because these on-site surface and shallow ground waters are not a source of municipal, industrial, or agricultural water supply. Surface-water flows in Acid-Pueblo and DP–Los Alamos canyons reach the Rio Grande only during spring snowmelt or heavy summer thunderstorms. No surface run-off to, or beyond, the Laboratory boundary has been recorded in Mortandad Canyon since 1960 when observations began.

Table 16. Maximun Chemical Concentrations in Water from On-Site Effluent Release Areas (mg/L)

	Number of Stations	Ca	Na	Cl	F	NO_3-N	TDS
Acid-Pueblo Canyon	8	34	140	239	0.8	3.7	452
DP–Los Alamos Canyon	8	48	125	140	1.4	0.4	430
Sandia Canyon	3	21	140	72	0.6	4.1	412
Mortandad Canyon	7	210	320	352	7.2	117	1780
Drinking water standard[a] (for comparison)		—	—	250	4.0	10	500

[a] NMEIB (1988) and EPA (1989).

5. Water Supply System. The main aquifer is the only aquifer in the area capable of municipal and industrial water supply (Sec. II). Water for the Laboratory and community is supplied from 17 deep wells in 3 well fields and 1 gallery. The well fields are on Pajarito Plateau and in canyons east of the Laboratory (Fig. 16). Seven test wells are also completed into the main aquifer.

The Los Alamos well field comprises five producing wells and one standby well. Well LA-6 is on standby status, to be used only in case of emergency. Water from this well contains excessive amounts of natural arsenic (up to 0.200 mg/L) and exceeds drinking water limits (Purtymun 1977). Wells in the field range in depth from 265 to 610 m (870 to 2000 ft). Movement of water in the upper 411 m (1350 ft) of the main aquifer in this area is eastward at about 6 m/yr (20 ft/yr) (Purtymun 1984). Well LA-4 in the field was inoperative during 1989, and no samples were collected.

The Guaje well field is composed of seven producing wells. Wells in this field range in depth from 463 to 610 m (1520 to 2000 ft). Movement of water in the upper 430 m (1410 ft) of the aquifer is southeastward at about 11 m/yr (36 ft/yr) (Purtymun 1984).

The Pajarito well field is composed of five wells ranging in depth from 701 to 942 m (2300 to 3090 ft). Movement of water in the upper 535 m (1750 ft) of the aquifer is eastward at 29 m/yr (95 ft/yr).

Water for drinking and industrial use is also obtained from a well at the Laboratory's experimental geothermal site (Fenton Hill, TA-57) about 45 km (28 mi) west of Los Alamos. The well is about 133 m (436 ft) deep, completed in volcanics.

All water comprising the municipal and industrial supply is pumped from wells, piped through transmission lines, and lifted by booster pumps into reservoirs for distribution to the community and Laboratory. Water from the gallery flows by gravity through a microfilter station and is pumped into one of the reservoirs for distribution. All supply water is chlorinated before entering the distribution system.

Water in the distribution systems was sampled at five community and Laboratory locations (fire stations) and at Bandelier National Monument and Fenton Hill (Fig. 16, Table G-15). For results from routine surveillance monitoring of individual wells for environmental quality, federal and state standards (Appendix A) are cited, but are used only for purposes of general comparison. Sampling to confirm compliance with federal and state drinking water standards in the distribution system is discussed in Sec. VIII.E.

a. Radioactivity in the Municipal and Industrial Water Supply. The maximum radioactivity concentrations found in the water supply (wells and gallery) and distribution (including Fenton Hill) systems are shown in Tables 17 and G-26. Analyses of water from each of the wells showed that concentration levels were below the drinking water regulatory levels applicable to the distribution system, with the exception of one gross alpha measurement. That measurement, when adjusted for the natural uranium content, was equal to the gross alpha limit. Cesium levels were within a factor of 2 of the individual sample analytical detection limits and do not indicate any contamination. Water in the distribution

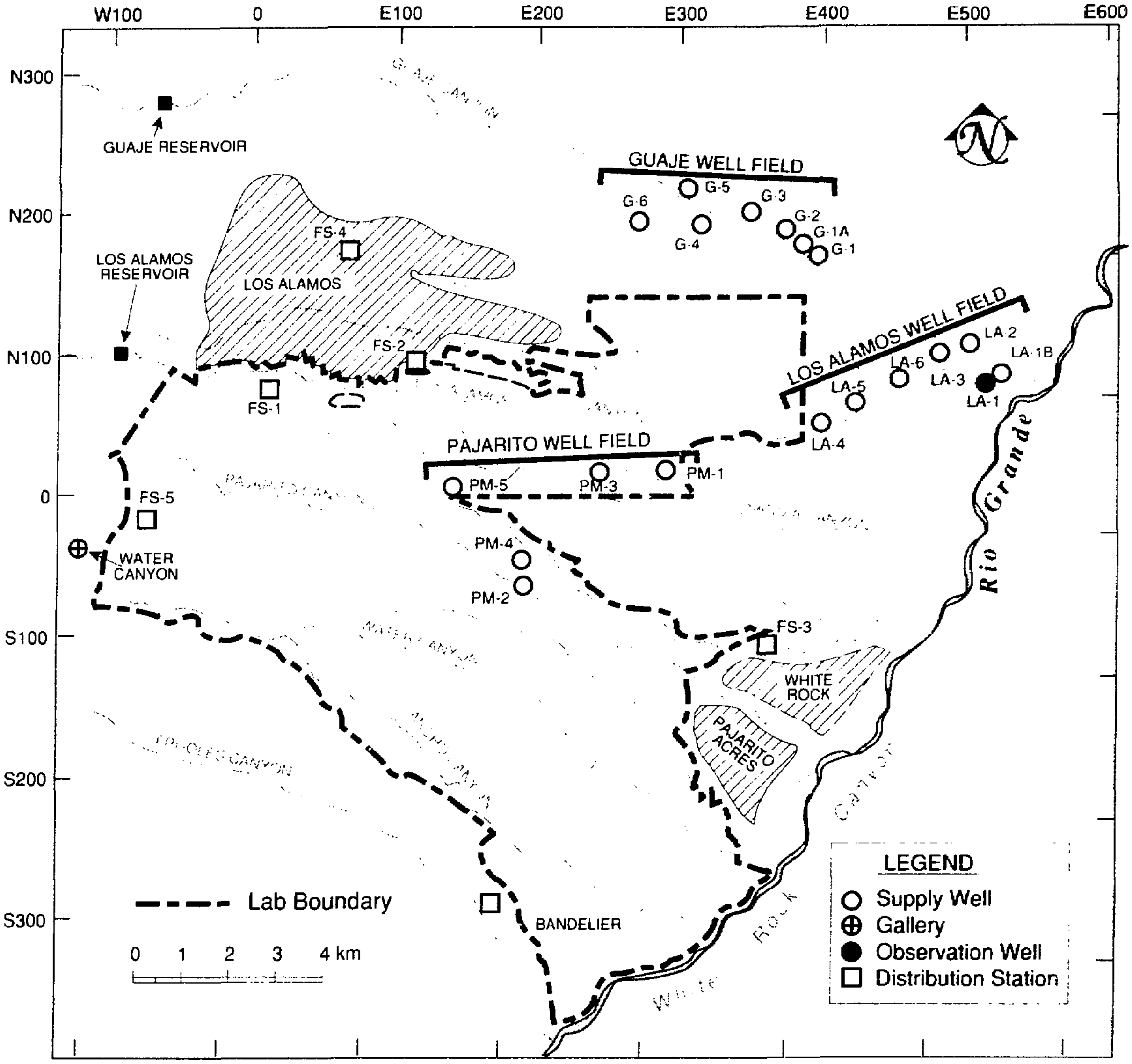

Fig. 16. Locations of reservoirs, well fields, supply wells, and gallery water supply.

system was in compliance with drinking water regulations (see Sec. VIII.E).

b. Chemical Quality of the Municipal and Industrial Water Supply. The chemical quality of water from wells and the distribution systems is within EPA's primary and secondary standards (Tables 18, G-27, and G-28) for all but one secondary parameter. Iron was 150% of the standard in the sample from one supply well, PM-5 (Table G-27). The well has previously shown a much lower level of iron; other parameters showed no significant change from those in previous years.

The quality of water from the wells varied with local conditions within the same aquifer (Tables G-27 and G-28). Water quality depends on well depth, lithology of the aquifer adjacent to the well, and yield from beds within the aquifer.

6. Transport of Radionuclides in Surface Run-Off. The major transport of radionuclides from canyons

Table 17. Maximum Concentrations of Radioactivity in Water from Supply Wells and the Distribution System

	Number of Stations Sampled	^{3}H (10^{-6} μCi/mL)	^{137}Cs (10^{-9} μCi/mL)	Total Uranium (μg/L)	^{238}Pu (10^{-9} μCi/mL)	^{239,240}Pu (10^{-9} μCi/mL)	Gross Alpha (10^{-9} μCi/mL)	Gross Beta (10^{-9} μCi/mL)
Analytical limits of detection		0.7	40	1.0	0.009	0.03	3	3
Maximum contaminant level (MCL)[a]		20	200	800[b]	15	15	15	—
Supply wells (Los Alamos)	16	0.4 (2)[c]	147 (74)	7.1 (<1)	0.039 (<1)	0.025 (<1)	18 (120)	10 (—)
Distribution (Los Alamos)	6	0.1 (<1)	100 (50)	5.4 (<1)	0.009 (<1)	0.009 (<1)	4 (27)	6.5 (—)
Distribution (Fenton Hill)	1	0.3 (2)	−37 (<1)	4.3 (<1)	0.000 (0)	0.005 (<1)	3 (20)	5.0 (—)

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[a] NMEIB (1988) and EPA (1989).

[b] DOE Derived Concentration Guide (see Appendix A).

[c] Percentages of MCL are in parentheses. The regulations are applicable to water in the distribution system but are used for comparison only in the case of individual supply wells.

Table 18. Maximum Chemical Concentrations in Water from Supply Wells and the Distribution System

	Standard[a]	Supply Wells	Percentage of Standard	Distribution System	Percentage of Standard
Number of Stations		16		7	
Chemical Constituents (mg/L)					
Primary					
Ag	0.05	0.001	<2	0.001	<2
As	0.05	0.042	84	0.018	2
Ba	1.0	0.090	9	0.060	6
Cd	0.01	0.006	60	0.001	10
Cr	0.05	0.024	48	0.020	40
F	4.0	2.9	73	1.8	45
Hg	0.002	<0.0002	<10	<0.0002	10
NO_3 (N)	10	0.6	6	0.4	4
Pb	0.05	0.015	30	0.006	12
Se	0.01	0.001	<10	0.001	10
Secondary					
Cl	250	16	6	59	24
Cu	1.0	0.071	7	0.071	7
Fe	0.3	0.45	150	0.110	37
Mn	0.05	0.017	34	0.007	14
SO_4	250	38	15	21	8
Zn	5.0	0.019	<1	0.108	2
TDS	500	427	85	334	78

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[a] EPA primary and secondary drinking water standards are given for comparison only (see Appendix A).

that have received treated, low-level radioactive effluents is by surface run-off. Radionuclides in the effluents may become adsorbed or attached to sediment particles in the stream channels. Concentrations of radioactivity in the alluvium are highest near the treated effluent outfall but decrease down gradient in the canyon as the sediments and radionuclides are transported and dispersed by other treated industrial effluents, sanitary effluents, and surface run-off.

Surface run-off occurs in two modes: (1) spring snowmelt run-off occurs over a long period of time (days) at a low discharge rate and sediment load; (2) summer run-off from thunderstorms occurs over a short period of time (hours) at a high discharge rate and sediment load.

Four samples of summer run-off were analyzed for radioactivity in solution and suspended sediments in Los Alamos and Pueblo canyons near the Laboratory boundary and well LA-5 (Fig. 15 and Table G-29). These summer run-off samples contained only background amounts of tritium, cesium, uranium, plutonium, and gross gamma in solution (Table G-29). Concentrations of plutonium were above background levels in the suspended sediments of Los Alamos and Pueblo canyons (both formerly received industrial effluents). Cesium was above background in the suspended sediments of Los Alamos Canyon (Table 19). Other radionuclides in the suspended sediments were below background levels. Radioactivity in solution refers to the filtrate that passes

Table 19. Plutonium and Cesium in Suspended Sediments in Summer Run-Off in Los Alamos and Pueblo Canyons (pCi/g)[a]

	^{238}Pu	^{239,240}Pu	^{137}Cs
Los Alamos at State Road 4			
14:30	0.299	0.460	6.2
14:50	1.56	2.07	10.3
Pueblo at State Road 4			
15:05	0.010	1.76	0.4
Los Alamos below Pueblo			
15:15	0.213	1.34	5.6
Background (1974–1986)	0.006	0.023	0.44

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[a] Samples were collected September 5, 1989.

through a 0.45-µm pore-size filter; radioactivity in suspended sediments refers to the residue retained by the filter.

7. Organic Analyses of Surface and Ground Water. Surface- and ground-water samples for organic analyses were collected from regional surface-water sources (6 samples); the Laboratory on-site Pajarito Canyon observation wells (3 samples); and Laboratory on-site effluent release areas in Acid-Pueblo (7 samples), Los Alamos (7 samples), Sandia (3 samples), and Mortandad (7 samples) canyons. All samples were analyzed for 65 volatile compounds, 68 semivolatile compounds, 13 pesticide compounds, 4 herbicide compounds, and 4 polychlorinated biphenyl (PCB) compounds (Table G-30). The limits of quantification (LOQs) for these compounds are given in Appendix C. Of the nearly 5000 possible positive results, only 5 were found at levels above the LOQ. Only those compounds that exceeded the LOQs are discussed and shown in Table 20.

Table 20. Water Samples That Exceeded the LOQs for Volatile and Semivolatile Organic Compounds

Station	Compound	Concentration (µg/L)	LOQ (µg/L)
Volatile Organic Compounds			
PCO-2	Carbon disulfide	20	10
Pueblo 2	2-Butanone	15	10
Pueblo 3	2-Butanone	13	10
MCO-3	Trichlorofluormethane	200	200[a]
Semivolatile Organic Compounds			
MCO-7	Bis(2-ethylhexyl)phthalate	10	10

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[a] Spiked compound recovery was poor; the LOQ was estimated at 200 µg/L.

a. Volatile Compounds. Water samples from the 33 stations were analyzed for 65 volatile compounds (Table G-30). Carbon disulfide was reported from a shallow well, PCO-2, in Pajarito Canyon, at a concentration of 20 µg/L (the LOQ is 10 µg/L). In Pueblo Canyon, 2-butanone was reported in surface water at wells Pueblo 2 (15 µg/L, the LOQ is 10 µg/L) and Pueblo 3 (13 µg/L). Trichlorofluormethane, with a concentration of 200 µg/L (LOQ estimated at 200 µg/L), was reported from Mortandad Canyon (Table 20).

b. Semivolatile Compounds. Water from the 33 stations was analyzed for 68 semivolatile compounds (Table G-30). Only one station reported any semivolatile compounds in excess of the LOQ: bis(2-ethylhexyl)-phthalate, with a concentration of 10 µg/L (LOQ is 10 µg/L), was reported from shallow well MCO-7 in Mortandad Canyon (Table 20).

c. Pesticides. Water from 28 stations was analyzed for 13 pesticide compounds (Table G-30). No compounds above the LOQ were reported. Pesticide analyses for samples from five stations in Mortandad Canyon were not completed because of laboratory problems.

d. Herbicides. Water from 33 stations was analyzed for 4 herbicide compounds. No compounds above the LOQ were reported (Table G-30).

e. PCBs. Water from 28 stations was analyzed for 4 PCB compounds. No compounds above the LOQs were reported from the 28 stations. PCB analyses for samples from five stations in Mortandad Canyon were not completed because of laboratory problems.

C. Radioactivity in Soils and Sediments

1. Background Levels of Radioactivity in Soils and Sediments. Soil and sediment samples from regional stations were routinely collected and analyzed for radionuclides from 1974 through 1986 (Purtymun 1987a). The results were used to establish background levels of ^{3}H, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu in soils and sediments (Table 21). The average of the concentration levels in these samples plus twice the standard deviation was used to establish the upper limits of background concentrations. In 1989, samples were collected from 7 regional soil stations and 9 regional sediment stations (Table G-31), and concentrations of radionuclides in samples from these regional stations were measured. Results of the analyses are presented in Tables 21 and G-32. See Appendix B for a description of methods for collecting soil and sediment samples.

2. Perimeter Soils and Sediments. Samples were collected from six soil stations within 4 km (2.5 mi) of the Laboratory perimeter. Samples were also collected from 10 sediment stations near the Laboratory boundary and at the confluence of eight major canyons with the Rio Grande (Figs. 17 and 18). Perimeter soil and sediment sampling stations are listed in Table G-31, and detailed analytical results are given in Table G-33.

Concentrations of radioactivity in the perimeter soil samples exceeded statistically established regional background concentrations by as much as a factor of 2 for ^{239,240}Pu. These results are similar to results obtained in 1988.

Analyses of sediment samples from the perimeter stations indicated that concentrations of radionuclides were below statistically established regional background levels (Table 21).

3. On-Site Soils and Sediments. Soil samples were collected from 10 stations within Laboratory boundaries, and on-site sediment samples were collected from 24 stations within areas that have received treated effluent (Table G-31, Figs. 17 and 18).

Concentrations of ^{137}Cs and ^{239,240}Pu in soil samples exceeded statistically established regional background limits by as much as a factor of 1.4. The concentrations were within the ranges observed in previous years and did not indicate any new releases (Tables 21 and G-34). Tritium at one on-site station (Fig. 17, location S13) was about 15 times the regional background limit; no known release at that location could explain the anomaly, and the location will be resampled during the next routine collection.

Three canyons (Acid-Pueblo, DP–Los Alamos, and Mortandad) contain sediments contaminated with residual radioactivity from past or present releases of effluents (see Sec. VI.B.4.b). The concentrations of radionuclides in these canyons exceed statistically established regional background levels (Table 21). The concentrations in sediments from Pueblo and DP–Los Alamos canyons

Table 21. Maximum Concentrations of Radionuclides in Soils and Sediments

	Number of Sations Sampled	^{3}H (10^{-6} µCi/mL)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)
Analytical Limits of Detection		0.7	0.1	0.3	0.003	0.002
Soils						
Background (1974–1986)[a]	5	7.2	1.09	3.4	0.005	0.025
Regional stations	7	1.4 (0)[b]	0.88 (0)	3.8 (1)	0.003 (0)	0.019 (0)
Perimeter stations	6	3.8 (0)	1.1 (1)	5.8 (2)	0.008 (1)	0.048 (1)
On-site stations	10	120 (2)	1.3 (1)	4.0 (8)	0.005 (0)	0.035 (1)
Sediments						
Background (1974–1986)[a]	10	—	0.44	4.4	0.006	0.023
Regional stations	9	—	0.28 (0)	3.2 (0)	0.006 (0)	0.006 (0)
Perimeter stations	18	—	0.18 (0)	3.2 (0)	0.004 (0)	0.008 (0)
On-site stations (effluence release areas)						
Acid-Pueblo Canyon	6	—	0.41 (0)	3.0 (0)	0.53 (1)	9.3 (3)
DP–Los Alamos Canyon	11	—	2.5 (3)	4.5 (1)	0.19 (4)	0.47 (7)
Mortandad Canyon	7	—	26.7 (4)	4.6 (1)	4.1 (4)	14.5 (3)

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[a] The $\bar{x} + 2s$ (97.5 percentile value) of background analyses for soil and sediments (Purtymun 1987a).

[b] Numbers in parentheses indicate number of stations exceeding the 97.5 percentile background value.

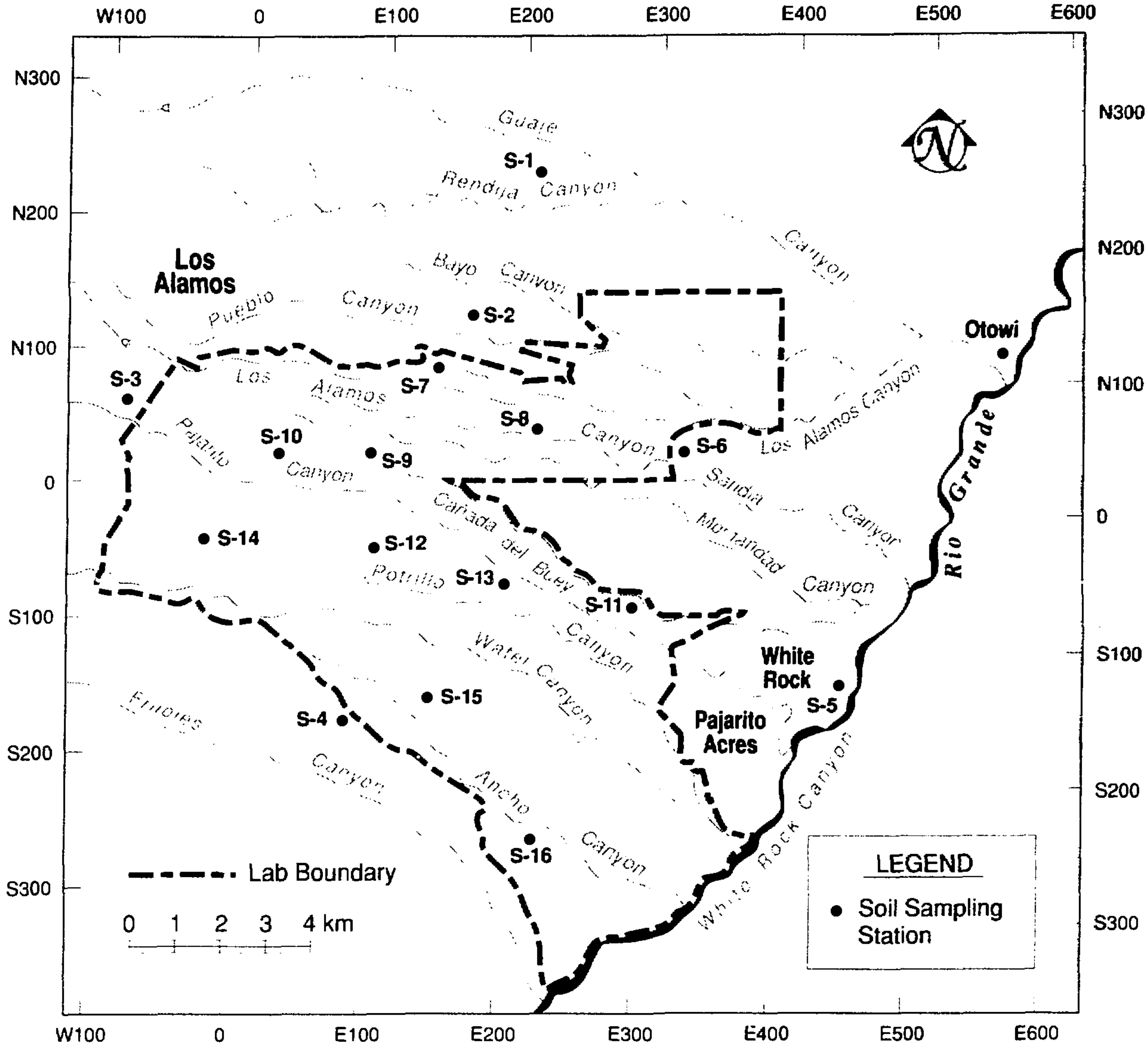

Fig. 17. Soil sampling locations on and near the Laboratory site.

generally decrease down gradient as the radionuclides are dispersed and mixed with uncontaminated sediments (Table G-34). Some of these sediments are transported into the Rio Grande. Theoretical estimates (ESG 1981), confirmed by actual measurement (see Sec. VI.C.4), show that the incremental contribution to radioactivity in sediments from Cochiti Reservoir is a small percentage of the contribution attributable to typical regional background levels. The resultant incremental doses through food pathways (see Sec. VII.C) are well below DOE's applicable RPS.

The concentrations in Mortandad Canyon also decrease down gradient; however, no run-off has reached, or extended past, the Laboratory boundary since before the TA-50 treatment plant started operating in 1963.

4. Sediments in Regional Reservoirs. Reservoir sediments were collected from three locations in the

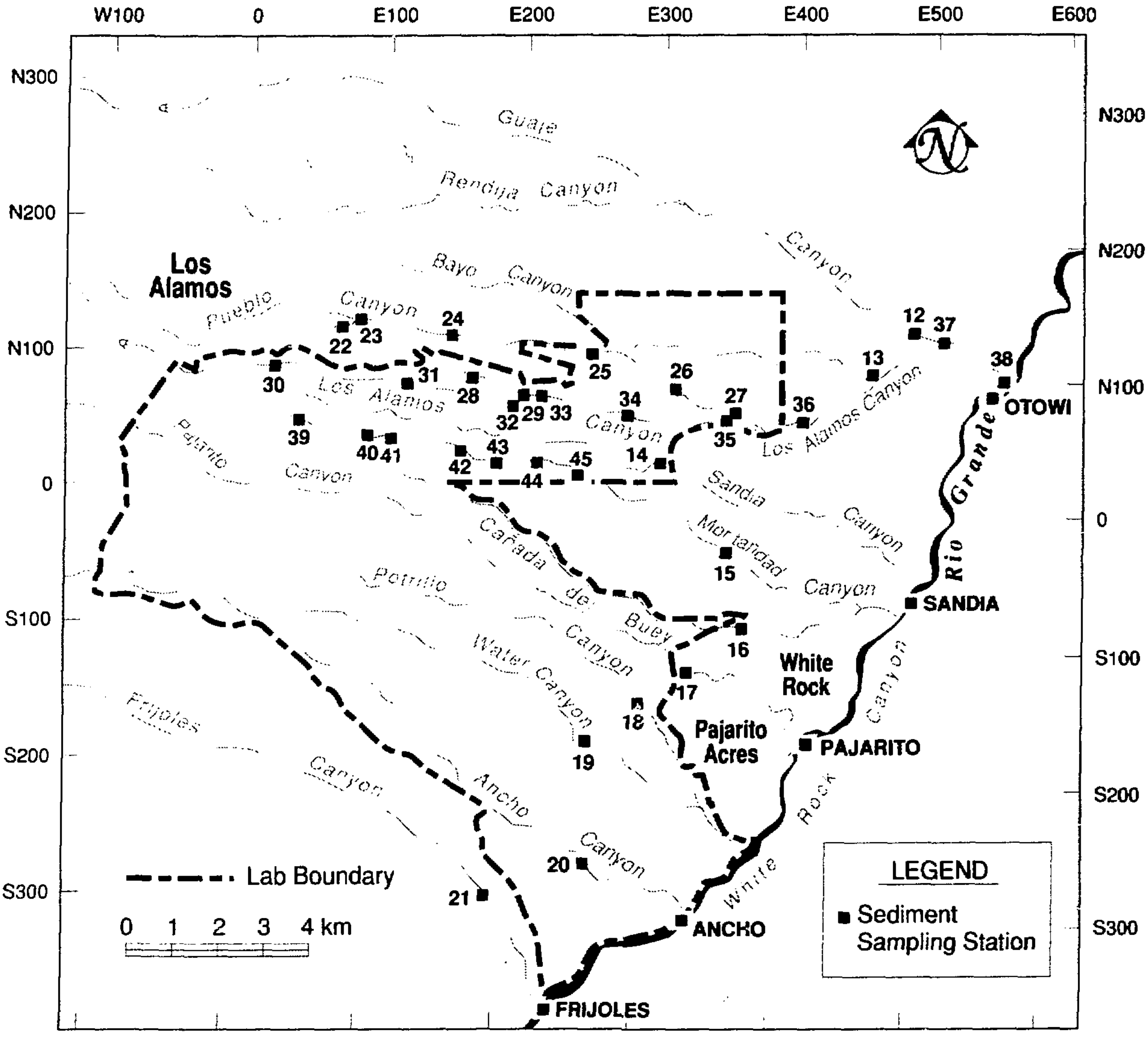

Fig. 18. Sediment sampling locations on and near the Laboratory site.

Abiquiu Reservoir on the Rio Chama and three locations in the Cochiti Reservoir on the Rio Grande south of Los Alamos (Fig. 19). Sediment samples were analyzed for ^{238}Pu and ^{239,240}Pu using 1-kg (2-lb, dry weight) samples (100 times the usual mass used for analyses). Large samples increase the sensitivity of the plutonium analyses and are necessary to effectively evaluate background plutonium concentrations for fallout from atmospheric tests. Normal sample sizes were used for analyzing for ^{3}H, ^{137}Cs, ^{90}Sr, and total uranium (Table G-35).

The cesium concentration of 0.60 pCi/g from the lower station at Cochiti exceeded the statistically established background level of 0.44 pCi/g. The strontium concentration of 2.1 pCi/g from the middle station at Abiquiu exceeded the statistically established background level of 0.87 pCi/g. Samples that occasionally exceed statistical limits are expected because of natural variability and do not necessarily indicate contamination. This is supported by the overall pattern of cesium and strontium concentrations in samples from the rest of the stations, all

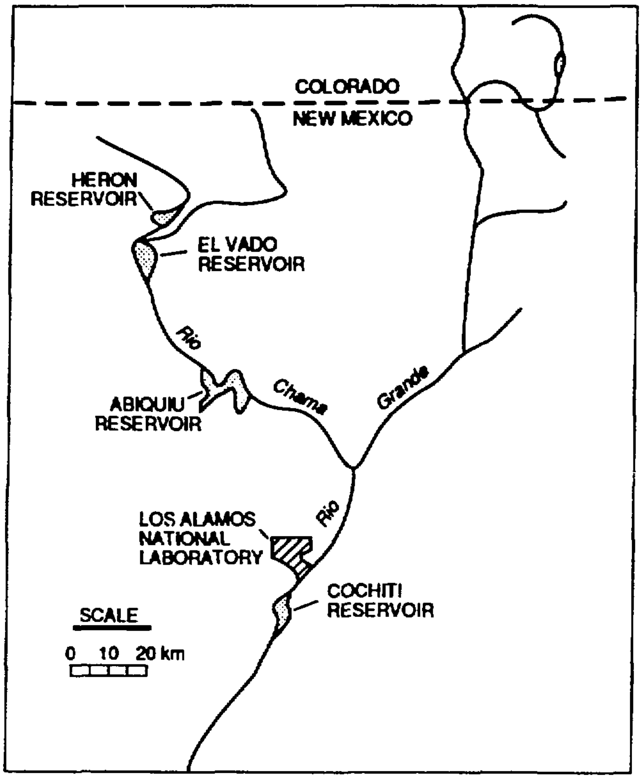

Fig. 19. Regional reservoirs for special sediment sampling.

of which were below background (Table G-35). Total uranium was below background at all six stations.

Levels of plutonium in samples collected in 1989 were similar to plutonium levels found in samples collected in previous years, when the concentrations were consistently higher at Cochiti Reservoir (Tables 22 and G-35). Sediments in Cochiti Reservoir contain a higher fraction of finer particles and organic materials than do sediments from Abiquiu. These characteristics enhance the capacity of sediment to adsorb plutonium and other metal ions. Only 1 of the 12 plutonium samples collected had concentrations that exceeded the statistically established background level. The sample from the middle station at Cochiti showed concentrations of 0.133 pCi/g, to be compared with the 97.5 percentile background level of 0.023 pCi/g. Since 1984, the average ratio of ^{238}Pu to ^{239,240}Pu ranged from 12 to 25 at Abiquiu Reservoir; the ratio at Cochiti ranged from 7 to 28. The plutonium isotopic ratio in worldwide fallout for northern New Mexico is about 20.

Variations in concentrations of plutonium, which also affect calculations of isotopic ratios, occur because fallout varies in the different areas where samples are taken, because of natural variation in transport processes from land surfaces into rivers, and because analyses become less precise as values approach detection limits.

Cesium, strontium, total uranium, and plutonium concentrations in the reservoir sediments are low (generally below background, but occasionally slightly above) and result in doses through food pathways that are only a fraction of a percentage of DOE's applicable RPS (see Sec. VII).

5. Transport of Radionuclides in Sediments and Run-Off from an Active Waste Management Area (TA-54). Radionuclides transported by surface run-off have an affinity for sediment particles, attached by ion exchange or adsorption. Thus, radionuclides in surface run-off tend to concentrate in sediments. Nine sampling stations were established in 1982 outside the perimeter

Table 22. Plutonium Analyses from Reservoirs on the Rio Chama and Rio Grande (fCi/g)[a]

		^{238}Pu	^{239,240}Pu	Ratio (^{239,240}Pu/^{238}Pu)
Abiquiu Reservoir				
1984	$\bar{x}$ (s)	0.7 (0.4)	12.7 (6.3)	18
1985	$\bar{x}$ (s)	0.7 (0.5)	8.8 (0.9)	12
1986	$\bar{x}$ (s)	0.3 (0.1)	7.5 (1.7)	25
1987	$\bar{x}$ (s)	0.2 (0.1)	3.8 (3.1)	19
1988	$\bar{x}$ (s)	0.3 (0.2)	7.5 (2.6)	25
1989	Upper	0.2 (0.1)	4.1 (0.2)	20
	Middle	0.3 (0.1)	3.6 (0.1)	12
	Lower	0.2 (0.1)	3.3 (0.2)	16
	$\bar{x}$ (s)	0.2 (0.6)	3.7 (0.4)	18
Cochiti Reservoir				
1984	$\bar{x}$ (s)	0.7 (1.1)	19.7 (14.0)	28
1985	$\bar{x}$ (s)	1.6 (0.6)	24.1 (7.3)	15
1986	$\bar{x}$ (s)	1.2 (0.5)	21.2 (6.1)	18
1987	$\bar{x}$ (s)	0.8 (0.7)	17.5 (13.8)	22
1988	$\bar{x}$ (s)	1.7 (2.3)	21.1 (2.9)	7
1989	Upper	0.7 (0.1)	12.9 (0.5)	20
	Middle	5.1 (0.1)	133.0 (7.0)	14
	Lower	1.7 (0.1)	2.0 (0.3)	1
	$\bar{x}$ (s)	2.5 (2.3)	49.3 (7.3)	20
Background				
(1974–1986)[b]		6.0	23.0	

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[a] Samples were collected in June 1989.

[b] Purtymun (1987a).

fence at Area G (TA-54) to monitor possible transport of radionuclides by storm run-off from the waste storage and disposal area (Fig. 20). The samples were collected in August 1989 (Table G-36).

a. *Radioactivity.* Some radionuclides are transported from the surface at Area G in suspended or bed sediments. This contamination is from the land surface and is not related to the wastes in the pits and shafts. It is residual contamination in the land surface that occurred during handling of the wastes. Total uranium in bed sediments at station 5 (4.6 µCi/g) was slightly above the background level of 4.4 µCi/g. Plutonium-238 in excess of background (0.006 pCi/g) occurred at station 7 (0.026 pCi/g) and station 9 (0.011 pCi/g). Plutonium-239,240 exceeded background (0.023 pCi/g) at station 9 (0.150 pCi/g). Tritium, cesium, and gross gamma were near, or below, background. When combined with storm run-off in Cañada del Bucy or Pajarito Canyon, the concentrations of radionuclides in the sediments from Area G are dispersed and are not detectable at the Laboratory boundary at State Road 4.

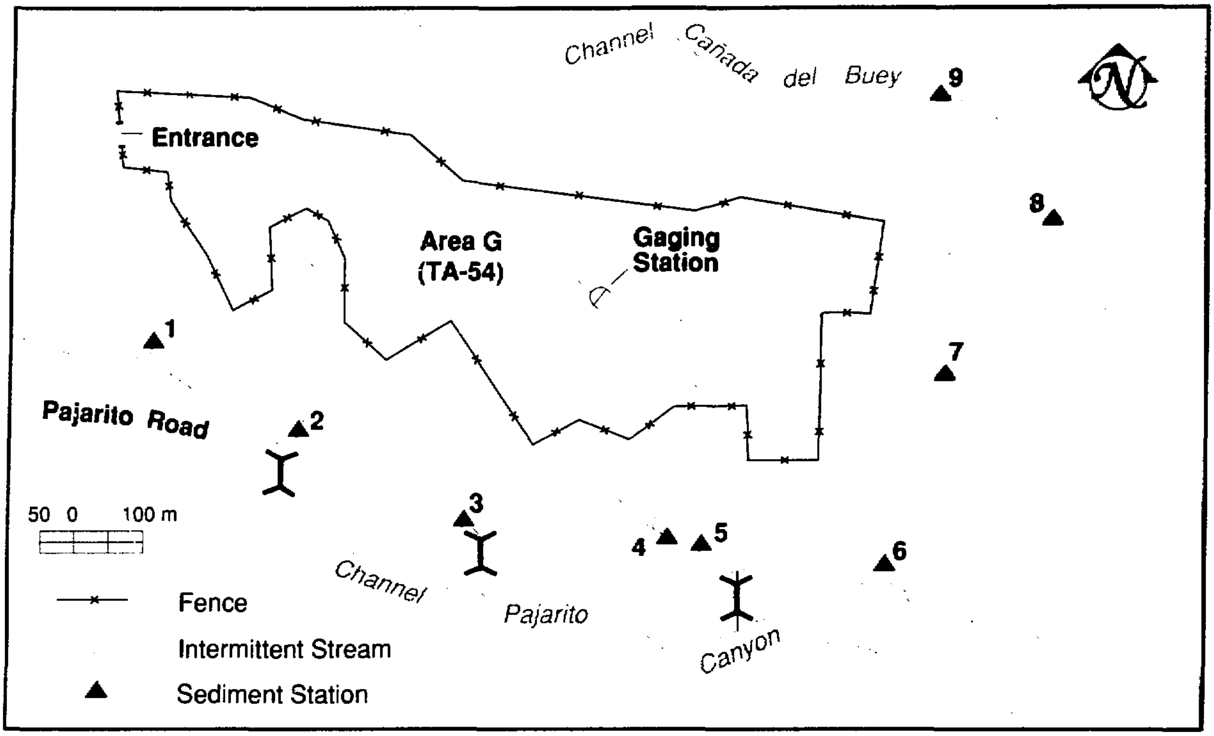

Fig. 20. Locations of sampling stations for surface run-off at TA-54.

b. Organic Analyses of Bed Sediments. Samples of bed sediments were collected from the 9 sediment stations around Area G and were analyzed for 65 volatile compounds, 68 semivolatile compounds, 22 pesticide compounds, 3 herbicide compounds, and mixed PCBs (Table G-37). Because of analytical laboratory soil methodology and instrument problems, the LOQs for these analyses were higher (500–1000 µg/kg) than those for analyses obtained using normal procedures, as described in Appendix C. Only those compounds with concentrations that exceeded the LOQs are discussed (Table 23).

(1) Volatile Compounds. Samples of sediments from the 9 stations were analyzed for 65 volatile compounds; 4 were reported (Table 23).

The compound 2-butanone was reported at all the stations, in concentrations ranging from 590 to 3500 µg/kg; chloroform was reported from stations 1, 2, 3, 4, and 8, in concentrations ranging from 520 to 650 µg/kg; toluene was reported from all stations, in concentrations ranging from 980 to 1400 µg/kg; and the compound *m*-xylene was reported from stations 3, 4, and 8, in concentrations ranging from 500 to 520 µg/kg. For all these compounds, the LOQ is 500 µg/kg. The compounds reported from all stations, 2-butanone and toluene, were probably present because of contamination of the sample during analyses, as each sediment station has its own drainage area and contamination of all the drainage areas is unlikely. The chloroform and *m*-xylene reported were at, or very near, the LOQs and may or may not have been present. Because of these uncertainties, another set of samples was collected for volatile compound analyses in October 1989. All results from analyses of these samples were below the LOQs.

(2) Semivolatile Compounds. Samples of sediments from the 9 stations were analyzed for 68 semivolatile compounds. Only two stations had analyses positive for these compounds, and only two compounds were reported (Table 23). Sediments from station 1 contained benzoic acid at a concentration of 6500 µg/kg; sediments from station 8 contained bis(2-ethylhexyl)phthalate at a concentration of 370 µg/kg. The LOQ for these compounds is 330 µg/kg.

(3) Pesticide, Herbicide, and PCB Compounds. Sediments from the 9 stations were analyzed for 22 pesticide compounds, 3 herbicide compounds, and mixed PCBs. All analyses gave results below LOQs (Table G-37).

Table 23. Volatile and Semivolatile Organic Compounds in Sediments at TA-54 That Exceeded the LOQs (µg/kg)

Station No.	Concentrations	LOQ
Volatile Compounds		
2-Butanone		
1	3000	500
2	3500	500
3	590	500
4	2400	500
5	3400	500
6	1800	500
7	610	500
8	2500	500
9	1200	500
Chloroform		
1	520	500
2	500	500
3	520	500
4	650	500
8	620	500
Toluene		
1	1400	500
2	1300	500
3	1400	500
4	1300	500
5	1300	500
6	1200	500
7	1100	500
8	1300	500
9	980	500
m-Xylene		
3	520	<500
4	500	<500
8	520	<500
Semivolatile Compounds		
Benzoic acid		
1	6500	330
Bis(2-ethylhexyl)phthalate		
8	370	330

VII. FOODSTUFFS MONITORING

Most produce, fish, and honey samples collected near the Laboratory showed no influence from Laboratory operations. Some on-site samples contained slightly elevated levels of radionuclides. The slightly elevated levels of ^{239,240}Pu in downstream catfish may be associated with higher levels in sediments in Cochiti Reservoir (see Sec. VI). However, these elevated levels in catfish have not been seen consistently in the past and thus may just reflect statistical variability. Concentrations of radionuclides in foodstuffs contributed only a minute fraction of the Laboratory's contribution to individual and population doses received by the public.

A. Background

Produce, fish, and honey have been routinely sampled to monitor for potential radioactivity from Laboratory operations. Produce and honey collected in the Española Valley and fish collected at Abiquiu Reservoir are not affected by Laboratory operations. These regional sampling locations (produce and fish, Fig. 21: honey, Fig. 22) are upstream from the confluence of the Rio Grande and the intermittent streams that cross Laboratory land. They are also sufficiently distant from the Laboratory as to be unaffected by airborne emissions (Sec. V). Consequently, these regional areas are used as background sampling locations for the foodstuffs sampling program. Section III presents the radiological health significance of these data.

B. Produce

Data in Table G-38 summarize produce sampling results for ^{3}H (in tissue water), ^{90}Sr, ^{238}Pu, ^{239,240}Pu, and total uranium. Sampling and preparation methods are described in Appendix B.

Concentrations of ^{3}H, ^{238}Pu, and ^{239,240}Pu in produce from regional, perimeter, and on-site sampling locations were statistically indistinguishable (nonparametric, one-way analysis of variance at the 95% confidence level). In 1988, one sample of chile from White Rock contained high concentrations of ^{238}Pu (0.9 ± 0.04 pCi/g) and ^{239,240}Pu (0.08 ± 0.008 pCi/g). Chile sampled from the same garden in 1989 contained plutonium levels consistent with those found regionally (0.000 ± 0.005 pCi/g of ^{238}Pu and 0.005 ± 0.004 pCi/g of ^{239,240}Pu). It appears that 1988 results were anomalies.

In 1989, uranium levels were higher in Española Valley produce, reflecting uptake of naturally occurring uranium.

Occasional elevated radionuclide levels in on-site samples are probably the result of Laboratory operations. However, on-site produce is not a regular component of the diet of either Laboratory employees or the general

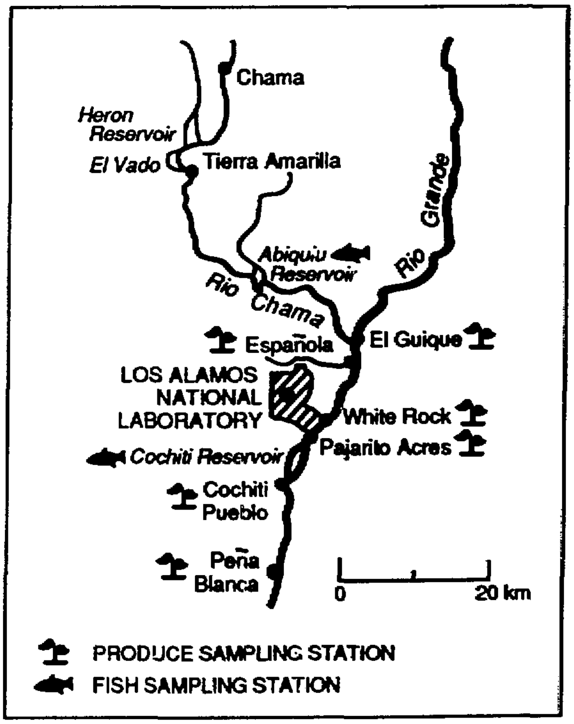

Fig. 21. Produce and fish sampling locations.

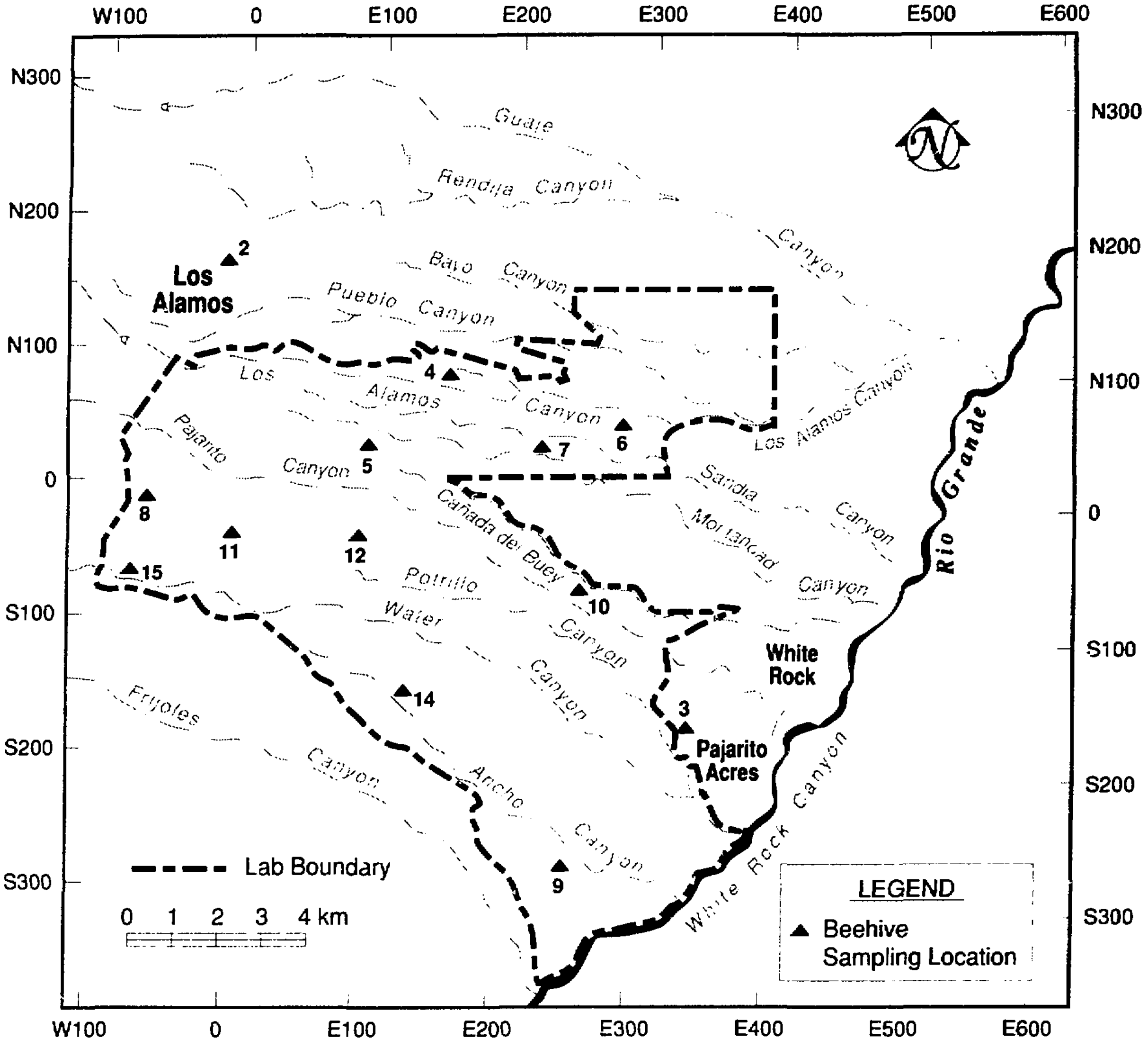

Fig. 22. On-site and perimeter locations of beehives.

public. The Laboratory contributions to doses received from produce consumption pose no threat to the health and safety of the general public (Sec. III).

C. Fish

Fish were sampled in two reservoirs (Fig. 21). Abiquiu Reservoir is upstream from the Laboratory on the Rio Chama and serves as a background sampling location. Cochiti Reservoir potentially could be affected by Laboratory effluents because it is downstream from the Laboratory on the Rio Grande. Sampling procedures are described in Appendix B. Edible tissue was radiochemically analyzed in fish species for ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and total uranium.

Results for fish are presented in Table G-39. For ^{90}Sr, ^{137}Cs, and ^{239,240}Pu, no differences were apparent (student's *t*-test, 95% confidence level) between the upstream and downstream samples for either fish species. Levels of ^{239}Pu were significantly higher in Cochiti for catfish only, but the difference was small (0.00008 pCi/g). This may reflect higher levels of ^{239,240}Pu in sediments from Cochiti (Table 22), but the difference has not been consistently apparent over past years. Uranium levels within species exhibited distinct patterns. Body burdens in bottom-feeding catfish tended to be higher than those found in crappie. Uranium levels were significantly higher in Cochiti crappie, although the difference remained low (1 ng/g).

The data indicate that Laboratory operations do not result in significant doses to the general public from consuming fish from Cochiti Reservoir (Sec. III).

D. Honey

Honey beehive locations are listed in Table G-40 and shown in Fig. 22. None of the honey produced by the hives in Los Alamos County is available for consumption. The most recent data (1988) for bees and honey are shown in Tables G-41 through G-44.

Radionuclide data were within the variation exhibited in previous years. Some activation products were elevated at the Los Alamos Meson Physics Facility at TA-53 (LAMPF). Tritium concentrations were elevated at several on-site hives, particularly at TA-33 and TA-53. These results reflect activities that are ongoing at the Laboratory. Most radionuclide results, on and off site, were within the counting uncertainty of the analytical systems. As in past years, levels of trace elements in bees and honey were variable.

VIII. ENVIRONMENTAL COMPLIANCE

In accordance with the policy of the DOE, the Laboratory must comply with federal and state environmental requirements. These requirements address handling, transport, release, and disposal of hazardous materials, as well as protection of ecological, archaeological, historic, atmospheric, and aquatic resources.

The Laboratory recently received federal and state permits for operating hazardous waste treatment and storage areas and is renewing a federal hazardous waste permit for discharge of liquid effluents. Corrective actions carried out under the federal permit are being managed by the Laboratory's Environmental Restoration Program. The Laboratory was in compliance with permit limits for treated liquid discharges in 98% and 99%, respectively, of monitored sanitary and industrial effluent outfalls. Under a Federal Facility Compliance Agreement with the EPA, sanitary waste treatment facilities are being upgraded to improve compliance.

All airborne releases were well within regulatory limits during 1989. A total of 61 asbestos-removal jobs was carried out during the year, and appropriate notification was provided to state regulators.

Concentrations of constituents in the drinking water distribution system remained within federal water supply standards.

The Laboratory evaluated 462 activities for compliance with cultural resource requirements. During 1989, 12 documents describing new Laboratory activities were prepared to comply with the National Environmental Policy Act.

A. Resource Conservation and Recovery Act (RCRA)

1. Background. RCRA, as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984, mandates a comprehensive program to regulate hazardous wastes, from generation to ultimate disposal. The emphasis of the amendments is to reduce hazardous waste volume and toxicity and to minimize land disposal of hazardous waste. Major requirements under HSWA that impact waste handling at the Laboratory are presented in Table 24.

The EPA has granted RCRA authorization to New Mexico, transferring regulatory control of hazardous wastes to the state's Environmental Improvement Division (NMEID). State authority for hazardous waste regulation is the Hazardous Waste Act and Hazardous Waste Management Regulation. However, NMEID has not yet obtained authorization for implementing the 1984 RCRA amendments. The state adopted new regulations that use the federal codification. Although this modification will make the state regulations more consistent with federal regulations and easier to interpret, some confusion will continue because only those federal regulations in effect on July 1, 1987, were adopted.

The Laboratory produces a wide variety of hazardous wastes. Small volumes of all chemicals listed under 40 CFR 261.33 could occur at the Laboratory as a result of ongoing research. Process wastes, such as liquid wastes from circuit board preparation and lithium hydride scrap from metal machining, are generated from ongoing manufacturing operations that support research. Although they occur in larger volumes than discarded laboratory chemicals, process wastes are few in number, they are well defined, and they are not acutely toxic. High-explosive (HE) wastes include small pieces of explosives and contaminated sludges and liquids that are thermally treated on site.

During 1989, the New Mexico Environmental Improvement Board (NMEIB) adopted new Solid Waste Management Regulations that require permitting of

Table 24. Major Regulatory Requirements of the Hazardous and Solid Waste Amendments of 1984 Impacting Waste Management at the Laboratory

The Hazardous and Solid Waste Amendments (HSWA) of 1984

- prohibit placement of bulk liquids, containerized liquid hazardous waste, or free bulk or free liquids, even with adsorbents, in landfills;
- prohibit landfill disposal of certain wastes and require that the EPA review all listed wastes to determine their suitability for land disposal;
- establish minimum technology requirements for landfills to include double liners and leak detection;
- require EPA to establish minimum technology requirements for underground tanks;
- require generators of manifested wastes to certify that they have minimized the volume and toxicity of wastes to the degree economically feasible;
- require operators of landfills or surface impoundments to certify that a ground-water monitoring program is in place, or to demonstrate that they have a waiver, by November 8, 1985, with failure to do so resulting in loss of interim status on November 23, 1985;
- require federal installations to submit an inventory of hazardous waste facilities by January 31, 1986; and
- require the preparation, by August 8, 1985, of a health assessment for landfills and surface impoundments seeking a Part B permit.

existing and new landfills used for domestic solid-waste disposal. Notices of intent to continue to operate the county landfill on East Jemez Road and the Area J landfill at TA-54 were submitted to the NMEID in accordance with the new regulations. NMEID will request permit applications from owners of existing landfills on a priority basis, with applications for landfills that have serious environmental problems to be requested first.

The county landfill is located on property owned by the DOE and is operated by Los Alamos County under a special use permit. Approximately one-third of the domestic solid waste disposed of at the county landfill originates from the Laboratory. The Area J landfill is operated by the Laboratory and receives nonhazardous nonradioactive solid waste, which is kept under the administrative control of the Laboratory.

The new Solid Waste Management Regulations also cover the transportation and disposal of special waste, including infectious and asbestos waste. All nonradioactive infectious waste from the Laboratory is disposed of off site by a medical-waste disposal contractor.

Both nonradioactive and low-level radioactive asbestos waste are disposed of at the Area G landfill located at TA-54, which is the Laboratory's low-level radioactive waste landfill regulated by DOE orders issued under the Atomic Energy Act. A notice of intent to continue to operate the Area G landfill was submitted to NMEID, in anticipation that NMEID might determine such a notice is required for continued disposal of nonradioactive asbestos waste at Area G.

The Laboratory is planning a separate trench for nonradioactive asbestos waste at Area J so that all nonradioactive waste can be kept outside of Area G. Construction of this trench is expected to be approved and completed during 1990.

2. RCRA Closure Activities. The status of Laboratory hazardous waste operations to be closed under RCRA regulations is given below:

- *TA-16, Ground-Surface Impoundment for Burning Waste.* This site is essentially closed. The liner was decontaminated and cut up and is now stored in barrels at the site as nonhazardous waste. Samples of the liner rinsate and of soils beneath the impoundment showed that both were clean. However, 12 background samples were also taken to confirm that the concentrations of metals detected were not influenced by the site. The Laboratory is awaiting approval from the state of New Mexico for backfilling and reseeding the site. No formal approval of the closure plan has yet been received, so it is expected that approval for backfilling will be accompanied by written acceptance of the closure plan.
- *TA-54, Storage Tanks for Waste Oil at Area L.* Waste oil in six above-ground storage tanks was pumped out and disposed of off site as hazardous waste during 1988 and the tanks were moved to Area G to make room for needed facilities at Area L. Although closure of these tanks was originally scheduled for FY 1989, action was delayed because the state has not yet approved the closure plan.
- *TA-35, Waste Oil Storage Pits.* Closure plans for the two waste oil pits associated with buildings 85 and 125 at TA-35 were submitted in October 1988, and oral approval to proceed with closure activities was subsequently received from the state. In late March 1989, the contents of the pits were removed for incineration off site. The next month, contamination was discovered when the liner was chiseled through and samples of the underlying soils were taken. Discussions among EPA officials indicated that a clean closure could be achieved, even if residual contamination remained in place, provided that the residual was below a health-based limit. The state agreed to approve this strategy if the Laboratory would remediate the site by removing all organic volatile and semivolatile constituents above 1 ppm and demonstrate that the residuals are no longer a threat to human health. This strategy has been adopted.

  Excavation of the two sites was completed this year and verification sampling was completed in November. In October, an underground storage tank and associated piping connected to pit No. 85 were uncovered, samples were taken, and waste materials were transported off site for incineration. The closure plan has been modified to include the underground storage tank.
- *TA-16, Landfill at Area P.* Closure and post-closure-care plans for the Area P landfill were submitted on November 25, 1985. Because approval has not yet been received from the state of New Mexico to proceed with this closure (or to modify the plan), no work has taken place.

3. Permit Application. The NMEID held a public hearing in July 1989 on the Laboratory's hazardous waste permit. After public comments were received, a permit was issued in November 1989 (Table 25). The Laboratory appealed a specific requirement of the permit (monitoring for radioactive emissions from the incinerator). No action has been taken on the appeal.

The EPA held a public hearing in August 1989 on the HSWA portion of the permit. The permit was issued on March 8, 1990. Corrective actions taken under this portion of the permit will be administered by the Laboratory's Environmental Restoration Program Office in the Health, Safety, and Environment Division (HSE-DO), with support from the Environmental Protection Group (HSE-8) and other groups in the Laboratory.

4. Area P Landfill and Surface Impoundment. A modified landfill closure and postclosure plan was prepared for submittal to the NMEID in late 1987. Modifications were necessary because the landfill will eventually be subject to permit standards under 40 CFR 264 once the NMEID issues its RCRA permit to the Laboratory. Furthermore, Group HSE-8 wanted to establish a 30-year postclosure ground-water monitoring plan that would be consistent with monitoring parameters and that would fulfill requirements under both interim and permit standards. To this end, HSE-8 personnel constructed nine ground-water monitoring wells and five neutron moisture-access monitoring wells. To date, no recoverable

Table 25. Environmental Permits under Which the Laboratory Operated in 1989[a]

Permit Type	Permitted Activity	Issue Date	Expiration Date	Administering Agency
RCRA hazardous waste facility	Hazardous waste storage, treatment, and disposal	November 1989[a]	—	NMEID
	Postclosure care	Application submitted September 1988		EPA
PCBs[b]	Disposal of PCBs	June 5, 1980	—	EPA
PCB oil	Incineration of PCB oils	May 21, 1984	—	EPA
NPDES,[c] Los Alamos	Discharge of industrial and sanitary liquid effluents	Modified permit May 29, 1987	March 1, 1991	EPA
NPDES, Fenton Hill	Discharge of industrial and sanitary liquid effluents	October 15, 1983[d]	—	EPA
Ground-water discharge plan, Fenton Hill	Discharge to ground water	June 5, 1985	June 1990	NMOCD[e]
NESHAP[f]	Construction and operation of four beryllium facilities	December 26, 1985; March 19, 1986; September 8, 1987	—	NMEID

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[a] Under appeal.
[b] Polychlorinated biphenyls.
[c] National Pollutant Discharge Elimination System.
[d] Renewal pending.
[e] New Mexico Oil Conservation Division.
[f] National Emission Standards for Hazardous Air Pollutants.

amounts of ground water have been observed; average unsaturated gravimetric borehole moisture contents range from 2% to 24%. On the basis of these and other hydrogeologic data, information on a ground-water monitoring waiver was requested from the NMEID in December 1987.

The closure plan for the surface impoundment was disapproved by NMEID pending receipt of further data from the Laboratory. The Laboratory has supplied the data and now awaits NMEID final approval.

All of the impoundment's waste water was completely removed in 1987 and shipped off site for final treatment and disposal. In addition, the surface impoundment's synthetic membrane underliner was completely removed. No contaminated subbase soils were detected after this action. This "clean" closure approach dictates that interim status standards be followed because closure will occur before the RCRA permit is issued. This clean closure does not require the typical 30-year, post-closure-care requirements for in-place closure. The same process could not be used for the landfill because hazards from explosives could preclude landfill excavations.

5. Underground Storage Tanks (USTs). In 1989, the EPA granted the state of New Mexico interim approval to implement a UST program. After reviewing the program, however, the EPA rejected the state's regulations, claiming that NMEID's program was not as stringent as Subtitle I of the federal regulations. NMEID contends that they still have regulative authority for the program. For this reason, the Laboratory is attempting to abide by both federal and state regulations.

Two tanks in need of upgrades were removed in 1989. Tests showed that both tanks were not tight. Tank No. TA-3-36-1, located at a TA-3 service station, was a 10 000-gal. gasoline tank. This tank was replaced with a 10 000-gal. double-walled tank with fiber glass piping. Tank No. MP-1, located at the motor pool, was a 10 000-gal. diesel tank. This tank was not replaced. On further investigation, neither tank showed signs of leaking and the tank shells were cleaned, cut up, and sold for scrap.

6. Other RCRA Activities. Areas L and G, located at TA-54 on Mesita del Buey, have been used for disposal of hazardous wastes and are subject to RCRA regulation. Information on a ground-water monitoring waiver for both Areas L and G has been submitted to NMEID. Vadose-zone (the subsurface above the main aquifer) monitoring is being conducted quarterly throughout Areas L and G to identify any releases from the disposal units. This type of monitoring is used to detect the presence of organic vapor in the vadose zone. A total of 26 monitoring systems has been emplaced, 9 during the past year.

Table G-45 lists several storage areas (for which a Part B permit is not being sought) and 12 miscellaneous units that are currently under interim status. TA-3-102, used to store drums containing lithium hydride scrap, was closed under interim status in 1988. TA-22-24 and TA-40-2 were areas with magazines used for storage of HE wastes. These areas were closed to waste storage in 1988 and were replaced by satellite storage units. In FY 1989, the TA-40 scrap detonation pit used for destroying HE scrap was closed to waste detonation. All scrap is now handled at other detonation and open-burning sites included in the Part B permit application. Closure plans for the TA-40 facility were submitted to NMEID in early 1986.

A RCRA-permitted controlled-air incinerator for treating hazardous waste is located at TA-50-37. A trial burn was conducted in October 1986. The raw data were submitted to NMEID in December 1986, and a final report for the test burn was submitted on March 5, 1987. These data and the report were used to support the Laboratory's application for a hazardous waste permit for this facility. The permit was issued in November 1989.

In August 1989, the EPA and NMEID conducted a joint hazardous waste compliance inspection (Tables 26 and G-46). Violations were noted and a Notice of Violation (NOV) was issued in October 1989. The Laboratory's response, sent to NMEID in November 1989, was found adequate by that agency. The EPA was the lead agency for this inspection.

B. Clean Water Act

1. Laboratory Liquid-Waste Discharge Permits. The primary goal of the Clean Water Act (33 U.S.C. 446 *et seq.*) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The act established the National Pollutant Discharge Elimination System (NPDES) that requires permitting of all point-source effluent discharges to the nation's waters. The permit establishes specific chemical, physical, and biological criteria that an effluent must meet before it is discharged. The DOE has two NPDES permits, one for

Table 26. Environmental Inspections and Audits Conducted at the Laboratory in 1989

Date	Purpose	Performing Agency
March 31	Inspection of spill clean up at three locations	NMEID
June 15–16	NPDES inspection of sanitary and industrial outfalls and record keeping	EPA
June 6–7	Data accuracy review of DOE environmental survey	DOE Headquarters
July 10–14	Review of environmental surveillance, environmental chemistry, and meteorology programs	DOE Albuquerque Operations Office (DOE/AL)
July 17–18	Operations surety audit of environmental protection and compliance programs	DOE/AL
August 4	Inspection of Pan Am World Services' environmental laboratories	NMEID
August 9	Inspection of polychlorinated biphenyl (PCB) equipment and record keeping	EPA
August 7–11	Hazardous waste management inspection	NMEID
August 15–17	Land disposal restrictions	EPA
August 21–23	Review of PCB control and NPDES programs	DOE/AL
October 27	Inspection of septic tank systems	NMEID
November 13–17	Review of National Environmental Policy Act, nonradioactive air, and spill prevention and control programs	DOE/AL

Laboratory facilities in Los Alamos and one for the hot dry rock geothermal facility (Fenton Hill site), located 50 km (30 mi) west of Los Alamos in the Jemez Mountains (Table 25). Both permits are issued and enforced by EPA Region VI in Dallas, Texas. However, through a joint federal and state agreement and grant, NMEID acts as the agent for the EPA and performs compliance monitoring and reporting.

The NPDES permit in effect for the Laboratory in 1989 (NM0028355) was reissued May 29, 1987, and will expire March 1, 1991. As of December 31, 1989, the permit regulates 102 industrial outfalls and 10 sanitary outfalls (Table G-47). Each outfall represents a sampling station for permit compliance monitoring.

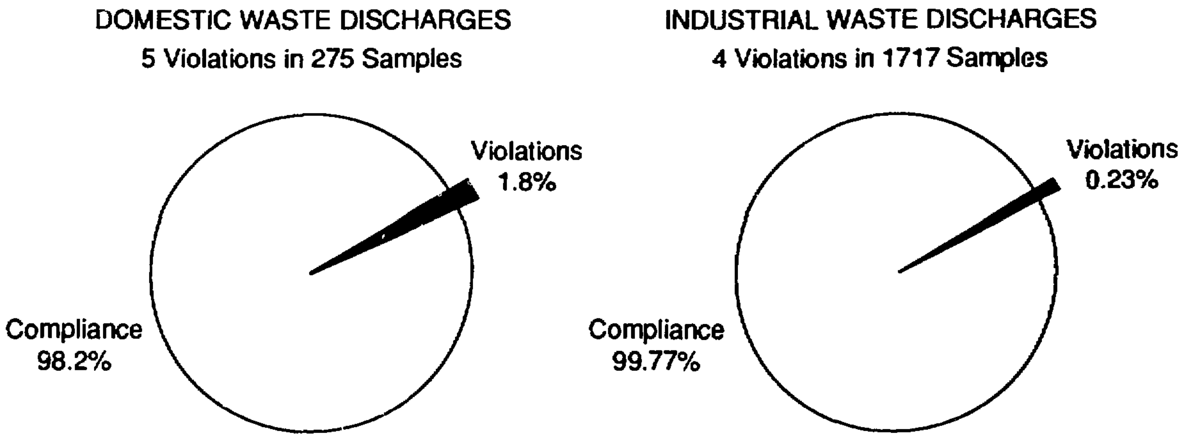
The Laboratory did not forward any NPDES permit modification requests to DOE for transmittal to EPA during 1989. However, a letter was written to EPA on January 24 regarding planned changes at TA-53, outfall 09S, that might affect permit compliance. The letter alerted EPA to the fact that the TA-53 waste-water treatment system was to be altered in 1989, primarily by taking one of three stabilization lagoons out of the sanitary waste-water processing train and reserving it solely for retention and evaporation of industrial waste water containing low levels of radioactive waste (tritium, for example). The letter described the proposal to segregate the sanitary and industrial waste waters, which historically had been commingled, and apprised EPA that long-range plans were being developed to provide enhanced waste-water treatment for both types of waste water at TA-53.

Weekly sampling results are tabulated in a Discharge Monitoring Report and submitted through DOE to EPA and NMEID on a monthly basis. Deviations from NPDES permit limitations are also explained separately to EPA and NMEID with the monthly submittal (Tables G-48 through G-50). During 1989, monitoring analyses showed 98.2% and 99.8% compliance, respectively, with NPDES limits at sanitary and industrial outfalls (Fig. 23).

During the second quarter of 1989, work was initiated to collect flow measurements and sample data on NPDES outfalls in anticipation of the September 1990 reapplication for reissuance of the Laboratory's permit (reapplication for NPDES permits is required every 5 years). Flow measurements taken during 7 consecutive days were collected on all NPDES outfalls, and representative outfalls were scheduled for sampling during the last quarter of the year. The sampling program entailed selection of three representative outfalls in each waste-water discharge category and sampling for 127 priority pollutants at each selected outfall. In addition, extensive effort was spent developing detailed information on waste-water treatment systems and gathering location and mapping information on each Laboratory outfall.

2. Federal Facility Compliance Agreement (FFCA). During 1989, the Laboratory completed its third set of negotiations on an FFCA. The agreement was signed by DOE/LAAO (DOE's Los Alamos Area Operations Office) on February 13, 1989, and included interim effluent limitations and a schedule of compliance for outfalls 04S (TA-18 sanitary treatment plant), 09S (TA-53 sanitary treatment plant), 02A (TA-16 and TA-21 steam plants), and 05A (high-explosive discharges). According to the schedule, outfalls 02A and 05A were brought into compliance by October 31, 1989 (Tables G-51 and G-52). The two sanitary treatment systems included in the FFCA are incorporated in the Sanitary Waste-Water Systems Consolidation Project, which is scheduled to be completed by July 1992.

3. Audits. In 1989, the EPA conducted one audit under the Clean Water Act (Table 26). An EPA Compliance Evaluation Inspection was conducted on June 15 and 16, 1989. The EPA inspector complimented the Laboratory's record-keeping and self-monitoring program for its completeness, accuracy, and level of detail, although several


DOMESTIC WASTE DISCHARGES
5 Violations in 275 Samples

INDUSTRIAL WASTE DISCHARGES
4 Violations in 1717 Samples

Fig. 23. Summary of Clean Water Act compliance in 1989, NPDES Permit NM0028355.

minor compliance discrepancies were noted. Regarding these discrepancies, a Notice of Deficiency was received from EPA on June 15, 1989, for three minor permit compliance problems. These problems were corrected immediately, and a letter to that effect was sent to DOE for submittal to EPA on June 30, 1989.

During August 21–25, 1989, DOE/AL (DOE's Albuquerque Operations Office) conducted an appraisal of the Laboratory's NPDES program. No findings resulted from the audit.

4. Administrative Order (AO). On August 30, 1988, EPA Region VI issued an AO to DOE regarding NPDES Permit NM0028355. The AO was based on self-monitoring reports submitted by the Laboratory that identified a number of violations occurring at outfalls during 1987 and 1988. DOE/LAAO responded to the AO in a submittal to EPA dated October 6, 1988. This AO was not closed out during 1989, nor has the previous AO, which was issued August 6, 1987 (response sent September 3, 1987), been closed out. There is no explanation for EPA's inactivity regarding the close-out of these AOs.

5. Fenton Hill Geothermal Project NPDES Permit. The NPDES permit for the Fenton Hill Geothermal Project was issued to regulate the discharge of mineral-laden water from the recycle loop of the geothermal wells (Table 25). NPDES permit NM0028576 was issued October 15, 1979, with an expiration date of June 30, 1983. Although the Laboratory applied for permit renewal more than 180 days before the expiration date, EPA Region VI, as of 1986, still had not acted on the application.

On April 15, 1987, EPA requested an updated application for the permit in order to reflect present conditions at the site; DOE submitted an application package on May 20, 1987. Subsequently, on September 25, 1987, EPA issued a proposed permit for comment and state certification (pursuant to Sec. 401, 33 U.S.C. 466 *et seq.*). State certification was granted by NMEID on January 8, 1988, with no additional state-imposed permit conditions. Issuance of the final NPDES permit was expected during the first quarter of 1988, but the final permit has not yet been issued by EPA. Therefore, the existing permit has been administratively continued until it can be supplanted by a new permit. EPA has not given any reason for the delay in final permit issuance.

The initial Fenton Hill NPDES permit regulates a single outfall. The daily monitoring requirements for the outfall during discharge include sampling for arsenic, boron, cadmium, fluoride, lithium, pH, and flow. Concentrations for each of these parameters are to be reported. However, only the parameter pH has a limit — that is, it must be within the range of 6.0 to 9.0 standard units. During 1989, there were no discharges from this outfall.

The proposed Fenton Hill NPDES permit will regulate the same single outfall. The daily monitoring requirements for the outfall during discharge will include sampling for flow, pH, and phenols.

6. Spill Prevention Control and Countermeasure (SPCC) Plan. The SPCC Plan addresses facilities improvements (for example, dikes, berms, or other secondary spill-containment measures), operational procedures, and mechanisms for reporting of hazardous substances and oil spills to the appropriate managerial and regulatory authorities. The plan complements existing Administrative Requirements in the Laboratory's Health and Safety Manual for accidental oil and chemical spills and environmental protection. Its goal is to minimize off-site oil and hazardous chemical discharges and to provide a spill response program.

During 1988, Title I engineering designs, primarily to provide secondary containment around existing storage tanks, were initiated on seven spill control projects. Title II design and construction were completed during 1989. Eleven major sites were augmented with secondary containment facilities during 1989. Simultaneously, spill prevention and control training lectures were given to more than a dozen operating groups Laboratory-wide, and spill response equipment was purchased and distributed to numerous operating groups.

7. Sanitary Waste-Water Systems Consolidation (SWSC) Project. The purpose of this project is to eliminate violations of the Laboratory's NPDES permit by construction of a new, centralized, sanitary wastewater treatment plant at TA-46. This plant will replace the TA-3 waste-water treatment plant, which is over 30 years old, and six smaller treatment facilities that do not consistently meet NPDES discharge requirements. The new treatment plant will also eliminate approximately 30 septic tank systems throughout the Laboratory. Completion of construction and full operation of this plant is required by July 1992 under the Laboratory's agreement (FFCA) with the EPA.

The proposed SWSC Project is designed to meet current and anticipated discharge requirements and to result in a significant savings in operating and maintenance costs. The project includes approximately 19 km (12 mi) of new gravity collection lines and five lift stations that will collect sanitary waste water from most of the technical areas of the Laboratory. The north interceptor will be located along Pajarito Road from TA-3 to TA-46, which is the site of the new treatment plant. The south interceptor will be located along R-Site Road from TA-9 to TA-18. Two lift stations will pump waste water from this location to the TA-46 plant. Excess, treated effluent will be discharged to Cañada del Buey under the Laboratory's NPDES permit.

The Title I planning for the SWSC Project was completed during 1989 by the consulting engineer and was approved by the Laboratory and DOE. Preparation of Title II plans and specifications for the project is under way and is scheduled to be completed by June 1990. The target date for completion of construction and start up of the new treatment plant is July 1992.

The SWSC Project will replace all of the Laboratory's existing waste-water treatment facilities except the TA-21 activated-sludge plant and the TA-53 lagoons. These facilities were not included in the original scope of the SWSC Project because of their remote locations. However, the proposed SWSC treatment plant at TA-46 includes adequate reserve capacity to treat waste water from these technical areas. A study is now under way to determine the feasibility of pumping waste water from TA-21 and TA-53 to the proposed treatment plant at TA-46. If pumping to TA-46 is not cost-effective, new treatment facilities will be recommended for TA-21 and TA-53 so that all sanitary waste-water facilities at the Laboratory will be improved and all discharges will meet NPDES permit requirements.

8. Upgrading of Septic Tank Systems. During 1989, a survey of all septic tank systems at the Laboratory was conducted. The survey identified 77 systems that were in operation, or under design, for disposal of sanitary waste water. Six of these systems were new facilities and were approved by the NMEID District II Office, which serves as the reviewing authority for septic tank systems installed at the Laboratory under New Mexico Liquid Waste Disposal Regulations. Seven existing systems, which were found during the survey to be unpermitted, were inspected and subsequently approved by NMEID.

New leach fields were installed at two existing septic tank systems at TA-9 to prevent effluent from surfacing. Also, overflow lines from six other septic tank systems were capped to prevent potential waste-water spills.

Approximately 30 septic tank systems at the Laboratory are scheduled to be replaced in 1992 by collection lines carrying waste water to the new SWSC treatment plant at TA-46.

C. National Environmental Policy Act (NEPA)

This act protects the environment by requiring that potential adverse impacts of proposed new projects be evaluated and that measures be taken, if needed, to lessen those impacts. Thus, NEPA aids in project planning. Laboratory staff, responsible for compliance with the NEPA program, review proposed projects to identify those likely to have environmental consequences. A standard questionnaire form submitted by project staff provides initial information on environmental, industrial hygiene, radiation protection, and other safety and health compliance issues relevant to a proposed project.

During 1989, 300 questionnaires on proposed projects were reviewed by the Laboratory Project Questionnaire Review Committee, comprising experts in various fields covered in the DOE definition of environment, safety, and health (for example, quality assurance, radiation safety, and industrial hygiene). On the basis of that committee's review, 53 projects were identified as having possible environmental impacts. The rest fell into specifically excluded categories that clearly pose no environmental impacts.

Descriptions of these 53 projects, called Action Description Memorandums (ADMs), will be prepared by Laboratory staff to describe the scope of the project, sensitive environmental issues, and waste management plans. ADMs are reviewed by the Laboratory Environmental Review Committee (LERC) for adequacy before being sent to DOE, where they are used to determine the level of NEPA documentation that will be required.

During 1989, seven new ADMs and one revision to an existing ADM were submitted to DOE/AL. For six of these ADMs, DOE/AL determined that the projects would pose no significant environmental impact. Laboratory personnel were directed to prepare an Environmental Assessment (EA) on one project; a decision is still pending on the remaining project.

An EA is the NEPA document used to present the environmental impacts of a proposed project when the impacts are expected to be insignificant, no public concern is expected, and some analysis beyond the ADM description is needed. During 1989, DOE/AL requested that Laboratory staff prepare EAs on three projects, although, based on the ADMs, decisions of no significant impact had previously been made on two of them. The EA for the proposed Weapons Engineering Tritium Facility was submitted to DOE/AL late in 1989; EAs for the Scintillation Vial Crusher and the Materials Science Laboratory are in preparation.

During 1988, an EA was prepared for the Special Nuclear Materials Research and Development (SNMs R&D) Laboratory. Because of public concern about plutonium reprocessing and potential significant environmental impacts, DOE Headquarters directed that an Environmental Impact Statement (EIS) be prepared. This NEPA document requires public involvement and more-detailed analyses. To prevent conflict of interest, EIS documents are prepared by a contractor independent of the Laboratory. The EIS process for the SNMs R&D facility was initiated in late 1989.

The status of environmental documentation during 1989 is summarized, by proposed project, in Table G-53.

D. Federal Clean Air Act and the New Mexico Air Quality Control Act

1. Federal Regulations. The following federal requirements, except for radioactive emissions, have been adopted by the state of New Mexico as part of its State Implementation Plan. However, if New Mexico does not enforce these federal requirements, the EPA retains the prerogative to do so.

a. National Emission Standards for Hazardous Air Pollutants (NESHAP). This regulation sets reporting; permitting; emissions control, disposal, and stack testing; and other requirements for specified operations involving hazardous air pollutants. NMEID has responsibility for administering these regulations, except for those governing radionuclides. Laboratory operations that are regulated by NESHAP include radionuclide emissions, asbestos disposal and removal, and beryllium machining.

The EPA has promulgated regulations for control of airborne radionuclide releases from DOE facilities (40 CFR 61, Subpart H). Since 1985, DOE and its contractors have been subject to EPA's radionuclide air emissions limits for exposure of the general public via the air pathway (DOE 1985). Laboratory operations are in compliance with these standards (Sec. III).

During 1989, Pan Am World Services completed 61 asbestos jobs, removing 2646 m^2 (8684 ft) of asbestos materials from pipe and 1786 m^2 (19 228 ft^2) from other facility components. These jobs involved the disposal of 245 m^3 (8666 ft^3) of asbestos-contaminated wastes.

Asbestos wastes are disposed of at TA-54 in accordance with required disposal practices. Three disposal certifications, including the annual notification for asbestos disposal during small jobs, were submitted to NMEID during 1989. Also submitted were 12 notifications of asbestos removal, including the annual notification for small renovation jobs. In 1989, 10% of the asbestos removed from pipe and other facility components involved small renovation jobs that required no job-specific notification to the state; the rest required job-specific notification.

The beryllium NESHAP includes requirements for notification, emissions limits, and stack-performance testing for beryllium sources. The four beryllium facilities at the Laboratory operate under state air quality permits containing these requirements. The Laboratory obtained a permit for a fifth beryllium-processing operation to be located in TA-3-35; this facility has not yet been constructed.

b. National and New Mexico Ambient Air Quality Standards. Federal and state ambient air quality standards are shown in Table 27. New Mexico standards are generally more stringent than the national standards. On the basis of available monitoring data and modeling, Laboratory emissions have not exceeded federal or state standards.

Regulated pollutants that are emitted by Laboratory sources include sulfur dioxide, particulate matter, carbon monoxide, nitrogen dioxide, lead, beryllium, heavy metals, and nonmethane hydrocarbons. Laboratory sources that emit these pollutants include beryllium machining and processing operations, the TA-3 power plant, steam plants, the asphalt plant, the lead-pouring facility, and operations involving the burning and detonation of high explosives and the burning of explosive-contaminated wastes (see Sec. V).

Table 27. National and New Mexico Ambient Air Quality Standards

Pollutant	Averaging Time	Unit	New Mexico Standard	Federal Standards	
				Primary	Secondary
Sulfur dioxide	Annual arithmetic mean	ppm	0.02	0.03	
	24 hours[a]	ppm	0.10	0.14	
	3 hours[a]	ppm			0.05
Total suspended particulate matter	Annual geometric mean	µg/m^3	60		
	30 days	µg/m^3	90		
	7 days	µg/m^3	110		
	24 hours[a]	µg/m^3	150		
PM_{10}[b]	Annual arithmetic mean	µg/m^3		50	50
	24 hours	µg/m^3		150	150
Carbon monoxide	8 hours[a]	ppm	8.7	9	
	1 hour[a]	ppm	13.1	35	
Ozone	1 hour[c]	ppm	0.06	0.12	0.12
Nitrogen dioxide	Annual arithmetic mean	ppm	0.05	0.053	0.053
	24 hours[a]	ppm	0.10		
Lead	Calendar quarter	µg/m^3		1.5	1.5
Beryllium	30 days	µg/m^3	0.01		
Asbestos	30 days	µg/m^3	0.01		
Heavy metals (total combined)	30 days	µg/m^3	10		
Nonmethane hydrocarbons	3 hours	ppm	0.19		

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[a] Maximum concentration, not to be exceeded more than once per year.

[b] Particles measured at an effective diameter of <10 µm.

[c] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above the limit is 1.

c. Prevention of Significant Deterioration (PSD). The PSD regulations have stringent requirements (preconstruction review, permitting, best available control technology for emissions, air quality increments that must not be exceeded, visibility protection requirements, and air quality monitoring) for the construction of any new major stationary source or major modification of a source located near a Class I area, such as Bandelier National Monument's Wilderness Area. To date, DOE and the Laboratory have not been subject to PSD regulations.

d. New Source Performance Standards (NSPS). The NSPS applies to 72 source categories. Its provisions include emission standards, notification, emission testing procedures and reporting, and emission monitoring requirements. DOE and the Laboratory have not been subject to NSPS.

2. State Regulations

a. Air Quality Control Regulation (AQCR) 301. Under this regulation, open burning of explosive materials is permitted when transport of these materials to other facilities may be dangerous. DOE and the Laboratory are permitted to burn waste explosives and explosive-contaminated wastes. Burning of waste explosives is done at the TA-16 burn ground. Other wastes that are potentially contaminated with small amounts of explosives are burned in a two-stage incinerator.

b. AQCR 501. Provisions of AQCR 501 set emission standards according to process rate and require the control of fugitive emissions from asphalt-processing equipment. The asphalt concrete plant operated by Pan Am World Services is subject to this regulation. This plant is old, subject to leaking, and is inspected annually. During the annual inspection, leaks causing fugitive emissions were discovered and repaired.

The asphalt plant meets the stack emission standard for particulate matter, as specified in this regulation. The plant, which has a 75 000-kg/h (75-ton/h) capacity, is required to meet an emission limit of 16 kg (35 lb) of particulate matter per hour. A stack test of the asphalt plant in 1977 indicated an average emission rate of 0.8 kg/h (1.8 lb/h) and a maximum rate of 1.0 kg/h (2.2 lb/h) over three tests (Kramer 1977). Although the plant is old and is not required to meet NSPS stack emission limits for asphalt plants, it meets these standards (Kramer 1977).

c. AQCR 604. Provisions of AQCR 604 require gas-burning equipment that was built before January 10, 1973, to meet an emission standard for NO_X of 0.3 lb/10^6 Btu when natural-gas consumption exceeds 10^{12} Btu/yr/unit. The TA-3 power plant's boilers have the potential to operate at heat inputs that exceed the 10^{12} Btu/yr/unit, but they have not been operated beyond this limit. Thus, these boilers have not been subject to this regulation. However, the TA-3 power plant meets the emission standard. The emission standard is equivalent to a flue gas concentration of 248 ppm. The TA-3 boilers meet the standard with measured flue gas concentrations of 15 to 22 ppm.

d. AQCR 702. Provisions of AQCR 702 require permitting of any new or modified source if it exceeds threshold emission rates. In the past, this regulation addressed only criteria pollutants. However, in September 1988, the NMEIB adopted revisions to AQCR 702 that require new sources of toxic air pollutants, constructed or reconstructed after December 31, 1988, to obtain air quality permits if they emit more than the specified emission rate for that chemical. More than 500 toxic air pollutants are regulated by these changes, and each chemical's specified hourly emission rate is based on its toxicity. The Laboratory's emissions of these toxic chemicals are low, as shown in Table G-54. Annual emission estimates were prepared in 1987 and 1988 by interviewing all Laboratory personnel regarding their use of the listed chemicals. Airborne emissions were estimated for each source using the information provided, and the data were stored in the HSE-8 Toxic Air Pollutant (TAP) data base. Emissions at Los Alamos are low because the Laboratory is primarily a research facility and chemical usage is small.

Chemical usage and maximum operating schedules are difficult to determine for research activities. Therefore, maximum hourly emissions are difficult to estimate. To adequately respond to AQCR 702, the Laboratory developed a methodology for estimating hourly emissions from the annual emissions in the TAP data base and for distributing the emissions throughout the year. These estimates can be used for new and modified sources that are similar to those already existing at the Laboratory. If a new source is not similar to any of those existing at the Laboratory, conservative estimates are made of maximum hourly chemical usage and emissions. Using a combination of these methodologies, Laboratory staff reviewed all new and modified sources, calculated air emissions, and compared their results with applicable limits to determine the need for obtaining additional permits.

e. AQCR 752. Provisions of this regulation required a one-time registration of all sources emitting toxic air pollutants in amounts in excess of a specified annual emission limit. Complying with this regulation required the Laboratory to estimate emissions for more than 500 chemicals. To calculate these emissions, a computerized data base has been developed that includes usage, products, and wastes for each regulated chemical. The results of this study are summarized in Table G-54, where the annual air emissions are ranked in pounds per year. In general, air emissions are small. Only one chemical, lithium hydride from the TA-3 machining shop, exceeded the limit and thus required registration with the state.

E. Safe Drinking Water Act (SDWA), Municipal and Industrial Water Supplies

1. Background. The Laboratory conducts two separate programs to monitor ground-water quality of the area and to meet regulatory requirements. The first program includes sampling of water supply wells and special monitoring wells under the Laboratory's long-term environmental surveillance program. These samples are collected by HSE-8 and are analyzed by the Health and Environmental Chemistry Group (HSE-9). The results of this program are reported in Sec. VI. The second program includes sampling from various points in the Laboratory and county distribution systems to ensure compliance with SDWA. Samples are analyzed for organic and inorganic chemicals and for radioactivity at the state Scientific Laboratory Division (SLD) in Albuquerque. The Pan Am Environmental Laboratory also collects samples throughout the Laboratory and county distribution systems and tests them for microbiological contamination, as required under SDWA. The Pan Am laboratory is certified by SLD for microbiological testing of drinking water.

The EPA is responsible for enforcement of SDWA and has established maximum contaminant levels for organic and inorganic chemicals and radioactivity in drinking water. These standards have been adopted by the state of New Mexico and are included in New Mexico Regulations Governing Water Supplies. NMEID has been authorized by EPA to administer federal drinking water regulations and standards in New Mexico.

During 1989, all water samples collected under the SDWA program at Los Alamos and tested by SLD in Albuquerque and the Pan Am laboratory were found to be in compliance with the maximum contaminant levels established by regulation. The following is a summary of the results of testing at Los Alamos.

2. Inorganic Chemical Monitoring of the Water Supply System. The Laboratory and county distribution systems were sampled at three locations for inorganic chemicals during 1989 to determine compliance with SDWA. Each location is representative of one of the well fields supplying the systems: Los Alamos Airport is representative of water quality of the Los Alamos Well Field; White Rock Fire Station, of the Pajarito Well Field; and Barranca School, of the Guaje Well Field (Fig. 16, Table G-15). Samples were collected by HSE-8 and shipped to SLD in Albuquerque for analysis. The SLD reports all test results directly to NMEID. All results were found to be in compliance with standards (Table 28).

3. Organic Chemical Monitoring of the Water Supply System. All of the water supply wells and the Water Canyon gallery were sampled during a period from November 1988 to June 1989 for volatile organic

Table 28. Inorganic Chemical Concentrations in the Water Distribution System (mg/L)

Contaminant	Los Alamos Airport	White Rock Fire Station	Barranca School	EPA Maximum Concentrate
Arsenic	<0.016	<0.005	<0.005	0.05
Barium	<0.1	<0.1	<0.1	1.0
Cadmium	<0.001	<0.001	0.005	0.01
Chromium	0.016	<0.005	0.006	0.05
Lead	<0.005	<0.005	<0.005	0.05
Mercury	<0.0005	<0.0005	<0.0005	0.002
Selenium	<0.005	<0.005	0.010	0.01
Silver	<0.001	<0.001	<0.001	0.05
Nitrate (as N)	0.46	0.43	0.45	10.0
Fluoride	1.51	0.58	0.51	4.0

chemicals, as specified under SDWA. This sampling included screening for 8 regulated and 51 unregulated organic chemicals. Analytical results reported in 1989 by SLD showed that no organic contamination was present in any of the water supply wells or the gallery (see Table 29).

4. Total Trihalomethane Monitoring of the Water Supply System. Under SDWA, testing for total trihalomethanes is required for public water systems once each quarter. During 1989, a total of 20 samples for the year was collected by HSE-8 at 5 locations throughout the Laboratory and county distribution systems. Samples were analyzed by SLD, and the results showed concentrations that were below the maximum contaminant level of 0.10 mg/L for total trihalomethanes (Table 30).

5. Radiological Monitoring of the Water Supply System. The water supply system was sampled for radioactivity at three locations during 1989, each representative of one of the well fields supplying the system. Slightly elevated results for gross alpha were found in the Los Alamos Airport sample taken in June. Because of these results, each of the three locations was resampled in August. Results from the resampling at the airport indicated that gross alpha was approximately one-third that reported from the original sample. All samples, from June and August, were analyzed by SLD and showed compliance with SDWA requirements (Table 31).

6. Microbiological Monitoring of the Water Supply System. Each month during 1989, approximately

Table 29. Volatile Organic Chemical Concentrations in Water Supply Wells (mg/L)

Well Samples	SDWA Volatile Chemicals[a] Group 1	SDWA Volatile Chemicals[a] Group 2
Wells		
LA-1B, 2, 3, and 5	N	N
G-1, 1A, and 2	N	N
G-4, 5, and 6	N	N
PM-1, 2, 3, and 5	N	N
PM-4	N	N
Water Canyon gallery	N	N

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[a] N = none detected above detection limit.

Table 30. Total Trihalomethane Concentrations in the Water Distribution System in 1989 (mg/L)[a]

Sampling Location	Quarters First	Quarters Second	Quarters Third	Quarters Fourth
Los Alamos Airport	<0.004	<0.004	0.02	<0.005
White Rock Fire Station	<0.004	<0.004	<0.04	<0.004
North Community Fire Station	<0.004	0.001	<0.04	<0.004
S-Site Fire Station	<0.004	0.003	<0.04	<0.004
Barranca Mesa School	<0.004	<0.004	<0.04	<0.004

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[a] The EPA maximum contaminant level is 0.10 mg/L.

Table 31. Radioactivity in the Water Distribution System[a]

		Radioactivity in Sample	
Analysis	Standard for Calibration	June 29, 1989 (pCi/L)	August 15, 1989 (pCi/L)
Los Alamos Airport			
Gross alpha	^{241}Am	4.90	1.50
	Natural uranium	6.40	2.00
Gross beta	^{137}Cs	3.40	2.00
	^{90}Sr, ^{90}Y	3.40	2.00
^{226}Rn	—	0.03	—
White Rock Fire Station			
Gross alpha	^{241}Am	1.00	0.60
	Natural uranium	1.20	0.70
Gross beta	^{137}Cs	3.70	4.50
	^{90}Sr, ^{90}Y	3.60	4.50
Barranca School			
Gross alpha	^{241}Am	0.30	0.60
	Natural uranium	0.40	0.80
Gross beta	^{137}Cs	2.20	3.00
	^{90}Sr, ^{90}Y	2.20	3.00

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[a] The EPA gross alpha maxmum contaminant level is 15 pCi/L.

45 samples were collected throughout the Laboratory and county distribution systems to determine the chlorine residual available for disinfection and the microbiological quality of the water supply. These samples were examined by the Pan Am laboratory for the presence of coliform bacteria, which are used as an indicator to determine if harmful bacteria could be present. During 1989, only one sample contained coliform bacteria. This sample was obtained from the water distribution system at TA-33, and the single coliform bacterium initially identified was later found to be a nonfecal, soil-related coliform. All analytical results from coliform testing showed compliance with regulations (Table 32).

During 1989, approximately 6% of the microbiological samples collected were found to have noncoliform bacteria present. Although the presence of noncoliform bacteria is not a violation of SDWA, it does indicate stagnant water and possibly dirt in the distribution lines. Both Pan Am Utilities and Los Alamos County have established water system flushing programs to reduce stagnant water in lines. These programs have been effective in reducing stagnant water and noncoliform bacteria for limited periods of time.

7. Other Environmental Activities for Protection of the Water Supply System. Other programs conducted to protect the water supply system include the following:

- *Wellhead Inspection Program.* A survey of water supply wells was conducted during 1989 by the Pan Am environmental group to detect any potential sources of contamination into the system. Daily inspections of the wells were also conducted by Pan Am Utilities to maintain pumping equipment and to identify any problem that might lead to a potential health hazard.
- *Disinfection Program for New Construction.* Whenever new construction or repair work is required on a water main, the pipe must be disinfected before it is returned to service. This disinfection is

Table 32. Microbiological Testing of the Water Distribution System

Month	No. of Tests Conducted	No. of Tests Positive for Bacteria	
		Coliform	Noncoliform
January	47	0	1
February	48	0	5
March	46	0	2
April	44	0	6
May	45	0	0
June	46	0	1
July	46	1[a]	5
August	45	0	1
September	45	0	5
October	44	0	2
November	45	0	4
December	45	0	0
Total	546	1[a]	32

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[a] Confirmed as nonfecal coliform bacteria.

accomplished by flushing the pipe and adding a high-strength chlorine solution to the main. The chlorinated water is then removed and the replacement water is checked for bacterial contamination by the Pan Am environmental group. During 1989, disinfection of new water mains and equipment was conducted as construction was completed.

- *Cross-Connection Control Program.* The Laboratory also maintains a cross-connection control program to ensure that a separation exists between the potable water supply and industrial or other nonpotable systems. During 1989, each of the backflow-prevention devices separating the potable water supply system from potential sources of contamination was tested to ensure proper operation.

8. Water Production Records. Monthly water production records are provided to the State Engineer's Office under the water rights permit, held by the DOE, for the Los Alamos water system. During 1989, total production from the wells and gallery for potable and nonpotable use was 6.5 × 10^6 m^3 (5300 acre-ft). This production amounts to 95% of the total diversion right of 6.8 × 10^6 m^3 (5500 acre-ft) that is available to the DOE under its permit.

F. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

This act requires registration of all pesticides, restricts use of certain pesticides, recommends standards for pesticide applicators, and regulates disposal and transportation of pesticides. A pesticide is defined as any substance intended to prevent, destroy, repel, or mitigate pests. The Laboratory's contractor, Pan Am World Services, stores, uses, and discards pesticides in compliance with the provisions of FIFRA. A Laboratory pest-control policy was established in June 1984 to establish procedures and identify suitable pesticides for controlling plant and animal pests. Anything outside the scope of the policy must be approved by the Pest Control Oversight Committee. No unusual events associated with compliance occurred during 1989. No external inspections of the Laboratory's pesticide operations or facilities were conducted in 1989.

G. National Historic Preservation Act

As required by Sec. 106 of the National Historic Preservation Act of 1966, which was implemented by 36 CFR 800, "Protection of Historic Properties," Laboratory undertakings are evaluated in consultation with the State

Historic Preservation Officer (SHPO) for possible effects on historic resources. During 1989, Laboratory archaeologists evaluated 462 undertakings, conducted 42 field surveys, recorded 14 new archaeological sites, and submitted 15 survey reports and 2 mitigation plans for SHPO review.

One project was monitored, the Power-Line Extension in Pajarito Canyon, Work Order 9092-44. No cultural resources were disturbed by the project. A follow-up report is in progress.

Because of the SWSC Project (Laboratory Job No. LJN 8165), one site was tested: the David Romero homestead corral (Laboratory of Anthropology, No. 16806-B). No subsurface features were encountered. The results of the testing will be reported in the cultural resource survey report for the SWSC Project sewer lines.

H. Endangered/Threatened/Protected Species and Floodplains/Wetlands Protection

The DOE and Laboratory must comply with the Endangered Species Act of 1973, as amended, and with Executive Orders 11988, "Floodplain Management," and 11900, "Protection of Wetlands." Compliance under NEPA requires review of projects for potential environmental impact to critical habitats, floodplains, and wetlands. Laboratory activities during 1989 to comply with these regulations were in four categories.

1. Floodplain/Wetland Assessments. Two assessments were scheduled for the summer of 1989 but were postponed until 1990 because of reassignment of personnel to NEPA compliance documents. The two assessments, for TA-18 and Cañada del Buey below the SWSC Project, will be completed in 1990. For compliance with the federal RCRA permit, the Laboratory arranged with the Fish and Wildlife Service for wetlands mapping, to be completed during 1990.

2. Endangered Species Surveys. About 500 projects were evaluated during 1989 to determine possible impact from construction activities on endangered, threatened, rare, and sensitive species. About 25 (5%) of these projects required reconnaissance surveys or qualitative field surveys; 12 projects required more extensive surveys. A project to replace a DOE-owned gas line required field surveys of portions of 53 km (33 mi) between Cuba and Kutze, New Mexico. Special surveys for the Jemez salamander and spotted owl were done for a DOE construction site on lands administered by the U.S. Forest Service. The reassignment of personnel required that approximately 13 surveys on other construction sites be postponed until 1990.

3. Monitoring of Sensitive Species. A raptor monitoring program was continued during 1989. A census of avian species in permanent plots established in 1984 was recorded during the breeding period, April through June.

4. Construction Site Monitoring. One site was monitored during construction to prevent undue destruction of the habitat for a raptor species.

I. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

CERCLA of 1980 and the Superfund Amendments and Reauthorization Act (SARA) of 1986 mandate cleanup of toxic and hazardous contaminants at closed and abandoned hazardous waste sites. The CERCLA/SARA-related actions for potential release sites at the Laboratory are being addressed under the DOE's Environmental Restoration Program in conjunction with RCRA corrective actions (see Sec. VIII.A).

J. Toxic Substances Control Act (TSCA)

TSCA (15 U.S.C. *et seq.*) establishes a list of toxic chemicals for which the manufacturing, use, storage, handling, and disposal are regulated. This is accomplished by requiring premanufacturing notification for new chemicals, testing of new or existing chemicals suspected of presenting unreasonable risk to human health or the environment, and controlling measures for chemicals found to pose an unreasonable risk.

The Code of Federal Regulations (40 CFR 761) contains regulations applicable to polychlorinated biphenyls (PCBs). The code applies to all persons who manufacture, process, distribute in commerce, use, or dispose of PCBs or PCB items. Substances that are regulated by this rule include, but are not limited to, dielectric fluids, contaminated solvents, oils, waste oils, heat transfer fluids, hydraulic fluids, paints, sludges, slurries, dredge spoils, soils, and materials contaminated as a result of spills. Most of the provisions of the regulations apply to PCBs only if they are present in concentrations above a specified level. For example, the regulations regarding storage and disposal of PCBs generally apply to materials whose PCB concentrations are 50 ppm and above. At the Laboratory, materials containing >500-ppm PCBs are transported off site for treatment and disposal, and materials containing 50- to 500-ppm PCBs are incinerated or disposed of in Area G. This area has been approved by the EPA for disposal of PCB-contaminated materials.

Efforts continued toward removal and disposal of PCB items from Laboratory grounds. During 1989, the following PCB waste was sent off site for disposal: >500-ppm PCB-containing oil (40 872 kg [90 108 lb]), >50-ppm PCB-containing oil (31 500 kg [69 440 lb]), 233 capacitors (6620 kg [14 595 lb]), 26 transformers (38 465 kg [84 800 lb]), debris (1798 kg [3963 lb]), and water contaminated with >500-ppm PCBs (294 kg [648 lb]). In addition, 905 905 kg (1 997 179 lb) of PCB-contaminated soil, debris, and equipment were disposed of at Area G. Eleven transformers are undergoing a 20-month retrofill process using silicone oil. These transformers are expected to be reclassified to non-PCB status in May 1990. At this time, no transformers are leaking PCBs.

Inspections in August by the EPA and NMEID resulted in three findings, all of which were corrected. The findings involved a curb that was 14.6 cm (5.75 in.) high instead of the required 15.2 cm (6 in.) high, improper storage of PCB-handling equipment, and failure to retrofill an elevator hydraulic system on schedule. In addition, the DOE conducted an audit in August, which found combustible materials within 5.2 m (17 ft) of a PCB transformer. This, too, was corrected.

K. Emergency Planning and Community Right-to-Know Act

Requirements for reporting toxic chemical releases under SARA, Title III Sec. 313, went into effect on March 17, 1988. The focus of this rule is the inventory provision for toxic chemical releases, which requires owners and operators of covered facilities (facilities that manufacture, import, process, or otherwise use a listed chemical) to report annually their releases of such chemicals into any environmental medium. The purpose of this provision is to make information about environmental releases of toxic chemicals publicly available. Reports must be submitted annually to the EPA and to the state in which the facility is located. This rule is in addition to other reporting requirements under SARA Title III, which went into effect in May 1987.

Under Sec. 313, a covered facility is one (1) that has 10 or more full-time employees, (2) that has a Standard Industrial Code between 20 and 39, and (3) that exceeds an applicable manufacturing process or use threshold. For manufacturing or processing, these thresholds vary by year. In 1987, the threshold was 34 000 kg (75 000 lb); in 1988, it was 22 700 kg (50 000 lb); and in 1989 it was 11 300 kg (25 000 lb). For toxic chemicals used for other purposes, the threshold for all years was 4540 kg (10 000 lb). For each toxic chemical that exceeds the appropriate threshold, the covered facility must report the amount of that chemical that was released to the air, water, and soil media for the applicable year. Other environmental release categories include underground injection and transfers of listed toxic chemicals to off-site Publicly Owned Treatment Works or to other treatment and disposal locations.

According to 40 CFR, Sec. 372.22, the Laboratory is not a covered facility under Sec. 313. However, DOE policy is that the Laboratory will comply with all Sec. 313 reporting requirements. Therefore, for calendar year 1988, the Laboratory reported environmental releases for nitric acid and sodium hydroxide. These were the only two compounds exceeding applicable threshold amounts, triggering the reporting requirement because these chemicals are not otherwise exempted under 40 CFR, Sec. 372.38. The reporting date under Sec. 313 for calendar year 1988 was July 1, 1989.

For nitric acid, the threshold amount was approximately 42 400 kg (93 400 lb) in 1988. Of this total, about 380 kg (850 lb) were reported as stack air emissions. The remaining amounts of nitric acid were either consumed in chemical reactions or were completely neutralized by sodium hydroxide in waste-water treatment operations and thus were not reported. For sodium hydroxide, the threshold amount in 1988 was approximately 26 200 kg (57 700 lb).

Reporting of sodium hydroxide is required. However, because all sodium hydroxide used at the Laboratory is completely neutralized in reactions with nitric, sulfuric, or hydrochloric acids during waste-water treatment operations, no environmental releases were reported for this compound.

For nitric acid releases in calendar year 1987, the Laboratory reported approximately 1500 kg (3300 lb) of non-point-specific air emissions and 1100 kg (2500 lb) of stack emissions. The dramatic reduction in reported nitric acid releases to the environment from calendar years 1987 to 1988 was not due to any major change in process or chemical use but rather to more-accurate data. A detailed Laboratory-wide air emissions study was made in 1988, which consisted of a room-by-room chemical-use inventory and selective testing of air emissions from stacks. As a result, air emissions were more accurately estimated.

L. Engineering Quality Assurance

The Laboratory has a quality assurance program (Engineering 1983) for engineering, construction, modification, installation, and maintenance of DOE facilities. The purpose of the program is to minimize the chance of deficiencies in construction; to improve the cost effectiveness of facility design, construction, and operation; and to protect the environment. A major goal of engineering quality assurance is to ensure operational compliance with all applicable environmental regulations. The quality assurance program is implemented from inception of design through completion of construction by a project team approach. The project team consists of individuals from DOE's program division, DOE/AL and DOE/LAAO; Laboratory operating group(s) and the Facility Engineering Division; and the design contractor, inspection organization, and construction contractor. Each proposed project is reviewed by personnel from HSE-8 to ensure that environmental integrity is maintained.

IX. ENVIRONMENTAL SUPPORT ACTIVITIES

In addition to environmental surveillance and compliance activities, the Laboratory carried out a number of related environmental activities. Selected studies are briefly described in this section. Many of these activities are ongoing and provide supplementary information for surveillance and compliance activities at the Laboratory.

A. Meteorological Monitoring (Brent Bowen, Jean Dewart, William Olsen, and Kathy Derouin)

1. Weather Summary. Slightly lower-than-normal precipitation fell in Los Alamos during 1989, totaling 41 cm (16.2 in.) of water equivalent during the year. This represented the driest year since 1980 and the first year with below-normal precipitation since 1983. April and November were particularly dry months. Snowfall totaled a near-normal 131 cm (51.5 in.) during the year. Spring (March–May) during 1989 became the warmest on record. Hot weather, primarily during the first 8 days of July, gave Los Alamos the second most number of days of reaching or exceeding 32°C (90°F). The year as a whole had above-normal temperatures and was the warmest year since 1981. The annual summary is shown in Fig. 24; other data are shown in Tables G-55 through G-58.

January and February both had heavy snowfall, resulting mainly from one large snowstorm in each month. A snowstorm on January 27 dropped nearly 30 cm (1 ft) of snow, thereby forcing the Laboratory and Los Alamos businesses and schools to close during the afternoon. January ended with 42 cm (16.6 in.) of snowfall. A similar amount of snow, 41 cm (16.3 in.), fell during February. Most of the month's snow fell during February 4--6 when 38 cm (15.0 in.) fell, including 25 cm (10.0 in.) on the 5th. The storm was associated with an arctic air mass, as temperatures were below −9°C (16°F) for much of the storm on the 5th and 6th. The temperature fell to −20°C (−4°F) and only reached −11°C (13°F) for a high on the 6th, both records for the date. The advance of the arctic air from the northeast caused a brief, dramatic temperature difference toward midnight on the 4th While the temperature at Los Alamos dropped to −8°C (17°F) and was still falling, Albuquerque reported a very mild 12°C (54°F). The rest of February was warm, with temperatures reaching 18°C and 17°C (64°F and 62°F) on the 25th and 26th, respectively.

The warm weather intensified during March, breaking numerous records. High-temperature records were broken for 5 consecutive days, beginning on the 8th. The temperature of 22°C (72°F) on the 9th became the highest temperature ever recorded in the entire month of March. The March high-temperature record lasted only 2 days, as the temperature reached 23°C (73°F) on the 11th. The weather cooled but remained mild later in the month. A storm dropped 16.5 cm (6.5 in.) of wet snow on the 20th. The month became the second-warmest March on record.

A high-pressure ridge located over the southwest United States during March persisted during April, keeping storms away, as well as causing warm temperatures. The high temperature of 24°C (75°F) on the 7th was the warmest temperature for so early in the season, besides breaking the record for the date. The high temperature of 23°C (74°F) on the 8th also was a record. Temperatures remained warm and again reached a record level of 26°C (78°F) on the 20th. On the following day (21st), the record-breaking 26°C (79°F) also was the warmest for so early in the season. Another record high of 22°C (72°F) was tied on the 24th. The month became the second-warmest April on record. The combination of the warmth and April's light precipitation caused drought conditions to develop, especially over the valley regions.

The very warm conditions prevailed into May, along with some much-needed rains. Temperatures reached record levels on the 6th with 26°C (78°F). The record high temperatures of 27°C and 28°C (81°F and 83°F) on the 7th and 8th, respectively, were the highest temperatures recorded for so early in the year. An intense thunderstorm dropped heavy rains and large hail on the 9th, causing

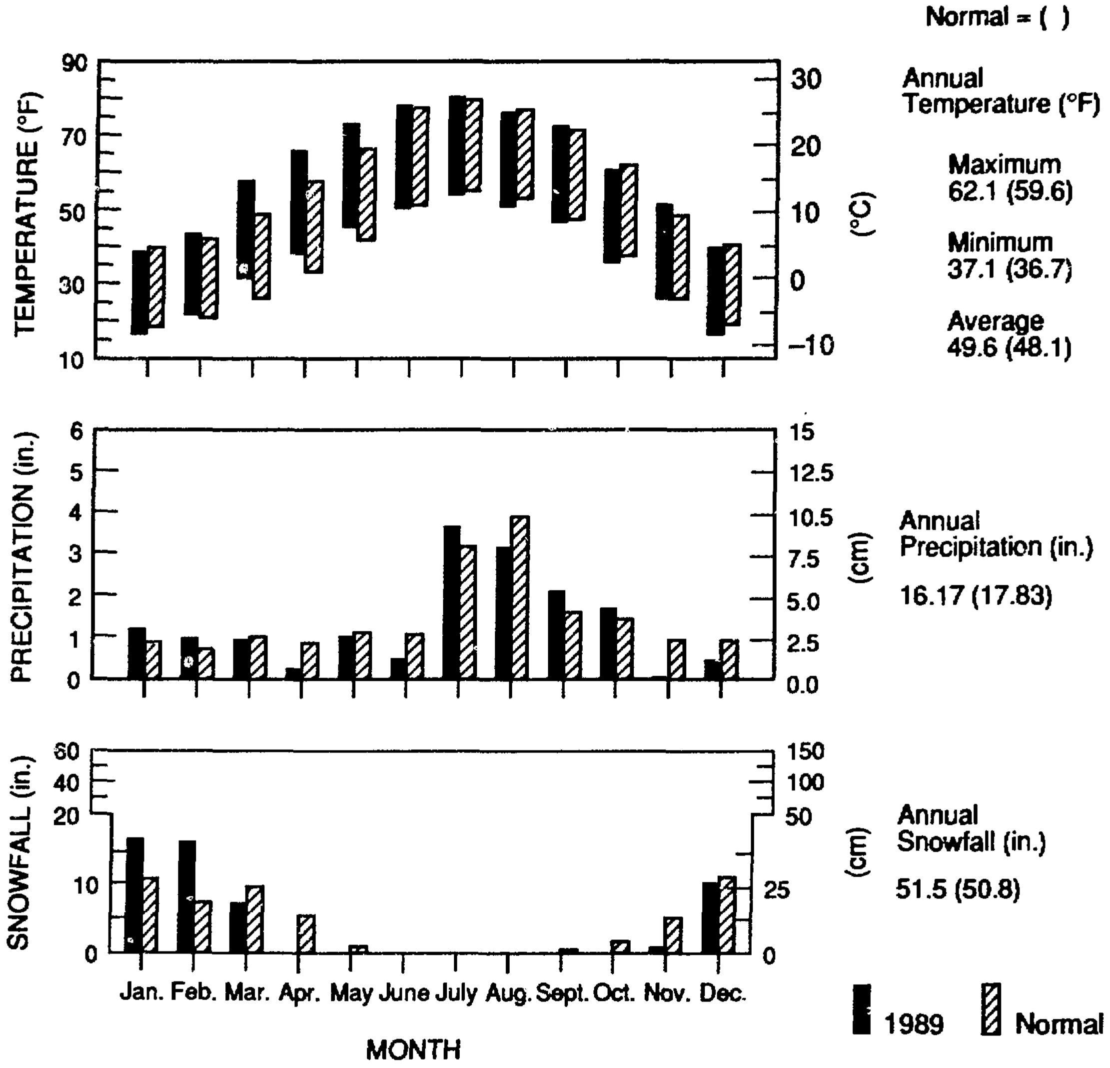

Fig. 24. Summary of weather in Los Alamos (TA-59) during 1989.

traffic accidents and some damage to cars and homes in White Rock. A 34-m/s (76-mph) peak wind gust was measured at East Gate during the storms. Another record fell on the 23d when the high temperature reached 29°C (84°F). The low temperature only reached 16°C (61°F) on the following morning (24th), unusually warm for May. Another thunderstorm caused very strong winds on the 27th, with peak gusts of 34 and 30 m/s (76 and 66 mph) recorded at the Area G and Bandelier sites, respectively.

The three consecutive warm months of March, April, and May gave Los Alamos its warmest spring on record. The average spring temperature of 11.3°C (52.4°F) easily exceeded the previous record warm spring by 1.2°C (2.2°F).

Average monthly temperatures returned to more normal levels for most of the summer, although temperatures continued to be unusually high during June and early July. Rainfall was light in June, totaling 1.3 cm (0.51 in.). The high temperature of 33°C (92°F) set a record on the 19th and was the warmest temperature recorded for so early in the year. July began with unusually hot weather, with the high temperature reaching 32°C (90°F) or higher on 7 of the first 8 days of the month. The 34°C (93°F) high temperature on July 2 was the warmest temperature since the highest temperature on record of 35°C (95°F) was last reached on June 22, 1981. The month had 8 days with high temperatures of 32°C (90°F) or higher, the second highest on record for July and the third highest for any summer month. The dry and hot weather was followed later in the month by rainy and cool conditions. Typical thundershowers were frequent during August.

Weather conditions were uneventful during September and October, except for an unusually early light frost on September 14 when the temperature fell to a record low of 1°C (34°F). A storm dropped 4.1 cm (1.63 in.) of rain October 3–5. A large high-pressure system developed over the western United States and persisted during much of the rest of October, November, and December, thereby permitting only a few weak storms to affect the Los Alamos area. November had no measurable precipitation until 0.1 cm (0.04 in.) fell during the afternoon of the 30th. December also was dry, with only 1.3 cm (0.50 in.) of water-equivalent precipitation. A storm on the 30th dropped 11.4 cm (4.5 in.) of snow.

2. Wind Roses. The 1989 surface wind speed and direction measured at four sites at Los Alamos are plotted in wind roses for day, night, and total hours (day and night) (Figs. 25 through 27). A wind rose is a circle with lines extending from the center representing the direction *from* which the wind blows. The length of each line is proportional to the frequency of the wind speed interval from that particular direction. Each direction is 1 of 16 primary compass points (for example, N and NNE) and is centered on a 22.5°-wide sector of the circle. The frequency of the calm winds, defined as those having speeds <0.5 m/s (1.1 mph), is given in the circle's center. Day and night are defined by the times of sunrise and sunset.

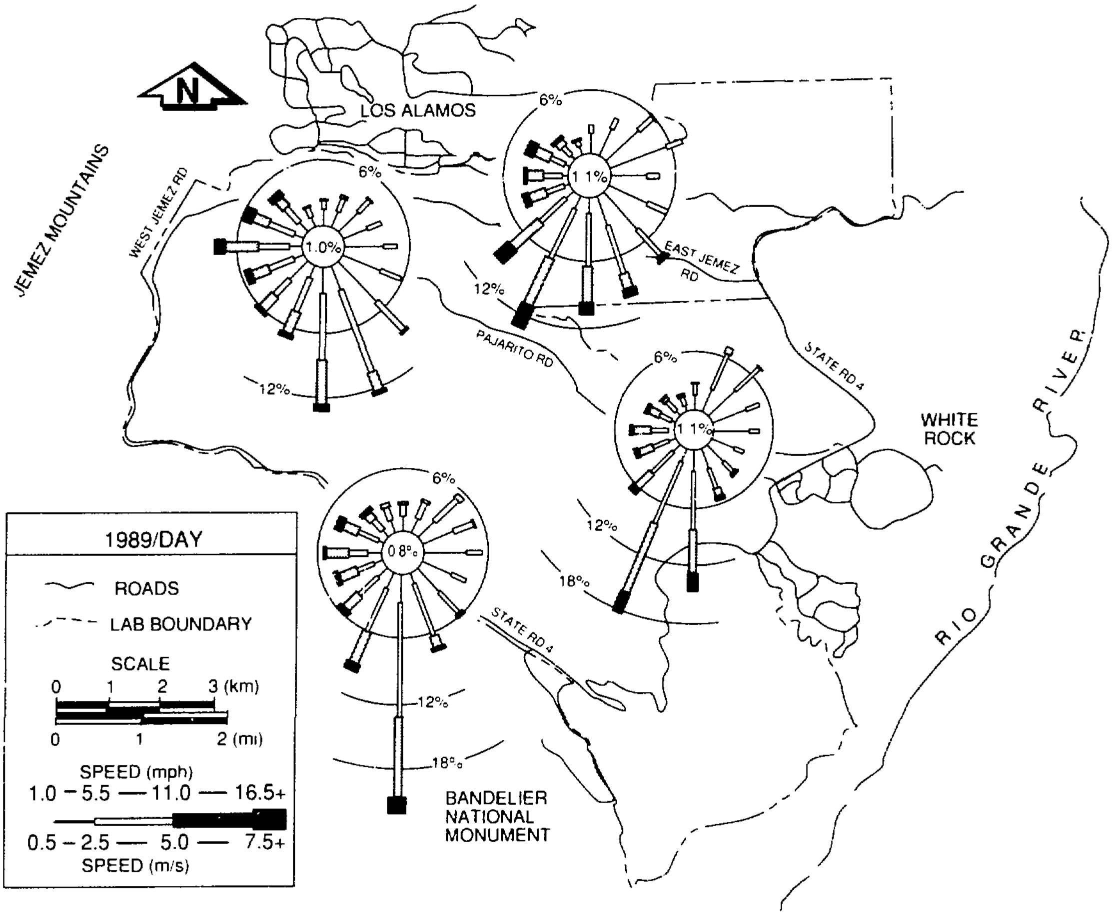

Fig. 25. Daytime wind roses at Laboratory stations during 1989. Surface winds are represented at TA-59 (upper left) clockwise to East Gate, Area G, and Bandelier.

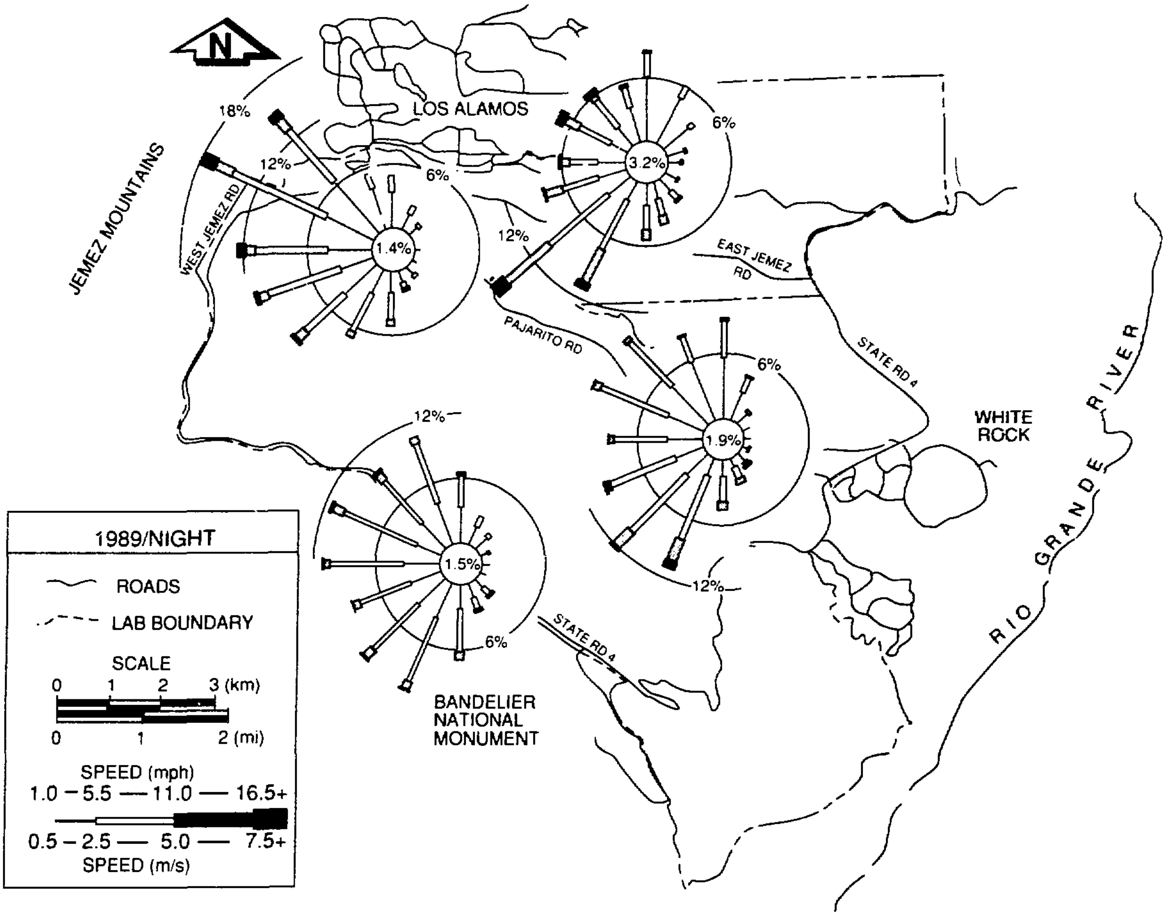

Fig. 26. Nighttime wind roses at Laboratory stations during 1989. Surface winds are represented at TA-59 (upper left) clockwise to East Gate, Area G, and Bandelier.

The wind roses represent winds at the Occupational Health Laboratory (OHL) building at TA-59 (2248 m [7373 ft] above sea level [ASL]), Bandelier (2146 m [7040 ft] ASL), East Gate (2140 m [7019 ft] ASL), and Area G (2039 m [6688 ft] ASL). Wind data were measured at heights of 23 m (69 ft) at OHL and about 11 m (36 ft) at the other three sites.

Surface winds at Los Alamos are generally light, with an average speed of 3 m/s (7 mph). Wind speeds >5 m/s (11 mph) occurred with frequencies ranging from 17% at OHL and Bandelier to 23% at East Gate. Many of the strong winds occurred during the spring. At least 34% of surface winds at all sites were <2.5 m/s (<5.5 mph). At the 92-m (300-ft) level (not shown in the figure), the average wind speed increases to more than 4 m/s (9 mph). At the higher level, wind speeds >5 m/s (>11 mph) occur 35% of the time, and speeds <2.5 m/s (<5.5 mph) occur 30% of the time.

Distribution of winds varies with site, height above ground, and time of day, primarily because of terrain features at Los Alamos. On days with sunshine and light large-scale winds, a deep, thermally driven upslope wind develops over the Pajarito Plateau. Note the high frequency of southeasterly through southerly winds during the day at OHL and, to a lesser extent, at East Gate (Fig. 25). Upslope winds are generally light, <3 m/s (<7 mph). Winds become more south-southwesterly and southerly at Bandelier and Area G. The winds at these sites are increasingly affected by the Rio Grande Valley and less affected by the plateau. Channeling of regional-scale winds by the valley contributes to the high frequency of south-southwesterly and north-northeasterly or

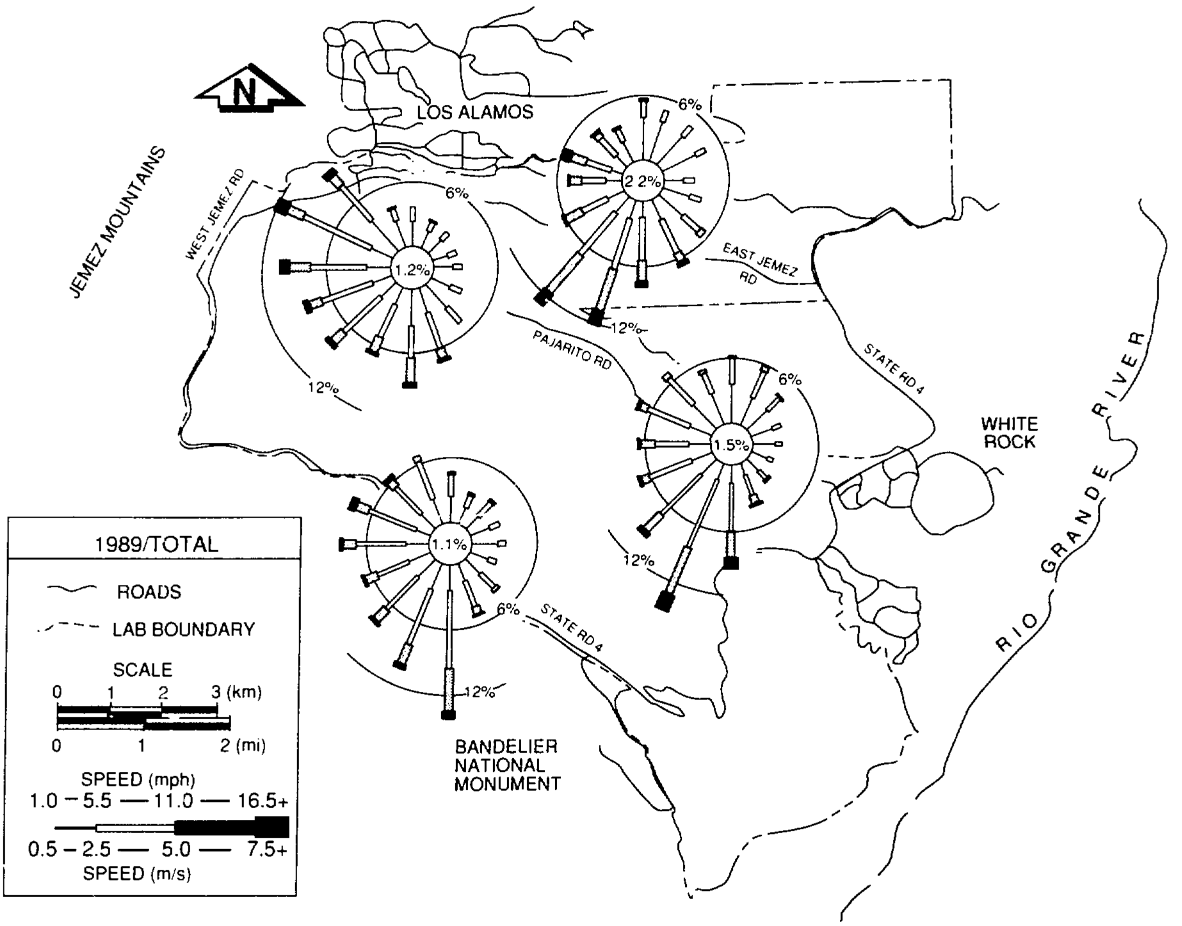

Fig. 27. Total wind roses at Laboratory stations during 1989. Surface winds are represented at TA-59 (upper left) clockwise to East Gate, Area G, and Bandelier.

northeasterly winds. In addition, a thermally driven up-valley wind may cause some of the south-southwesterly winds below 3 m/s (7 mph) at Area G.

Winds display a reversal during the night. A shallow drainage wind often forms and flows across the plateau and down the canyons on clear nights with light, large-scale winds. These winds are generally <4.5 m/s (<10 mph). Winds are most frequent from the west-northwest to northwest at OHL, whereas the drainage winds at Bandelier and Area G are evenly distributed from the west through the north. Downslope winds are much less frequent at East Gate. Winds over the plateau (measured at the 92-m [300-ft] level at the OHL) are dramatically different from those at the surface during nights, with valley-channeled winds dominating (not shown). A high frequency of winds are up-valley (southwesterly and south-southwesterly) and down-valley (northerly through northeasterly).

3. Precipitation Summary. Precipitation was slightly below normal in Los Alamos during 1989. Figure 28 shows precipitation analyses for the summer (June–August), as well as for the entire year. Monthly precipitation totals are presented in Table G-57. The dry months of April, November, and December were responsible for limiting the yearly totals. Summer rainfall was near normal, except for S-Site where a wet July with 17.7 cm (5.38 in.) of rain caused above-normal precipitation. A locally heavy rainfall of 5.0 cm (1.97 in.) fell at S-Site on July 14. Precipitation was generally highest in the northwest part of Los Alamos County, near the mountains and at the highest part of the Pajarito Plateau. Precipitation

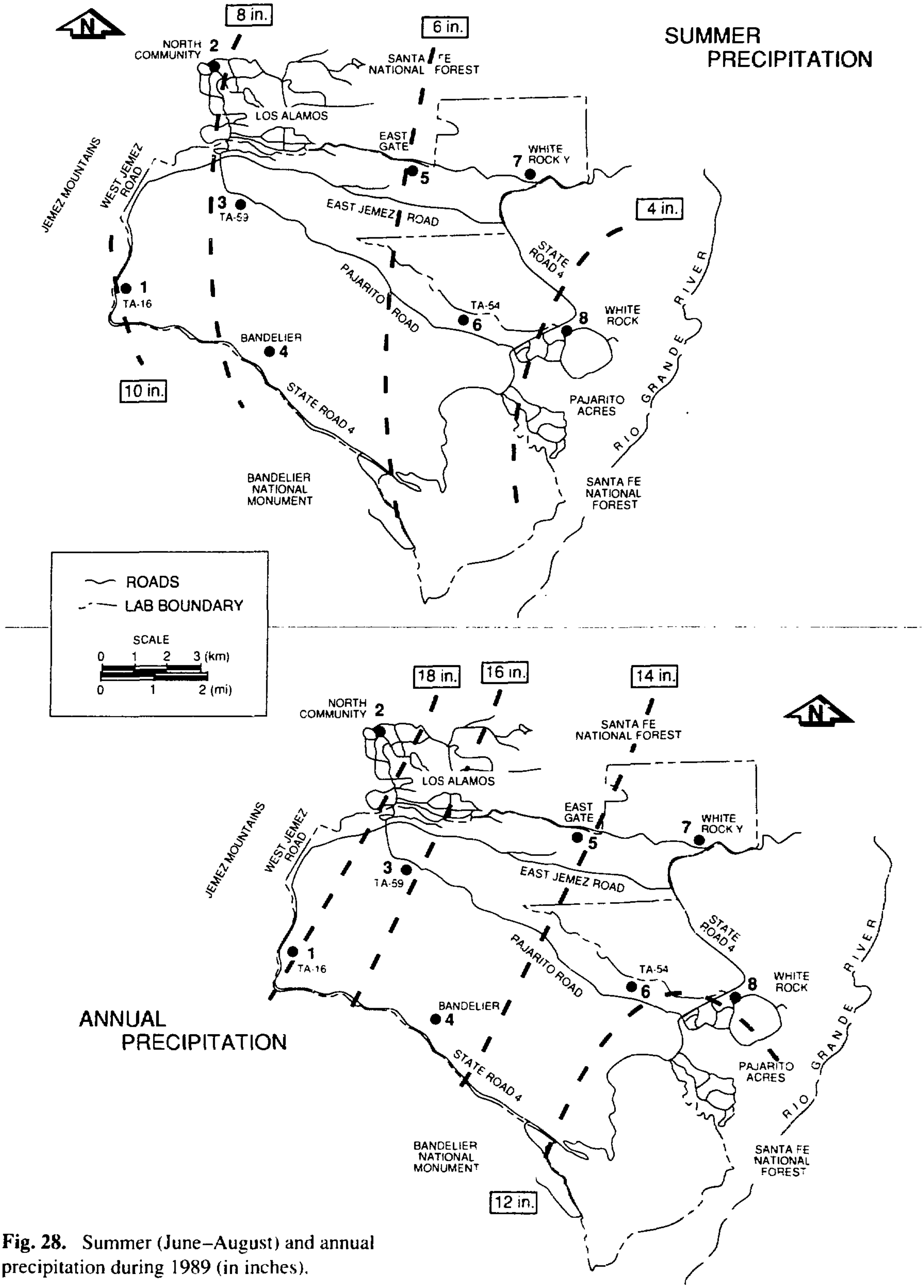

Fig. 28. Summer (June–August) and annual precipitation during 1989 (in inches).

decreased with lower elevation and increasing distance from the Jemez Mountains.

4. Visibility. The National Park Service has published the data from the Laboratory for three seasons in 1989: spring (March 1 through May 31), summer (June 1 through August 31), and fall (September 1 through November 30). These data show that typical visibility in this area is high, with median visibilities greater than 95 km (60 mi).

Season	Median Visibility km (mi)
Spring	116 (72)
Summer	101 (63)
Fall	137 (85)

Visibilities were lowest in the summer months, probably because of the high humidity associated with the common afternoon thunderstorms. About 10% of the time, visibilities were greater than 150 km (93 mi), with maximum visibility exceeding 250 km (150 mi). These visibilities are characteristic of clean air areas in relatively arid climates.

B. Environmental Studies at the Pueblo de San Ildefonso (W. D. Purtymun, Max Maes, and Jane Wells [Bureau of Indian Affairs, BIA])

To investigate the potential impacts of Laboratory operations on lands belonging to San Ildefonso Pueblo, the DOE entered into a Memorandum of Understanding with the Pueblo and the BIA to conduct environmental sampling on Pueblo land. During 1987 and 1988, water, soil, and sediment samples were collected (Purtymun 1988b, ESG 1989).

In 1989, the informal agreement was for the Laboratory to collect and analyze water from five stations east and west of the Rio Grande (station 19, Cottonwood Trading Post; station 3, Pajarito Well; station 8, Halladay Well; station 18, Otowi House; and station 10, West-Side Artesian Well) and sediments from four stations in Mortandad Canyon (Fig. 29). Splits of these samples were also

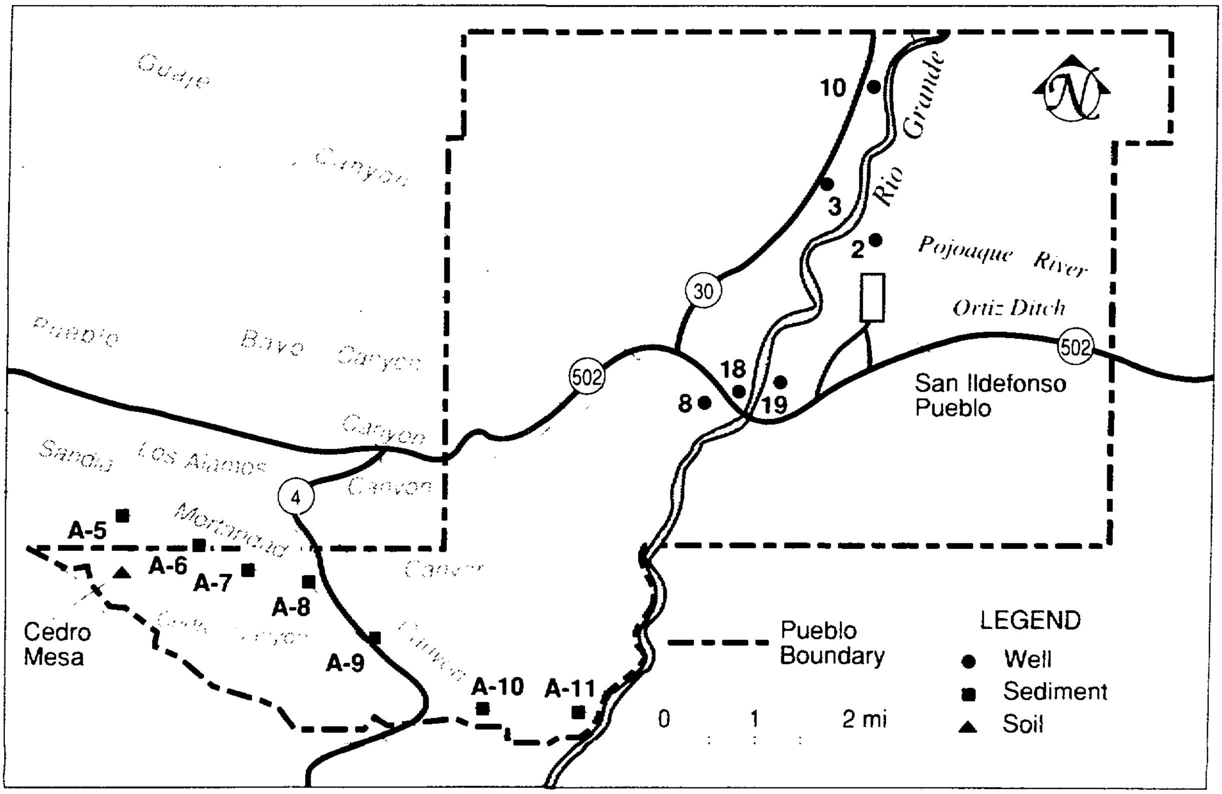

Fig. 29. Ground-water and sediment stations on Pueblo de San Ildefonso land.

analyzed by the BIA with comparable results (BIA 1989). Analyses of three other sediment samples from Mortandad Canyon (stations A-5, A-9, and A-11 on Fig. 29), performed as part of the routine monitoring effort, are included in the data and discussion in this section to present a continuous profile of the distribution of radionuclides in Mortandad Canyon.

1. Ground Water. Radiochemical analyses in 1989 of ground water from stations 3, 8, and 10 indicated no significant change from the analyses that were performed on wells at those locations in 1988 (Table 33). The gross alpha activity from station 3 decreased from 22×10^{-9} µCi/mL to 1×10^{-9} µCi/mL.

The gross alpha activity in water from station 19 was 26×10^{-9} µCi/mL. As detailed in Purtymun (1988b), the gross alpha activity in this area is due to uranium and not radium. Subtracting the activity caused by uranium yields $17 \pm 7 \times 10^{-9}$ µCi/mL, which approximately equals the EPA drinking water gross alpha standard (used for comparison only), which excludes activity from radon and uranium. Samples taken at the same time by the BIA and analyzed by their laboratory showed 9×10^{-9} µCi/mL of gross alpha activity. After subtracting the activity caused by uranium, their data indicate that essentially no alpha activity is attributable to other nuclides (BIA 1989).

No significant change was found in the chemical quality of the ground water from stations 3, 8, and 10 from the 1988 data to the 1989 data (Table 34). Chloride (250 mg/L), fluoride (4.0 mg/L), and iron (0.3 mg/L) standards were exceeded in water at station 10, with concentrations of 355, 5.6, and 0.59 mg/L, respectively. The total dissolved solids standard (500 mg/L) was exceeded, with concentrations of 842 mg/L at station 3, 1080 mg/L at station 10, and 958 mg/L at the Martinez house, which is supplied by the Pajarito Wells (station 3). Other chemical constituents in water from stations 3 and 10 and from the other three stations were at or below the standards. All these constituents are naturally occurring, and the levels are as expected for the area.

Special sampling and analyses were conducted during 1989 at station 3, known as the Pajarito Wells site, to investigate what appeared to be anomalous changes in the chemical quality of water that were noted between samples collected in 1987 and those collected in 1988 (ESG 1989). Samples were collected on six occasions during the latter half of 1989 and analyzed for selected constituents (Table 35). The Pajarito Wells pump house controls the operation of two separate wells by a timer, and thus the apparent anomaly was simply the result of having collected samples from periods when different wells were being pumped. Well 1 has somewhat poorer quality, with higher calcium, chloride, hardness, and specific conductance, than does well 2. The difference in quality is natural and is attributable to the different location and depth of the two wells, with no indication of a contamination problem. A sample was also collected from the Martinez house (Table 33), adjacent to and served by the Pajarito Wells pump house and storage tank. The quality of water was within the range of values found for the two separate wells.

2. Sediments. The industrial waste treatment plant at TA-50 releases treated effluent into the upper reaches of Mortandad Canyon. The effluent, containing traces of radionuclides, infiltrates into the underlying alluvium, forming an aquifer of limited extent perched on the underlying tuff in the upper- and mid-reaches of the canyon within Laboratory boundaries. A large proportion of the radionuclides in the effluent when it is first released as surface flow is adsorbed or attached to the sediments in the stream channel; thus, the principal means of transport is in surface run-off. Mortandad Canyon heads on the Pajarito Plateau at TA-3 and has a small drainage area. The alluvium thickens in the middle and lower reaches of the canyon. The small drainage area and the thick section of unsaturated alluvium in the middle reach of the canyon have retained all the run-off since 1960 when hydrologic studies began in the canyon. Thus, there has been no run-off to transport radionuclides to, or past, the Laboratory boundary since the start of effluent release in 1963.

During 1989, sediments were collected and analyzed for radionuclides from seven sediment stations, one west of the Laboratory and Pueblo boundaries and six within the Pueblo (Fig. 29 and Table 36). The analytical results for samples from the stations were compared with results from regional soil and sediment samples collected over many years to establish background levels for northern New Mexico (Purtymun 1987a).

Plutonium concentrations in samples taken in 1989 at stations A-5, A-6, and A-7 showed some differences from those taken in 1988. In 1989, the ^{239,240}Pu concentration in samples from station A-5 (0.018 pCi/g) was lower than that in 1988 by a factor of about 3, or about the same as observed in 1987 (0.023 pCi/g), and was within the statistical range attributable to worldwide fallout in

Table 33. Radiochemical Quality of Ground Water from Wells, Pueblo de San Ildefonso

Station Number and Well Identification	3H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	^{239,240}Pu (10^{-9} µCi/mL)	Gross Alpha (10^{-9} µCi/mL)	Gross Beta (10^{-7} µCi/mL)
19 Cottonwood Trading Post	0.7 (0.3)	17 (41)	14 (0.7)	−0.004 (0.004)	0.013 (0.014)	26 (7.0)	3.2 (0.5)
10 West-Side Artesian Well	0.0 (0.3)	−29 (42)	23 (1.2)	−0.018 (0.011)	0.018 (0.012)	10 (3.0)	1.1 (0.4)
8 Halladay Well	−0.2 (0.3)	−15 (50)	1.6 (0.6)	−0.010 (0.010)	0.005 (0.005)	4.0 (1.0)	1.7 (0.4)
18 Otowi House Well	−0.3 (0.3)	36 (58)	<0.5	0.004 (0.012)	0.012 (0.009)	6.0 (2.0)	3.0 (0.5)
3 Pajarito Well (pump 2)	0.0 (0.3)	−50 (42)	7.3 (0.7)	0.018 (0.017)	0.009 (0.006)	1.0 (2.0)	4.7 (0.6)
G. Martinez House[a]	0.1 (0.3)	18 (56)	12 (0.6)	−0.031 (0.019)	−0.008 (0.008)	4.0 (1.0)	2.7 (0.5)
Summary							
Maximum concentration	0.7	36	23	0.018	0.018	26	4.7
Standard[b]	20	200	800[c]	15	15	15	—
Maximum as a percentage of standard	3.5	18	3.9	<1	<1	173	
Limits of detection	0.3	40	1	0.009	0.03	0.1	—

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[a] House adjacent to and served by Pajarito Well (station 3).

[b] Maximum contaminant level (MCL), used for comparison only (NMEIB 1988, EPA 1989).

[c] Derived Concentration Guide, Appendix A.

Table 34. Chemical Quality of Ground Water from Wells, Pueblo de San Ildefonso (mg/L)[a]

								Summary	
	Standard[b]	Station 19 Cottonwood Trading Post	Station 10 West-Artesian Well	Station 8 Halladay Well	Station 18 Otowi House Well	Station 3 Pajarito Wells (pump 2)	G. Martinez House[c]	Maximum Concentration	Maximum Concentration as a Percentage of Standard
Chemical Constituents									
Primary[b]									
Ag	0.05	<0.005	<0.005	<0.005	0.010	<0.005	<0.005	0.010	20
As	0.05	0.002	0.007	0.010	0.010	0.010	0.006	0.010	20
Ba	1.0	0.140	0.045	0.400	0.011	<0.001	0.098	0.400	40
Cd	0.01	<0.001	<0.001	0.010	0.010	<0.0005	<0.001	0.010	100
Cr	0.05	0.006	0.006	0.015	<0.001	0.008	0.006	0.015	30
F	4.0	0.4	5.6	0.6	0.5	3.2	0.4	5.6	140
Hg	0.002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<10
NO_3-N	10	2.0	<0.1	0.5	0.6	0.3	0.2	2.0	20
Pb	0.05	<0.001	<0.001	<0.001	0.010	0.001	<0.001	0.010	20
Se	0.01	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	100
Secondary[b]									
Cl	250	6	355	3	9	157	206	355	140
Cu	1.0	0.003	0.001	0.008	0.010	0.004	0.029	0.029	30
Fe	0.3	0.270	0.590	0.260	0.108	0.280	0.290	0.59	200
Mn	0.05	<0.001	0.017	0.008	0.009	0.002	0.003	0.017	34
SO_4	250	19	80	14	46	42	51	80	32
Zn	5.0	0.104	0.017	0.027	0.009	0.080	0.063	0.104	2
TDS[d]	500	214	1080	118	284	842	958	1080	220

Table 34 (Cont)

	Standard[b]	Station 19 Cottonwood Trading Post	Station 10 West-Artesian Well	Station 8 Halladay Well	Station 18 Otowi House Well	Station 3 Pajarito Wells (pump 2)	G. Martinez House[c]	Summary: Maximum Concentration	Summary: Maximum Concentration as a Percentage of Standard
Miscellaneous									
SiO_2		28	23	27	36	33	35	—	—
Ca		40	11	4	40	34	30	—	—
Mg		3.0	0.9	<0.5	3.5	3.2	4.5	—	—
K		2.0	1.6	<1.0	2.3	2.8	3.2	—	—
Na		24	350	37	28	210	250	—	—
CO_3		<5	<5	<5	<5	<5	<5	—	—
HCO_3		163	350	85	156	430	520	—	—
P		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	—	—
Total hardness		133	40	12	131	108	134	—	—
Conductance (µmho)		360	1820	220	410	1340	1650	—	—
pH (standard units)			7.5	8.1	9.1	7.5	7.4	7.2	—

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[a] Units are milligrams per liter, except as noted.

[b] Primary and secondary drinking water standards are used for comparison only (NMEIB 1988, EPA 1989). Samples were collected August 29, 1989.

[c] House is adjacent to station 3, Pajarito Well.

[d] Total dissolved solids.

Table 35. Comparison of Chemical Quality of Water from Pajarito Wells, Station 3[a]

Constituents	6-5-89 Pump 1	6-29-89 Pump 1	8-2-89 Pump 1	8-29-89 Pump 2	10-4-89 Pump 2	11-6-89 Pump 1	11-6-89 Pump 2
Ca	—	60	11	34	21	52	23
Mg	—	6.4	4.4	3.2	1.8	6.7	1.9
Cl	225	241	218	157	37	244	51
SO_4	56	57	52	42	24	57	25
Total hardness	166	—	152	108	68	198	79
Specific conductance (μmho)	1800	1850	1720	1340	610	1450	545
Total uranium	12	—	22	11	7.3	—	—

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[a] Units are micrograms per liter, unless otherwise noted.

Note: Pajarito well 1, depth 49 m (160 ft); screens at 30 to 37 m (100 to 120 ft) and 43 to 46 m (140 to 150 ft). Pajarito well 2, depth 52 m (170 ft); screens at 37 to 43 m (120 to 140 ft) and 46 to 49 m (150 to 160 ft).

Table 36. Radiochemical Analyses of Sediments from Mortandad Canyon

Station	Location	^{137}Cs (pCi/g)	Total Uranium (μg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Gamma (counts/min/g)
Sediments[a]						
A-5	Laboratory	0.63 (0.18)	2.6 (0.3)	0.002 (0.002)	0.018 (0.005)	2.2 (0.4)
A-6	San Ildefonso	1.1 (0.18)	3.8 (0.4)	0.004 (0.002)	0.038 (0.006)	4.3 (0.5)
A-7	San Ildefonso	0.45 (0.14)	1.9 (0.2)	0.010 (0.002)	0.108 (0.006)	3.3 (0.5)
A-8	San Ildefonso	0.05 (0.07)	4.1 (0.4)	0.002 (0.001)	0.002 (0.002)	−1.7 (0.4)
A-9	San Ildefonso	0.18 (0.12)	2.4 (0.2)	0.000 (0.001)	0.002 (0.001)	1.9 (0.4)
A-10	San Ildefonso	−0.5 (0.11)	2.5 (0.3)	0.003 (0.002)	0.003 (0.001)	2.2 (0.4)
A-11	San Ildefonso	−0.01 (0.12)	1.4 (0.2)	0.001 (0.001)	0.000 (0.001)	0.4 (0.4)
Soil						
Cedro Mesa,	San Ildefonso	1.67 (0.26)	3.8 (0.4)	0.004 (0.002)	0.050 (0.006)	4.5 (0.6)
Background						
Sediments (1974–1986)		0.44	4.4	0.006	0.023	7.9
Soils (1974–1986)		1.09	3.4	0.005	0.025	6.6

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[a] Samples in Mortandad Canyon were collected on August 29, 1989, with the exception of station A-5 (May 1, 1989); A-9 at State Road 4 (April 25, 1989); and A-11 at the Rio Grande (October 6, 1989).

northern New Mexico. At station A-6, the 1989 value observed for ^{239,240}Pu (0.038 pCi/g) was about double the values observed in 1987 and 1988 (0.021 and 0.01 pCi/g, respectively). The highest value in 1989 was obtained at station A-7, which showed a higher concentration of ^{239,240}Pu (0.108 pCi/g) than that from previous years' samples (0.019 and 0.012 pCi/g in 1987 and 1988, respectively) and about 4 times the level generally attributable to worldwide fallout. Station A-7 also showed ^{238}Pu (0.010 pCi/g) to be slightly above fallout levels.

Physical appearance of the stream channel at the time of collection gave no indication of any water run-off or transport of sediments across the Laboratory boundary, consistent with other observations during the thunderstorm season that no run-off in Mortandad Canyon extended near the Laboratory boundary. (No run-off has been observed to reach the Laboratory boundary in Mortandad Canyon since 1960 when the United States Geologic Survey [USGS] initiated special studies there.) At these low levels, considerable variability is expected because of different particle-size distributions in grab samples. Samples with a large fraction of small particles typically exhibit higher mass concentrations of plutonium because of their high adsorption capacity. The sediments in this part of Mortandad Canyon are more like soils because there has been no run-off to separate out silt and clay-size particles that typically show higher concentrations of plutonium.

Cesium concentrations from samples at stations A-5, A-6, and A-7 showed minor differences from previous results. In 1989, the ^{137}Cs concentrations at stations A-5 and A-7 (0.63 and 0.45 pCi/g, respectively) were higher than those in 1988 (0.58 and 0.04 pCi/g) and slightly lower than those in 1987 (0.83 and 0.51 pCi/g). The 1989 value at station A-6 (1.1 pCi/g) was slightly higher than that obtained in previous results (0.89 and 0.73 pCi/g in 1987 and 1988, respectively), but about the same as the statistical background limit for regional soils.

A soil sample was collected from a circular depression on Cedro Mesa south of Mortandad Canyon on Pueblo lands (Fig. 29, Table 36). It showed concentrations of ^{239,240}Pu and ^{137}Cs at levels about twice the statistically derived level for regional background soils (Purtymun 1987a). The location was selected because it would retain surface run-off from the surrounding mesa surface and accumulate any airborne or fallout deposition. The observed values are consistent with those from worldwide fallout deposition on what is probably a higher proportion of silt and clay-sized particles in the sampled location compared with particles in typical regional soils (because there is no outflow from the depression). Sample results do not suggest any direct contribution of contaminants from the Laboratory.

C. Environmental Monitoring at the Fenton Hill Site (William Purtymun, Max Maes, and Mary Carol Williams [Laboratory Health and Environmental Chemistry Group, HSE-9])

The Laboratory operates a program to evaluate the feasibility of extracting thermal energy from the hot dry rock geothermal reservoir at the Fenton Hill Geothermal Site (TA-57), which is located about 45 km (28 mi) west of Los Alamos on the southern edge of the Valles Caldera. The hot dry rock energy concept involves drilling two deep holes, connecting these holes by hydraulic fracturing, and bringing geothermal energy to the surface by circulating water through the system. Environmental monitoring is performed adjacent to the site to assess any impacts from the geothermal operations.

The chemical quality of surface and ground waters in the vicinity of TA-57 (Fig. 30) has been monitored for use in geohydrologic and environmental studies. These water-quality studies began before the construction and testing of the hot dry rock system (Purtymun 1974d). The most recent samples were collected in December 1989.

Surface-water stations (11 located on the Jemez River, the Rio Guadalupe, and their tributaries) are divided into four general groups on the basis of predominant ions and total dissolved solids (TDS) found in the water (Table 37). The predominant ion groups are (1) sodium and chloride, (2) calcium and bicarbonate, (3) calcium and sulfate, and (4) sodium and bicarbonate. Detailed analyses are found in Table G-59.

Ground-water stations (five mineral and hot springs, seven wells, and seven springs) are also grouped according to predominant ions. These ions are (1) sodium and chloride, (2) calcium and bicarbonate, and (3) sodium and bicarbonate (Table 37). Detailed analyses are found in Table G-60.

Analyses of surface and ground waters were performed for 14 trace metals (Table G-61). Slight variations were found in the chemical quality of surface and ground waters among the individual stations when the analyses were compared with those from previous years; however, these variations are within normal seasonal fluctuations (Purtymun 1988a).

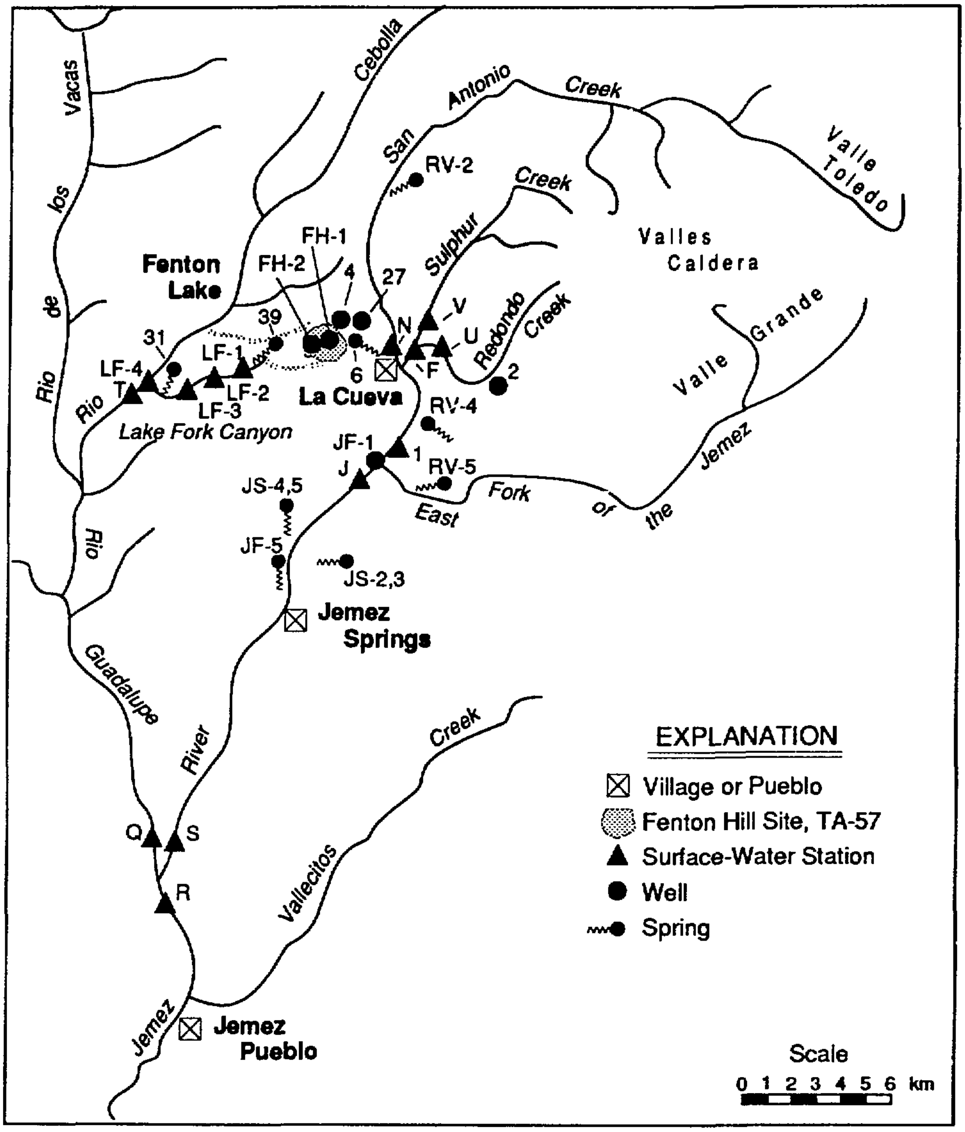

Fig. 30. Sampling stations for surface and ground water near the Fenton Hill Site (TA-57).

There were no significant changes in the chemical quality of surface and ground water at the individual stations from previous years (Purtymun 1988a).

D. Environmental Studies at TA-49
(W. D. Purtymun, Alan Stoker, and Max Maes)

From 1959 to 1961, hydronuclear experiments were conducted in underground shafts at the Laboratory at TA-49. This technical area is located on Frijoles Mesa in the southwest corner of the Laboratory between TA-28 and TA-33 (Fig. 4). The experiments involved a combination of conventional (chemical) high explosives, usually in a nuclear weapons configuration. The quantity of fissile material was kept far below the amount required for a nuclear explosion (Purtymun 1987b). The underground shafts ranged in depth from 15 to 36 m (50 to 120 ft) beneath the surface of the mesa (Purtymun 1987b, ESG 1988).

Table 37. Quality of Surface and Ground Waters in the Vicinity of Fenton Hill Geothermal Site, December 1989[a] (concentrations in mg/L)

Surface Water

	Na	Cl	TDS
Sodium and Chloride			
Redondo Creek (U)	10	10	216
Jemez River (R)	43	85	570
Jemez River (S)	119	125	532

	Ca	HCO_3	TDS
Calcium and Bicarbonate			
San Antonio Creek (N)	24	63	190
Rio Cebolla (T)	26	71	208
Rio Guadalupe (Q)	81	206	232
Lake Fork 1 (LF-1)		Dry	
Lake Fork 2 (LF-2)		Dry	
Lake Fork 3 (LF-3)	14	54	200
Lake Fork 4 (LF-4)	18	67	152

	Ca	SO_4	TDS
Calcium and Sulfate			
Sulphur Creek (V)	56	275	582
Sulphur Creek (F)	49	114	302

	Na	HCO_3	TDS
Sodium and Bicarbonate			
Jemez River (J)	27	78	228

Ground Water

	Na	Cl	TDS
Sodium and Chloride			
Location JF-1 (hot spring)	641	810	—[b]
Location JF-5 (hot spring)	1130	1600	—[b]

	Ca	HCO_3	TDS
Calcium and Bicarbonate			
FH-1 (supply well)	80	148	350
Location 39 (spring)	13	38	120
Location 6 (spring)	26	100	91
Location 27 (well)	28	91	214
Location 42 (well)	16	34	64
Location 48 (well)	31	89	212
Location 53 (well)	52	148	212
Location 54 (well)	82	267	344
Location 55 (well)	87	222	564

	Na	HCO_3	TDS
Sodium and Bicarbonate			
JS-2, 3 (spring)	18	69	114
JS-4, 5 (spring)	19	85	184
Location 4 (well)	21	75	231
Location 31 (spring)	14	67	196
RV-2 (hot spring)	27	47	270
RV-4 (hot spring)	58	118	240
RV-5 (hot spring)	24	82	162
Location 47 (well)	320	78	592

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[a] See Fig. 30 for sampling locations. One sample was taken at each location.

[b] Analyses are missing, but conductance measurements were consistent with previous observations.

Three deep test wells (DT-5A, DT-9, and DT-10) were used to monitor possible movement of contaminants from the shafts to the main aquifer (Fig. 31). The depth to the main aquifer is about 360 m (1200 ft). No water is perched in beds between the surface of the mesa and the top of the main aquifer. The chemical and radiochemical quality of water from these wells indicated no contamination from activities at TA-49 (Sec. VI.B.4.a. and Tables G-22 and G-23).

Eleven stations were established in 1972 to monitor surface sediments in natural drainage from the experimental area. Another station was added in 1981 as the drainage changed (Fig. 31). Sediment samples from the 12 stations were analyzed for radiochemical and chemical constituents and for organic compounds.

Results of analyses of sediment samples for radiochemicals were compared with the statistically established levels for regional background (1977–1986 [Purtymun 1987a]). As shown in Table G-62, ^{137}Cs exceeded background (0.44 pCi/g) at stations A-2 (0.59 pCi/g), A-4 (0.86 pCi/g), A-5 (0.49 pCi/g), A-6 (1.7 pCi/g), and A-10 (0.47 pCi/g); ^{238}Pu exceeded background (0.006 pCi/g) at station A-3 (0.015 pCi/g); and ^{239,240}Pu exceeded background at stations A-2 (0.074 pCi/g), A-3 (0.902 pCi/g), and A-6 (0.058 pCi/g). Total uranium in sediments from all 12 stations was at, or below, background levels.

Plutonium in similar concentrations has been reported in previous monitoring. The cesium and plutonium reported are not the result of movement of contaminants from the shafts but are attributed to a surface contamination incident that occurred in 1960 (Purtymun 1987b, ESG 1988).

Sediments from the 12 stations were analyzed for chemical constituents (Fig. 31). The results of the analyses indicated that constituents were below threshold limits

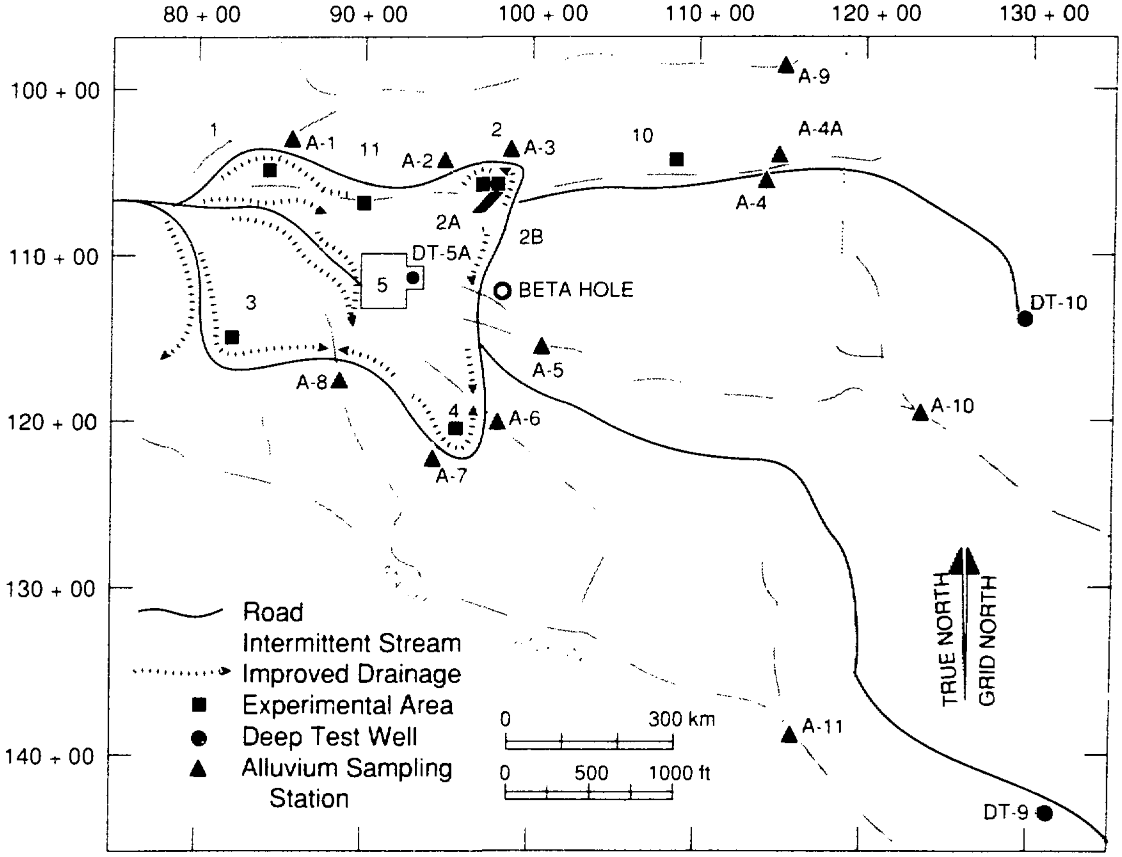

Fig. 31. Locations of experimental areas and test wells at TA-49.

for EPA's extraction procedure toxic criteria concentrations (Table G-63). The great majority of results were below limits of analytical detection.

Samples of sediments from the 12 stations were analyzed for 65 volatile organic compounds, 68 semivolatile organic compounds, 22 pesticide compounds, 5 herbicide compounds, and mixed polychlorinated biphenyl (PCB) compounds (Table G-64). The limits of quantification (LOQs) for the organic compounds are given in Appendix C. All samples were analyzed for these compounds, but only compounds that exceeded the LOQs are discussed.

Six volatile compounds above LOQs were reported from various stations (Table 38). Carbon disulfide above

Table 38. Volatile and Semivolatile Compounds Reported in Sediments at TA-49 (μg/kg)

Station No.	Concentrations	LOQ
Volatile Compounds		
Carbon disulfide		
A-2	51	2
A-3	57	2
A-6	35	2
A-7	280	2
A-8	84	2
A-9	120	2
A-10	49	2
A-11	130	2
Trichlorofluoromethane		
A-3	13	2
A-7	16	2
A-9	13	2
A-11	21	2
2-Butanone		
A-3	95	10
A-4	32	10
A-8	77	10
A-10	71	10
1,1,1,-Trichloroethene		
A-3	12	10
A-6	20	10
A-7	50	10
A-8	25	10
4-Methyl-2-pentanone		
A-5	14	10
p-Isopropyltoluene		
A-5	11	2
A-8	6	2
Semivolatile Compounds		
Bis(2-ethylhexyl)phthalate		
A-2	470	330
A-3	2400	330
A-4A	600	330
A-7	410	330
A-10	500	330
A-11	510	330

LOQ (2 µg/kg) was reported from eight stations, with concentrations that ranged from 35 to 280 µg/kg. Trichlorofluoromethane above LOQ (2 µg/kg) was reported from four stations, in concentrations ranging from 13 to 21 µg/kg. The concentrations of 2-butanone above LOQ (10 µg/kg) ranged from 32 to 95 µg/kg and were reported from four stations. Other volatile organic compounds reported were 1,1,1-trichloroethene (four stations), 4-methyl-2-pentanone (one station), and *p*-isopropyltoluene (two stations).

In evaluating the volatile compounds above LOQs, environmental staff could not account for the presence of these compounds in the sediments of the dry stream channels that drain TA-49. There were no operations at TA-49 that would have resulted in widespread contamination of organic compounds. Their occurrence at, or slightly above, LOQs in the distribution of the drainage areas at the individual stations indicates that the samples were contaminated during collection or laboratory analyses.

Sediments from the 12 stations were analyzed for 68 semivolatile compounds. The compound bis(2-ethylhexyl)phthalate exceeded the LOQ (330 µg/kg) at six stations, in concentrations ranging from 410 to 2400 µg/kg. Phthalates are well-known ubiquitous contaminants (plasticizers) generally found in the environment and often picked up during analyses in the laboratory. The remarkably similar concentrations at five of the six stations suggest laboratory contamination.

The concentrations of pesticides (22 compounds), herbicides (5 compounds), and mixed PCBs were below LOQs in sediments from the 12 stations (Table G-64). Because of the uncertainties in the analyses of volatile and semivolatile compounds, additional samples will be collected next year for organic analyses.

E. Community Relations Program

The Laboratory's Environmental Safety and Health Community Involvement Team was formed to provide a proactive program of involvement and information exchange among Laboratory personnel, residents in surrounding communities, special interest groups, media reporters, and representatives of city, state, and federal governments. The goal is to inform the public of planned and ongoing actions, to focus on and attempt to resolve conflicts, and to identify and alleviate public concerns and fears.

To this end, town hall meetings were scheduled in Los Alamos, Santa Fe, Taos, and Española. The topic presented in October was "Hazardous Waste Management Practices at LANL." In November and January, the topic was changed to "Hazardous Waste Incineration at LANL." The meetings were scheduled for 2 hours; the topic was presented during the first hour and a question-and-answer session followed.

As part of the Community Involvement Program, the Laboratory declared October 1989 as Environmental Awareness Month. During that month, a staff member of the Health, Safety, and Environment (HSE)-Division's Environmental Protection Group (HSE-8) briefed 9000 Laboratory employees on environmental awareness and commitment. The 1.5-hour presentation, which included 43 color slides and 100 Vu-Graphs, was given on 39 separate occasions and covered the following topics: an overview of regulatory agencies, environmental rule-making, specific environmental compliance issues at the Laboratory, and recommendations for personal actions to improve environmental compliance.

On October 20 and 21, 1989, in conjunction with Environmental Awareness Month, the Laboratory sponsored a tour of the Tsirege Ruin. The site is one of the largest Anasazi ruins on the Pajarito Plateau, where ancestors of San Ildefonso Pueblo members lived in the 1500s. The land is owned by DOE and, for security reasons, is normally closed to the public. The tour was well received, as indicated by the 600 people who attended.

In addition, a poster and essay contest was sponsored for the public schools in seven counties in northern New Mexico. Students in kindergarten through sixth grade entered the poster contest; middle school and high school students entered an essay contest. Several hundred students participated in the competition. Awards were given in each category and finalists were honored at a luncheon hosted by the Laboratory for them, their families, and their teacher sponsors. After lunch, tours of Laboratory facilities were conducted.

During 1989, the Española Valley and Pojoaque Valley Waste-Water Master Plan was completed by a group of local and tribal governments and other area organizations concerned with the control of ground-water pollution from septic tank systems and other sources. The Laboratory was invited to join the steering committee for the construction to follow and to provide technical assistance for the preparation of the plan. The Laboratory also assisted in the printing of the final report.

The purpose of the plan is to identify areas affected by ground-water pollution in the study area and to recommend alternative waste-water treatment and management options that can be used to control pollution. The master plan is designed to provide specific recommendations for pollution control for localized areas and to provide a long-term strategy for waste-water treatment on a regional basis. Construction of two septage-disposal facilities was identified as the highest priority for pollution control in the study area.

The steering committee is seeking funds from state and federal sources to implement the waste-water master plan. The steering committee also has initiated a study to improve domestic water quality and water supply systems in the area. The proposed study for a water supply master plan would be similar in approach to that for the waste-water master plan and would provide a long-term strategy for improving the domestic water supply of the Española and Pojoaque valleys.

F. National Atmospheric Deposition Program (NADP) Network Station (Craig Eberhart and Chris Holmes)

Group HSE-8 operates a wet deposition station that is part of the NADP network. The station is located at the Bandelier National Monument. The 1989 annual and quarterly deposition rates are presented in Table 39.

Deposition rates for the various ionic species vary widely and are somewhat dependent on precipitation. The highest deposition rates usually coincide with high precipitation. The lowest rates normally occur in the winter, probably reflecting the decrease in wind-blown dust. The ions in the rainwater are from both nearby and distant anthropogenic and natural sources. High nitrate and sulfate deposition may be caused by anthropogenic sources, such as motor vehicles, copper smelters, and power plants.

The natural pH of rainfall, without anthropogenic contributions, is unknown. Because of the contribution from entrained alkaline soil particles in the southwest, natural pH may be higher than 5.6, the pH of rainwater in

Table 39. Annual and Quarterly Wet Deposition Statistics for 1989

	Quarter				
	First	Second	Third	Fourth	Total
Field pH (standard units)					
Mean	4.8	5.3	4.9	5.0	5.0
Minimum	4.4	4.2	4.6	4.9	4.2
Maximum	5.7	6.6	6.1	5.1	6.6
Precipitation (in.)	3.5	1.4	6.0	1.9	12.8
Deposition (microequivalents per square meter)					
Ca	21.3	39.2	55.2	1.3	117.0
Mg	1.3	3.0	4.6	0.1	8.9
K	0.6	6.3	3.4	0.1	10.3
Na	4.3	5.0	9.7	1.9	20.8
NH_4	4.4	11.6	55.2	6.3	77.6
NO_3	53.9	51.7	271.5	18.0	395.1
Cl	4.8	7.1	20.2	3.1	35.3
SO_4	58.3	46.6	216.6	14.7	336.2
PO_4	0.6	5.0	0.0	0.0	5.6
H	0.8	0.1	3.2	0.4	4.4

equilibrium with atmospheric carbon dioxide. Some studies indicate that there may be an inverse relationship between elevation and pH effect that lowers the pH of samples measured in the field. For the latest quarter, all field measurements were below 5.6, possibly indicating contributions from acidic species other than carbon dioxide.

The NADP conducted an audit of the Bandelier site this year, examining the physical characteristics of the site and its operation. Except for a few minor equipment flaws, the operation of the station was in compliance with NADP guidelines.

G. Drilling and Development of New Otowi Wells (Alan Stoker [HSE-8] and Glenn Hammock [consultant to the Laboratory's Project Management Group, ENG-1])

Drilling started in the fall of 1989 on the first of two new water supply wells to be completed under the FY 1988 Utilities Restoration Water Well Replacement, a construction line item. These two wells are the initial part of a long-range plan to replace the capacity of the Los Alamos Well Field, which includes six wells drilled 29 to 43 years ago (Purtymun 1988c). The capabilities of all but one of the wells have deteriorated significantly with time. Only four of these wells contributed to the water supply in 1989 (see Sec. VI.B.5).

The contract for drilling the two new wells was awarded to Beylik Drilling, Inc., of La Habra, California. The first well, to be called Otowi-4 (O-4), is located in Los Alamos Canyon near test well 3 (map designation 41 in Fig. 15). Site preparation began in September 1989. A 97-cm (38-in.)-diameter surface casing was set and cemented in a 120-cm (48-in.) hole to a depth of about 18 m (60 ft) by September 21. A 91-cm (36-in.)-diameter hole for the conductor casing was drilled and reamed to a depth of 234 m (786 ft) by November 9. The 71-cm (28-in.)-diameter conductor casing was set and cemented to a depth of 222 m (730 ft). Drilling of a 43-cm (17-in.)-diameter pilot hole had progressed to a depth of 741 m (2430 ft) on December 31. The hole encountered the expected geologic strata, including the Bandelier Tuff, Puye Conglomerate, Chino Mesa Basalts, and Tesuque Formation. The top of the aquifer in the Tesuque Formation was encountered at a depth of about 238 m (780 ft), as expected.

The pilot hole is planned to reach a depth of about 850 m (2800 ft). Geophysical logging will be used to help determine the depth of the best water-producing interval. The pilot hole will then be reamed to a diameter of 66 cm (26 in.) to accommodate the 41-cm (16-in.)-diameter well screen and casing. This should be completed early in calendar year 1990. Once well O-4 is completed, the contractor will move to the location in Pueblo Canyon near test well 1 (map designation 39 in Fig. 15) to start drilling the second new well, to be called Otowi-1 (O-1).

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APPENDIX A

STANDARDS FOR ENVIRONMENTAL CONTAMINANTS

Throughout this report, concentrations of radioactive and chemical constituents in air and water samples are compared with pertinent standards and guidelines in regulations of federal and state agencies. No comparable standards for soils, sediments, and foodstuffs are available. Laboratory operations are conducted in accordance with directives for compliance with environmental standards. These directives are contained in DOE Orders 5400.1 ("General Environmental Program"), 5480.1 ("Environmental Protection, Safety, and Health Protection Standards"), 5480.11 ("Requirements for Radiation Protection for Occupational Workers"), and 5484.1 ("Environmental Radiation Protection, Safety, and Health Protection Information Reporting Requirements," Chap. III, "Effluent and Environmental Monitoring Program Requirements"). All of these DOE orders are being, or have been, recently revised.

DOE regulates radiation exposure to the public and the worker by limiting the radiation dose that can be received. Because some radionuclides remain in the body and result in exposure long after intake, DOE requires consideration of the dose commitment caused by inhalation, ingestion, or absorption of such radionuclides. This evaluation involves integrating the dose received from radionuclides over a standard period of time. For this report, 50-year dose commitments were calculated using dose factors from Refs. A1 and A2. The dose factors adopted by DOE are based on the recommendations of Publication 30 of the International Commission on Radiological Protection (ICRP).[A3] Those factors that have been used in this report are presented in Appendix D.

In 1985, DOE adopted interim limits that lowered its Radiation Protection Standard (RPS) for members of the general public.[A4] Table A-1 lists currently applicable RPSs for operations at the Laboratory. Off-site measurements are compared with DOE's Derived Concentration Guides (DCGs) for uncontrolled areas, on the basis of a revised RPS for the general public of 100-mrem/yr effective dose equivalent (Table A-2).[A5] These DCGs represent the smallest estimated concentrations in water or air, taken in continuously for a period of 50 years, that will result in annual effective dose equivalents equal to the RPS of 100 mrem. The new RPSs and the information in Ref. A1 are based on recommendations of the ICRP and the National Council on Radiation Protection and Measurements (NCRP).[A3-A5]

The effective dose equivalent is the hypothetical whole-body dose that would result in the same risk of radiation-induced cancer or genetic disorder as a given exposure to an individual organ. The effective dose is the sum of the individual organ doses, weighted to account for the sensitivity of each organ to radiation-induced damage. The weighting factors are taken from the recommendations of the ICRP. The effective dose equivalent includes dose from both internal and external exposure.

Radionuclide concentrations in air and water in uncontrolled areas measured by the Laboratory's surveillance program are compared with DCGs in this report. In addition to the 100-mrem/yr effective dose RPS, exposures from the air pathway are also limited by EPA's 1989 standard of 25 mrem/yr (whole body) and 75 mrem/yr (any organ) (Table A-1).[A6] To demonstrate compliance with these standards, doses from the air pathway are compared directly with the EPA dose limits. On December 15, 1989, the EPA modified this limit to 10-mrem/yr effective dose equivalent.[A7] This limit will be in effect for 1990.

For chemical constituents in drinking water, standards have been promulgated by the EPA and adopted by the NMEID (New Mexico Environmental Improvement Division) (Table A-3).[A8] The EPA's primary Maximum Contaminant Level (MCL) is the maximum permissible level of a contaminant in water that is delivered to the ultimate user of a public water system.[A9] The EPA's secondary water standards control contaminants in drinking water that primarily affect aesthetic qualities associated with public acceptance of drinking water.[A9] At considerably higher concentrations of these contaminants, health implications may arise.

Radioactivity in drinking water is regulated by EPA regulations contained in 40 CFR 141.[A9] These regulations provide that combined ^{226}Ra and ^{228}Ra may not exceed

Table A-1. DOE Radiation Protection Standards for External and Internal Exposures

Exposure of Any Member of the Public[a]

	Effective Dose Equivalent[b] at Point of Maximum Probable Exposure
All Pathways	
Occasional annual exposure	500 mrem/yr
Prolonged[c] annual exposure	100 mrem/yr

No individual organ shall receive an annual dose equivalent in excess of 5000 mrem.

	Dose Equivalent at Point of Maximum Probable Exposure
Air Pathway Only[d]	
Whole-body dose	25 mrem/yr
Dose to any organ	75 mrem/yr

Occupational Exposures[a]

Stochastic Effects	5 rem (annual effective dose equivalent[e])
Nonstochastic Effects	
Lens of eye	15 rem (annual dose equivalent[e])
Extremity	50 rem (annual dose equivalent[e])
Skin of the whole body	50 rem (annual dose equivalent[e])
Organ or tissue	50 rem (annual dose equivalent[e])
Unborn Child	
Entire gestation period	0.55 rem (annual effective dose equivalent[e])

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[a] In keeping with DOE policy, exposures shall be limited to as small a fraction of the respective annual dose limits as practicable. DOE's RPS applies to exposures from routine Laboratory operation, excluding contributions from cosmic, terrestrial, global fallout, self-irradiation, and medical diagnostic sources of radiation. Routine operation means normal, planned operation and does not include actual or potential accidental or unplanned releases. Exposure limits for any member of the general public are taken from Ref. A4. Limits for occupational exposure are taken from DOE Order 5480.11.

[b] As used by DOE, effective dose equivalent includes both the effective dose equivalent from external radiation and the committed effective dose equivalent to individual tissues from ingestion and inhalation during the calendar year.

[c] For the purposes of DOE's RPS, a prolonged exposure will be one that lasts, or is predicted to last, longer than 5 years.

[d] These levels are from EPA's regulations promulgated under the Clean Air Act (40 CFR 61, Subpart H).

[e] Annual effective dose equivalent is the effective dose equivalent received in a year.

Table A-2. DOE's Derived Concentration Guides (DCGs) for Uncontrolled Areas and Derived Air Concentrations (DACs) for Controlled Areas[a]

	DCGs for Uncontrolled Areas (µCi/mL)		DACs for Controlled Areas (µCi/mL)
Nuclide	Air	Water	
^{3}H	1×10^{-7}	2×10^{-3}	2×10^{-5}
^{7}Be	5×10^{-8}	1×10^{-3}	8×10^{-6}
^{89}Sr	3×10^{-10}	2×10^{-5}	6×10^{-8}
^{90}Sr [b]	9×10^{-12}	1×10^{-6}	2×10^{-9}
^{137}Cs	4×10^{-10}	3×10^{-6}	7×10^{-8}
^{234}U	9×10^{-14}	5×10^{-7}	2×10^{-11}
^{235}U	1×10^{-13}	6×10^{-7}	2×10^{-11}
^{238}U	1×10^{-13}	6×10^{-7}	2×10^{-11}
^{238}Pu	3×10^{-14}	4×10^{-7}	2×10^{-12}
^{239}Pu [b]	2×10^{-14}	3×10^{-7}	2×10^{-12}
^{240}Pu	2×10^{-14}	3×10^{-7}	2×10^{-12}
^{241}Am	2×10^{-14}	6×10^{-7}	2×10^{-12}
	(pg/m^{3})	(mg/L)	(pg/m^{3})
Uranium, natural	1×10^{5}	8×10^{-1}	3×10^{7}

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[a] Guides for uncontrolled areas are based on DOE's RPS for the general public;[A5] those for controlled areas are based on occupational RPSs for DOE Order 5480.11 ("Radiation Protection for Occupational Workers," December 21, 1988). Guides apply to concentrations in excess of those occurring naturally or that are due to fallout.

[b] Guides for ^{239}Pu and ^{90}Sr are the most appropriate to use for gross alpha and gross beta, respectively.

5×10^{-9} µCi/mL. Gross alpha activity (including ^{226}Ra, but excluding radon and uranium) may not exceed 15×10^{-9} µCi/mL.

A screening level of 5×10^{-9} µCi/mL is established to determine when analysis specifically for radium isotopes is necessary. In this report, plutonium concentrations are compared with the gross alpha standard for drinking water (Table A-3). For manmade beta- and photon-emitting radionuclides, drinking water standards are limited to concentrations that would result in doses not exceeding 4 mrem/yr, calculated according to a specified procedure.

In their regulations, the EPA has established minimum concentrations of certain contaminants in water extract from wastes in order for these wastes to be designated as hazardous by reason of toxicity.[A10] The extraction procedure (EP) must follow steps outlined by the EPA in 40 CFR 261, Appendix II. In this report, the EP toxicity minimum concentrations (Table A-4) are used for comparison with concentrations of selected constituents in extracts from the Laboratory's active waste areas.

Table A-3. Maximum Contaminant Level (MCL) in the Water Supply for Inorganic Chemicals and Radiochemicals[a]

Inorganic Chemical Contaminant	MCL (mg/L)	Radiochemical Contaminant	MCL (µCi/mL)
Primary Standards			
Ag	0.05		
As	0.05	Gross alpha[b]	15×10^{-9}
Ba	1	^3H	20×10^{-6}
Cd	0.010		
Cr	0.05		
F	4.0		
Hg	0.002		
NO_3 (as N)	10		
Pb	0.05		
Se	0.01		
Secondary Standards			
Cl	250		
Cu	1		
Fe	0.3		
Mn	0.05		
SO_4	250		
Zn	5.0		
TDS[c]	500		
pH	6.5–8.5		

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[a] Source: Refs. A8 and A9.

[b] See text for discussion of application of gross alpha MCL and gross alpha screening level of 5×10^{-9} µCi/mL.

[c] Total dissolved solids.

Table A-4. Minimum Concentrations of Inorganic Contaminants for Meeting EPA's Extraction Procedure (EP) Toxicity Characteristics for Hazardous Waste[a]

Contaminant	Criteria Concentration (mg/L)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	1.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0

[a] Source: Ref. A10.

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APPENDIX B

PROCEDURES FOR SAMPLING, DATA HANDLING, AND QUALITY ASSURANCE

A. Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLDs) used at the Laboratory are lithium fluoride (LiF) chips, 6.4 mm square by 0.9 mm thick. The TLDs, after being exposed to radiation, emit light upon being heated. The amount of light is proportional to the amount of radiation to which the TLD was exposed. The TLDs used in the Laboratory's environmental monitoring program are insensitive to neutrons, so the contribution of cosmic neutrons to natural background radiation is not measured.

The chips are annealed to 400°C (752°F) for 1 hour and then cooled rapidly to room temperature. This is followed by annealing at 100°C (212°F) for 1 hour and again cooling rapidly to room temperature. For the annealing conditions to be repeatable, chips are put into rectangular borosilicate glass vials that hold 48 LiF chips each. These vials are slipped into a borosilicate glass rack so they can be placed all at once into ovens maintained at 400°C and 100°C.

Four LiF chips constitute a dosimeter. The LiF chips are contained in a two-part threaded assembly made of an opaque yellow acetate plastic. A calibration set is prepared each time chips are annealed. The calibration set is read at the start of the dosimetry cycle. The number of dosimeters and exposure levels are determined for each calibration in order to efficiently use available TLD chips and personnel. Each set contains from 20 to 50 dosimeters. These are irradiated at levels between 0 and 80 mR using an 8.5-mCi ^{137}Cs source calibrated by the National Bureau of Standards.

A factor of 1 mrem (tissue) = 1.050 mR is used in evaluating the dosimeter data. This factor is the reciprocal of the product of the roentgen-to-rad conversion factor of 0.958 for muscle for ^{137}Cs and of 0.994, which corrects for attenuation of the primary radiation beam at electronic equilibrium thickness. A rad-to-rem conversion factor of 1.0 for gamma rays is used, as recommended by the International Commission on Radiation Protection.[B1,B2] A method of weighted least-squares linear regression is used to determine the relationship between TLD reader response and dose (the weighting factor is the variance).[B3]

The TLD chips used were all from the same production batch and were selected by the manufacturer so that the measured standard deviation in thermoluminescent sensitivity is 2.0% to 4.0% of the mean at a 10-R exposure. At the end of each field cycle, whether a calendar quarter or the Los Alamos Meson Physics Facility operation cycle, the dose at each network location is estimated from the regression along with the regression's upper and lower 95% confidence limits at the estimated value.[B4] At the end of the calendar year, individual field cycle doses are summed for each location. Uncertainty is calculated as the summation in quadrature of the individual uncertainties.[B3]

Further details are provided in the TLD quality assurance project plan.[B5]

B. Air Sampling

Samples are collected monthly at 25 continuously operating stations.[B6] Air pumps with flow rates of about 3 L/s are used. Airborne aerosols are collected on 79-mm-diameter polystyrene filters. Each filter is mounted on a cartridge that contains charcoal. This charcoal is not routinely analyzed for radioactivity. However, if an unplanned release occurs, the charcoal can be analyzed for any ^{131}I it may have collected. Part of the total air flow is passed through a cartridge containing silica gel to absorb atmospheric water vapor for tritium analyses. Air flow rates through both sampling cartridges are measured with rotameters, and sampling times are recorded. The entire air sampling train at each station is cleaned, repaired, and calibrated as needed.

Two clean control filters are used to detect any possible contamination of the 25 sampling filters while they are in transit. The control filters accompany the 25 sampling filters when they are placed in the air samplers and when they are retrieved. The control filters are analyzed for radioactivity along with the 25 sampling filters. Analytical results for the control filters are subtracted from the appropriate gross results to obtain net data.

At one on-site location (N050, E040), airborne radioactivity samples are collected weekly. Airborne particulate matter on each filter is counted for gross alpha and gross beta activities, which help trace temporal variations in radionuclide concentrations in ambient air. The same measurements are made monthly on a filter from the Española (station 1) regional air sampler.

On a quarterly basis, the monthly filters for each station are cut in half. The filter halves are combined to produce two quarterly composite samples for each station. The first group is analyzed for ^{238}Pu, ^{239,240}Pu, and ^{241}Am (on selected filters). The second group of filter halves is saved for uranium analysis.

Filters from the first composite group are ignited in platinum dishes, treated with HF-HNO_3 to dissolve silica, wet ashed with HNO_3-H_2O_2 to decompose organic residue, and treated with HNO_3-HCl to ensure isotopic equilibrium. Plutonium is separated from the resulting solution by anion exchange. For 11 selected stations, americium is separated by cation exchange from the eluant solutions resulting from the plutonium separation process. The purified plutonium and americium samples are separated, electrodeposited, and measured for alpha-particle emission with a solid-state alpha-detection system. Alpha-particle energy groups associated with decay of ^{238}Pu, ^{239,240}Pu, and ^{241}Am are integrated and the concentration of each radionuclide in its respective filter sample is calculated. This technique does not differentiate between ^{238}Pu and ^{240}Pu. Uranium analyses by neutron activation analysis (see Appendix C) are done on the second group of filter halves.

Silica gel cartridges from the 25 air sampling stations are analyzed monthly for tritiated water. The cartridges contain blue-"indicating" gel to determine the degree of desiccant saturation. During cold months of low absolute humidity, sampling flow rates are increased to ensure collection of enough water vapor for analysis. Water is distilled from each silica gel cartridge and an aliquot of the distillate is analyzed for tritium by liquid scintillation counting. The amount of water absorbed by the silica gel is determined by the difference between weights of the gel before and after sampling.

Analytical quality control for analyses done in the air sampling program is described in Appendix C. In brief, both blanks and standards are analyzed in conjunction with normal analytical procedures. About 10% of the analyses are devoted to quality control.

Further details may be found in the air sampling quality assurance project plan.[B7]

C. Water Sampling

Surface- and ground-water sampling stations are grouped by location (regional, perimeter, on-site) and hydrologic similarity. Water samples are taken once or twice a year. Samples from wells are collected after sufficient water has been pumped or bailed to ensure that the sample is representative of the aquifer. Spring samples (ground water) are collected at the discharge point.

The water samples are collected in 4-L (for radiochemical) and 1-L (for chemical) polyethylene bottles. The 4-L bottles are acidified in the field with 5 mL of concentrated nitric acid and then are returned to the laboratory within a few hours of sample collection for filtration through a 0.45-µm millipore membrane filter. The samples are analyzed radiochemically for ^{3}H, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu, as well as for gross alpha, beta, and gamma activities. Water samples for chemical analyses are handled similarly.

Storm run-off samples are analyzed for radionuclides in solution and suspended sediments. The samples are filtered through a 0.45-µm filter. Solution is defined as filtrate passing through the filter; suspended sediment is defined as the residue on the filter.

Further details may be found in the water sampling quality assurance project plan.[B8]

D. Soil and Sediment Sampling

Two soil sampling procedures are used. The first procedure is used to take surface composite samples. Soil samples are collected by taking five plugs, 75 mm (3.0 in.) in diameter and 50 mm (2.0 in.) deep, at the center and corners of a square area 10 m (33 ft) on a side. The five plugs are combined to form a composite sample for radiochemical analysis.

The second procedure is used to collect surface and subsurface samples at one sampling location. Samples are collected from three layers in the top 30 cm (12 in.) of soil. A steel cylinder is inserted into the soil at the sampling point. The soil enclosed by the cylinder is then collected by undercutting the cylinder with a metal spatula. A second spatula is then placed on top of the cylinder and the sample is transferred into a plastic bag and labeled.

Samples of the three layers are preserved by freezing. All equipment used for collection of these samples is washed with a soap and water solution and dried with paper towels. This is done before each sample is taken to reduce the potential for cross-contamination.

Sediment samples are collected from dune buildup behind boulders in the main channels of perennially flowing streams. Samples from the beds of intermittently flowing streams are collected in the main channel. Reservoir sediments are collected from a boat, using an Eckman dredge. Bottom reservoir sediments are collected from an area 10 by 15 cm (4 in. by 6 in.) to a depth of 5 cm (2 in.).

Depending on the reason for taking a particular soil or sediment sample, it may be analyzed to detect any of the following: gross alpha and gross beta activities, ^{90}Sr, total uranium, ^{137}Cs, ^{238}Pu, and ^{239,240}Pu. Moisture distilled from soil samples may be analyzed for ^{3}H.

Further details may be found in the soil and sediment sampling quality assurance plan.[B8]

E. Foodstuffs Sampling

Local and regional produce are sampled annually. Fish are sampled annually from reservoirs upstream and downstream from the Laboratory.

Produce and soil samples are collected from local gardens in the fall of each year.[B9] Each produce or soil sample is sealed in a labeled, plastic bag. Samples are refrigerated until preparation for chemical analysis. Produce samples are washed, as if prepared for consumption, and quantitative wet, dry, and ash weights are determined. Soils are split and dried at 100°C (212°F) before analysis. A complete sample bank is kept until all radiochemical analyses are completed. Water is distilled from samples and submitted for tritium analysis. Produce ash and dry soil are submitted for analyses of ^{90}Sr, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu.

At each reservoir, hook and line, trot line, or gill nets are used to capture fish.[B9] Fish, sediment, and water samples are transported under ice to the Laboratory for preparation. Sediment and water samples are submitted directly for radiochemical analysis. Fish are individually washed, as if for consumption, and dissected. Wet, dry, and ash weights are determined, and ash is submitted for analysis of ^{90}Sr, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu.

Further information may be found in the foodstuffs sampling quality assurance project plan.[B10]

F. Meteorological Monitoring

Meteorological data are continuously gathered on instrumented towers at five Laboratory locations. Data taken include measurements of wind speed and direction, standard deviations of wind speed and direction, vertical wind speed and its standard deviation, air temperature, dew-point temperature, relative humidity, solar radiation, and precipitation.

These parameters are measured at discrete levels on the towers at heights ranging from ground level to 91 m (300 ft). Each parameter is measured every 3 to 5 seconds and averaged or summed over 15-minute intervals. Data are recorded on digital cassette tape or transmitted by phone line to a microcomputer at the Occupational Health Laboratory at TA-59.

Data validation is accomplished with automated and manual screening techniques. One computer code compares measured data with expected ranges and also makes comparisons based on known meteorological relationships. Another code produces daily plots of data from each tower. These graphics are reviewed to provide another check of the data. This screening helps to detect problems with the instrumentation that might develop between calibrations. (Depending on the instruments, calibrations are done annually or semiannually).

Further details may be found in the meteorological monitoring quality assurance project plan.[B11]

G. Data Handling

Measurements of radiochemical samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values that are lower than the minimum detection limit of an analytical technique (see Appendix C) are sometimes obtained. Consequently, individual measurements can result in values of zero and negative numbers. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values are included in the population calculations.[B12]

For individual measurements, uncertainties are reported as the standard deviation. These values are associated with the estimated variance of counting and indicate the precision of the counts.

Standard deviations for the station and group (regional, perimeter, on-site) means are calculated using the following equation:

$$s = \sqrt{\frac{\sum_{i=1}^{N} \left(\bar{c} - c_i\right)^2}{(N-1)}} ,$$

.where

c_i = concentration for sample i,

$\bar{c}$ = mean of samples from a given station or group, and

N = number of samples comprising a station or group.

This value is reported as the uncertainty for the station and group means.

H. Quality Assurance

Collection of samples for chemical and radiochemical analyses follows a set procedure to ensure proper sample collection, documentation, submittal for chemical analysis, and posting of analytical results.

Before sample collection, the schedule and procedures to be followed are discussed with the chemist or chemists involved with doing the analyses. The discussion includes

- number and type of samples;
- type of analyses and required limits of detection;
- proper sample containers;
- preparation of sample containers with preservative, if needed; and
- sample schedule to ensure minimum holding time of analyses to comply with EPA criteria.

The Laboratory's Health and Environmental Chemistry Group (HSE-9) issues to the collector a block of sample numbers (for example, 86.0071) with individual numbers assigned by the collector to an individual station. These sample numbers follow the sample from collection through analyses and posting of individual results.

Each number, representing a single sample, is assigned to a particular station and is entered into the collector's log book. After the sample is collected, the date, time, temperature (if water), other pertinent information, and remarks are entered opposite the sample number and station previously listed in the log book.

The sample container is labeled with station name, sample number, date, and preservative, if added.

After the sample is collected, it is delivered to the Group HSE-9 section leader, who makes out a numbered request form entitled "HSE-9 Analytical Chemical Request." The request form number is also entered in the collector's log book opposite sample numbers submitted, along with the date the sample was delivered to the chemist. The analytical request form serves as a "chain-of-custody" for the samples.

The analytical request form contains the following information related to ownership and the sample program submitted: (1) requester (i.e., sample collector), (2) program code, (3) sample owner (i.e., program manager), (4) date, and (5) total number of samples. The second part of the request form contains (1) sample number or numbers, (2) matrix (e.g., water), (3) types of analyses (i.e., specific radionuclide and/or chemical constituents), (4) technique (i.e., analytical method to be used for individual constituents), (5) analyst (i.e., chemist to perform analyses), (6) priority of sample or samples, and (7) remarks. One copy of the form goes to the collector for his file and the other copies follow the sample.

Quality control, analytical methods and procedures, and limits of detection related to Group HSE-9's analytical work are presented in Appendix C.

The analytical results are returned to the sample collector, who posts data according to sample and station taken from the log book. These data sheets are included in the report and are used to interpret data for the report.

Further details may be found in the quality assurance project plan for each program.[B5,B7,B8,B10,B11]

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APPENDIX C

ANALYTICAL CHEMISTRY METHODOLOGY

Most analytical chemistry services are provided by the Laboratory's Health and Environmental Chemistry Group (HSE-9). Overflow work is contracted to several commercial laboratories.

A. Radioactive Constituents

Environmental samples are routinely analyzed for the following radioactive constituents: gross alpha, beta, and gamma; isotopic plutonium; americium; uranium; cesium; tritium; and strontium. Detailed procedures have been published in this appendix in previous years.[C1,C2] Occasionally, other radionuclides from specific sources are determined: ^{7}Be, ^{22}Na, ^{40}K, ^{51}Cr, ^{60}Co, ^{65}Zn, ^{83}Rb, ^{106}Ru, ^{134}Cs, ^{140}Ba, ^{152}Eu, ^{154}Eu, and ^{226}Ra. All but ^{226}Ra are determined by gamma-ray spectrometry on large Ge(Li) detectors. Depending on the concentration and matrix, ^{226}Ra is measured by emanation[C3] or by gamma-ray spectrometry of its ^{214}Bi decay product.[C4] Uranium isotopic ratios (^{235}U/^{238}U) are measured by neutron activation analysis where precisions of ±5% are adequate.[C5] More-precise work requires mass spectrometry. Uranium isotopic ratios are readily determined in environmental materials with precisions of 1%–2% relative standard deviation (RSD), at considerably reduced cost relative to neutron activation, by inductively coupled plasma mass spectrometry (ICPMS).

B. Stable Constituents

A number of analytical methods are used for various stable isotopes. The choice of method is based on many criteria, including the operational state of the instruments, time limitations, expected concentrations in samples, quantity of sample available, sample matrix, and EPA regulations.

Instrumental techniques available include neutron activation, atomic absorption, ion chromatography, color spectrophotometry (manual and automated), potentiometry, combustion analysis, ICPMS, and inductively coupled plasma atomic emission spectrometry (ICPAES). Standard chemical methods are also used for many of the common water-quality tests. Atomic absorption capabilities include flame, furnace, cold vapor, and hydride generation, as well as flame-emission spectrophotometry. The methods used and references for determination of various chemical constituents are summarized in Table C-1 (Refs. C5–C67). In 1986, the EPA Region VI administration granted HSE-9 limited approval for alternative test procedures for uranium in drinking water (delayed neutron assay) and for chloride in drinking water and waste water (flow injection, without distillation). EPA approval for other modified methods is actively being sought. HSE-9 is participating in the EPA-sponsored study to evaluate ICPMS for acceptance as an EPA-approved methodology.

C. Organic Constituents

Environmental water samples are analyzed by EPA or modified EPA methodology. Methods used are supported by documented spike/recovery studies, method and field blanks, matrix spikes, surrogate spikes, and blind quality control samples. EPA procedures are modified to take advantage of recent advances in analytical separation and analysis techniques. Volatile organic compounds are analyzed using a modified form of EPA method 524. Our current target list of volatile compounds totals 65. Water samples are analyzed by purge-and-trap gas chromatography/mass spectrometry (PAT). Soils are analyzed using heated PAT. Semivolatile organic compounds are analyzed by EPA method 625 using EPA-CLP (Contract Laboratory Program) protocol. Manual and automated methods have been developed using neutron activation to screen oil samples for potential polychlorinated biphenyl (PCB) contamination via total chlorine determination.[C68] Volatile organics trapped on charcoal are analyzed using a carbon disulfide desorption/gas chromatography/mass spectrometry method.

Instrumentation available for organic analysis includes gas chromatographs with a variety of detector systems, including mass spectrometry, flame ionization, and electron

Table C-1. Analytical Methods for Various Stable Constituents

Technique	Stable Constituents Measured	References
Standard chemical methods	Total alkalinity, hardness, SO_3^{-2}, SO_4^{-2}, TDS (total dissolved solids), conductivity, COD (chemical oxygen demand)	C6, C64
Color spectrophotometry	NO_3^-, PO_4^{-3}, Si, Pb, Ti, B	C6, C64
Neutron activation:		
Instrumental thermal	Al, Sb, As, Ba, Br, Ca, Ce, Cs, Cl, Cr, Co, Dy, Eu, Au, Hf, In, I, Fe, La, Lu, Mg, Mn, K, Rb, Sm, Sc, Se, Na, Sr, S, Ta, Tb, Th, Ti, W, V, Yb, Zn	C7, C12–C15, C64
Instrumental epithermal	Al, Sb, As, Ba, Br, Cs, Cr, F, Ga, Au, In, I, La, Mg, Mn, Mo, Ni, K, Sm, Se, Si, Na, Sr, Th, Ti, W, U, Zn, Zr	C7, C9, C16–C21, C64
Thermal neutron capture gamma ray	Al, B, Ca, Cd, C, Gd, H, Fe, Mg, N, K, Si, Na, S, Ti	C7, C22–C29, C64
Radiochemical	Sb, As, Cu, Au, Ir, Hg, Mo, Os, Pd, Pt, Ru, Se, Ag, Te, Th, W, U, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb, Lu, $^{235}U/^{238}U$	C5–C7, C30–C38, C51, C64
Delayed neutron assay	U	C7, C8, C10, C11, C39, C40, C64
Atomic absorption	Sb, As, Ba, Be, Bi, Cd, Ca, Cr, Co, Cu, Ga, In, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Na, Sr, Te, Tl, Sn, Ti, V, Zn, Al	C6, C41–C48, C52–C54, C64
Inductively coupled plasma mass spectrometry	Sb, As, Ba, Be, B, Bi, Cd, Cr, Co, Cu, Ga, In, Pb, Li, Mn, Hg, Mo, Ni, Se, Br, Ag, Sr, Te, Th, Sn, Ti, V, Zn, U, I, Tl, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tb, Lu	C64
Ion chromatography	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{-2}, PO_4^{-3} Na^+, K^+, Mg^{+2}, Ca^{+2}	C49, C64
Potentiometric	F^-, NH_4^+, pH, Br^-, Cl_2 (total), Cl_2 (free)	C50, C55, C64
Combustion	C, N, H, S, total organic carbon	C29, C61, C62, C64
Corrosivity	—	C56, C57
Ignitability (flash point)	—	C56, C58
Automated colorimetry	CN^-, NH_4^+, PO_4^{-3}, NO_3^-, NO_2^-, Cl^-, COD, TKN (total Kjeldahl nitrogen), Si, B, SO_4^{-2}, Cr^{+6}	C6, C59–C61, C64
Inductively coupled plasma atomic emission spectrometry	Al, Ag, As, B, Be, Ba, Cd, Co, Cu, Ca, Cr, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Re, S, Sb, Se, Si, Th, Tl, V, Y, Zn	C64–C67

capture. Also available is a high-pressure liquid chromatograph equipped with an ultraviolet (UV) and refractive index detection system, an infrared spectrophotometer, and a UV/visible spectrophotometer for colorimetric analyses. Methods used for sample preparation include solvent extraction, soxhlet extraction, liquid/liquid extraction, kuderna danish concentration, column separation, head space, and PAT. The methods used for analyses in 1989, along with references, are shown in Table C-2. Tables C-3 through C-7 show compounds determined by these methods and representative detection limits.[C69,C70]

The organic mixed-waste program is functioning on a limited-sample basis. Equipment and personnel are being dedicated to this analytical program. Special handling procedures for low-level mixed-waste samples have been implemented. Future expansion into a larger laboratory will allow the program to process an increased number of samples.

D. Analytical Chemistry Quality Evaluation Program

1. Introduction. Control samples are analyzed in conjunction with the normal analytical chemistry workload. Such samples consist of several general types: calibration standards, reagent blanks, process blanks, matrix blanks, duplicates, spikes, and reference materials. Analysis of control samples fills two needs in analytical work: (1) it provides quality control over analytical procedures so that problems that might occur can be identified and corrected, and (2) data obtained from analysis of control samples permit evaluation of the capabilities of a particular analytical technique to determine a given element or constituent under a certain set of circumstances.

In 1989, blind samples were added to our previously completely open quality assurance (QA) sample system. Blind QA samples are disguised and numbered to resemble unknown samples in a set, and no attempt is made to conceal the identity of the open QA samples from the analyst. In neither case are the concentrations of the analytes of interest revealed until after the data have been formally reported.

These samples are submitted to the laboratory at regular intervals and are analyzed in association with other samples; that is, they are not handled as a unique set of samples. We feel it would be difficult for analysts to give the samples special attention, even if they were so

Table C-2. Method Summary (Organic Compounds)

Analyte	Matrix	Method[a]	Technique[b]	Reference
Volatile organic compounds	Air	—	GC/MS	C64
	Soil	CLP/524	PAT/GC/MS	C63–C65
	Water	524	PAT/GC/MS	C63
EP[c] toxicity	Soil	1310, 8080 8150	GC/ECD	C65
PCBs	Water	606	GC/ECD	C63
	Soil	8080	GC/ECD	C65
	Oil	IH 320	GC/ECD	C64
Semivolatile organic compounds	Soil and waste	625	GC/MS	C69,C70

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[a] Contract Laboratory Program (CLP), industrial hygiene (IH).

[b] Gas chromatography (GC), purge and trap (PAT), electron capture detection (ECD), and mass spectrometry (MS).

[c] Extraction procedure (EP).

Table C-3. Volatile Organic Compounds in Water, Determined by PAT Analyses

Compound	CAS #	Representative Limits of Quantification (µg/L)
Chloromethane	74-87-3	20
Vinyl chloride	75-01-4	20
Bromomethane	74-83-9	20
Chloroethane	75-00-3	20
Acetone	67-64-1	20
Trichlorofluoromethane	75-69-4	10
1,1-Dichloroethene	75-35-4	10
Methylene chloride	75-09-2	10
Carbon disulfide	75-15-0	10
t-1,2-Dichloroethene	156-60-5	10
1,1-Dichloroethane	75-34-3	10
c-1,2-Dichloroethene	156-59-2	10
Bromochloromethane	74-97-5	10
Chloroform	67-66-3	10
1,2-Dichloroethane	107-06-2	10
1,1-Dichloropropene	563-58-6	10
Vinyl acetate	108-05-4	20
2-Butanone	78-93-3	10
2,2-Dichloropropane	590-20-7	10
1,1,1-Trichloroethane	71-55-6	10
Carbon tetrachloride	56-23-5	10
Benzene	71-43-2	10
1,2-Dichloropropane	78-87-5	10
Trichloroethene	79-01-6	10
Dibromomethane	74-95-3	10
Bromodichloromethane	75-27-4	10
t-1,3-Dichloropropene	1006-10-26	10
c-1,3-Dichloropropene	1006-10-15	10
1,1,2-Trichloroethane	79-00-5	10
1,3-Dichloropropane	142-28-9	10
Chlorodibromomethane	124-48-1	10
Bromoform	75-25-2	10
4-Methyl-2-pentanone	10-81-1	20
Toluene	108-88-3	10
2-Hexanone	59-17-86	20
1,2-Dibromomethane	74-95-3	10
Tetrachloroethene	127-18-4	10
Chlorobenzene	108-90-7	10
1,1,1,2-Tetrachloroethane	630-20-6	10
1-Chlorohexane	544-10-5	10
Ethylbenzene	100-41-4	10
m,p-Xylene (total)	108-38-3 + 106-42-3	10
o-Xylene	95-47-6	10
Styrene	100-42-5	10

Table C-3 (Cont)

Compound	CAS #	Representative Limits of Quantification (µg/L)
1,1,2,2-Tetrachloroethane	79-34-5	10
1,2,3-Trichloropropane	96-18-4	10
Isopropylbenzene	98-82-8	10
Bromobenzene	108-86-1	10
n-Propylbenzene	103-65-1	10
2-Chlorotoluene	95-49-8	10
4-Chlorotoluene	106-43-4	10
1,3,5-Trimethylbenzene	108-67-8	10
tert-Butylbenzene	98-06-6	10
1,2,4-Trimethylbenzene	95-63-6	10
sec-Butylbenzene	135-98-8	10
1,3-Dichlorobenzene	541-73-1	10
1,4-Dichlorobenzene	106-46-7	10
p-Isopropyltoluene	99-87-6	10
1,2-Dichlorobenzene	95-50-1	10
n-Butylbenzene	104-51-8	10
1,2-Dibromo-3-chloropropane	96-12-8	10
1,2,4-Trichlorobenzene	120-82-1	10
Naphthalene	91-20-3	10
1,2,3-Trichlorobenzene	87-61-6	10
Hexachlorobutadiene	87-68-3	10

Column: Supelco DB 624, 30 m × 0.530 mm × 1.5 µm. Limits of detection are estimated using the minimum signal required to yield identifiable mass spectral scan.

inclined. We endeavor to run at least 10% of stable constituent, organic, and selected radioactive constituent analyses as quality control samples using the materials described above. A detailed description of our quality assurance program and a complete listing of our annual results have been published annually since 1976.[C71, C72]

2. Radioactive Constituents. Quality control and quality assurance samples for radioactive constituents are obtained from outside agencies, in addition to those that are prepared internally. The Quality Assurance Division of the Environmental Monitoring Systems Laboratory (EPA, Las Vegas) provides water, foodstuffs, and air filter samples for analysis of gross alpha, gross beta, ^{3}H, ^{40}K, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs, ^{226}Ra, and ^{239,240}Pu as part of an ongoing laboratory intercomparison program. The National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) provides several soil and sediment standard reference materials (SRMs) for environmental radioactivity. These SRMs are certified for ^{60}Co, ^{90}Sr, ^{137}Cs, ^{226}Ra, ^{238}Pu, ^{239,240}Pu, ^{241}Am, and several other nuclides. The DOE's Environmental Measurements Laboratory also provides quality assurance samples.

Soil, rock, and ore samples obtained from the Canadian Geological Survey (CGS) are used for quality assurance of uranium and thorium determinations in silicate matrices. Our own in-house standards are prepared by adding known quantities of liquid NIST radioactivity SRMs to blank matrix materials.

3. Stable Constituents. Quality assurance for the stable constituent analysis program is maintained by analysis of certified or well-characterized environmental

Table C-4. Volatile Organic Compounds in Solids, Determined by SW-846 Method 8010 Analyses

Compound	CAS #	Limits of Quantification (µg/kg)
Chloromethane	74-87-3	20
Vinyl chloride	75-01-4	20
Bromomethane	74-83-9	20
Chloroethane	75-00-3	20
Acetone	67-64-1	20
Trichlorofluoromethane	75-69-4	10
1,1-Dichloroethene	75-35-4	10
Methylene chloride	75-09-2	10
Carbon disulfide	75-15-0	10
t-1,2-Dichloroethene	156-6	10
1,1-Dichloroethane	75-34-3	10
c-1,2-Dichloroethene	156-59-4	10
Bromochloromethane	74-97-5	10
Chloroform	67-66-3	10
1,2-Dichloroethane	107-06-2	10
1,1-Dichloropropene	563-58-6	10
Vinyl acetate	108-05-4	10
2-Butanone	78-93-3	20
2,2-Dichloropropane	590-20-7	10
1,1,1-Trichloroethane	71-55-6	10
Carbon tetrachloride	56-23-5	10
Benzene	71-43-2	10
1,2-Dichloropropane	78-87-5	10
Trichloroethene	79-01-6	10
Dibromomethane	74-95-3	10
Bromodichloromethane	75-27-4	10
t-1,3-Dichloropropene	1006-10-26	10
c-1,3-Dichloropropene	1006-10-15	10
1,1,2-Trichloroethane	79-00-5	10
1,3-Dichloropropane	142-28-9	10
Chlorodibromomethane	124-48-1	10
Bromoform	75-25-2	10
4-Methyl-2-pentanone	10-81-1	20
Toluene	108-88-3	10
2-Hexanone	59-17-86	20
1,2-Dibromomethane	74-95-3	10
Tetrachloroethene	127-18-4	10
Chlorobenzene	108-90-7	10
1,1,1,2-Tetrachloroethane	630-20-6	10
1-Chlorohexane	544-10-5	10
Ethylbenzene	100-41-4	10
m,p-Xylene (total)	108-38-3 + 106-42-3	10
o-Xylene	95-47-6	10
Styrene	100-42-5	10
1,1,2,2-Tetrachloroethane	79-34-5	10

Table C-4 (Cont)

Compound	CAS #	Limits of Quantification (µg/kg)
1,2,3-Trichloropropane	96-18-4	10
Isopropylbenzene	98-82-8	10
Bromobenzene	108-86-1	10
n-Propylbenzene	103-65-1	10
2-Chlorotoluene	95-49-8	10
4-Chlorotoluene	106-43-4	10
1,3,5-Trimethylbenzene	108-67-8	10
tert-Butylbenzene	98-06-6	10
1,2,4-Trimethylbenzene	98-63-6	10
sec-Butylbenzene	135-98-8	10
1,3-Dichlorobenzene	541-73-1	10
1,4-Dichlorobenzene	106-46-7	10
p-Isopropyltoluene	99-87-6	10
1,2-Dichlorobenzene	95-50-1	10
n-Butylbenzene	104-51-8	10
1,2-Dibromo-3-chloropropane	96-12-8	10
1,2,4-Trichlorobenzene	120-82-1	10
Naphthalene	91-20-3	10
1,2,3-Trichlorobenzene	87-61-6	10
Hexachlorobutadiene	87-68-3	10

Column: Supelco DB 624, 30 m × 0.53 mm fused silica capillary, using a methanolic partition with PAT. Limits of quantification are calculated from the intercept of the external calibration curve using a flame ionization detector.

materials. The NIST has a large set of silicate, water, and biological SRMs. The EPA distributes mineral analysis and trace analysis water standards. Rock and soil reference materials have been obtained from the CGS and the United States Geological Survey (USGS). Details of this program have been published elsewhere.[C72]

The analytical quality control program for a specific batch of samples is the combination of many factors. These include the "fit of the calibration," instrument drift, calibration of the instrument and/or reagents, recovery for SRMs, and precision of results. In addition, there is a program for evaluation of the quality of results for an individual water sample.[C73] These individual water sample quality ratios are the sum of the milliequivalent (meq) cations to the sum of meq anions, the meq hardness of the sum of meq Ca^{+2} and Mg^{+2}, the observed total dissolved solids (TDS) to the sum of solids, and the observed conductivity to the sum of contributing conductivities, as well as the two ratios obtained by multiplying (0.01) × (conductivity) and dividing by the meq cations and the meq anions.

4. Organic Constituents. Soil samples are received for the analysis of volatile and semivolatile organic compounds, pesticides, and herbicides for compliance work done under the Resource Conservation and Recovery Act (RCRA). Certified matrix-based reference materials were not available for these analyses, so stock solutions of the analytes were prepared and spiked directly on blank soil by the quality assurance section. Because homogeneity of the sample could not be ensured, the entire sample was analyzed. Volatile organic compounds are analyzed by gas chromatography/mass spectrometry and are now spiked in the microgram-per-kilogram range.

The majority of water samples submitted during 1989 were environmental compliance samples for the analysis of pesticides, herbicides, volatile and semivolatile organic compounds, and PCBs. Methods were developed and

Table C-5. Semivolatile Organic Compounds in Water

Compound	CAS #	Limits of Quantification (µg/L)
N-Nitrosodimethylamine	62-75-9	20
Aniline	62-55-3	20
Phenol	108-95-2	10
Bis(-2-chloroethyl)ether	111-44-4	10
2-Chlorophenol	95-57-8	10
1,3-Dichlorobenzene	541-73-1	10
1,4-Dichlorobenzene	106-46-7	10
Benzyl alcohol	100-51-6	10
1,2-Dichlorobenzene	95-50-1	10
2-Methylphenol	95-48-7	10
Bis(2-chloroisopropyl)ether	39638-32-9	10
4-Methylphenol	106-44-5	10
N-Nitroso-di-*n*-propylamine	621-64-7	10
Hexachloroethane	67-72-1	10
Nitrobenzene	98-95-3	10
Isophorone	78-59-1	10
2-Nitrophenol	88-75-5	10
2,4-Dimethylphenol	105-67-9	10
Benzoid acid	65-85-0	50
Bis(-2-chloroethoxy)methane	111-91-1	10
2,4-Dichlorophenol	120-83-2	10
1,2,4-Trichlorobenzene	120-82-1	10
Naphthalene	91-20-3	10
4-Chloroaniline	106-47-8	10
Hexachlorobutadiene	87-68-3	10
4-Chloro-3-methylphenol	59-50-7	10
2-Methylnaphthalene	91-57-6	10
Hexachlorocyclopentadiene	77-47-4	10
2,4,6-Trichlorophenol	88-06-2	10
2,4,5-Trichlorophenol	95-95-4	50
2-Chloronaphthalene	91-58-7	10
2-Nitroaniline	88-74-4	50
Dimethyl phthalate	131-11-3	10
Acenaphthylene	208-96-8	10
3-Nitroaniline	99-09-2	50
Acenaphthene	83-32-9	10
2,4-Dinitrophenol	51-28-5	50
4-Nitrophenol	100-02-7	50
Dibenzofuran	132-64-9	10
2,4-Dinitrotoluene	121-14-2	10
2,6-Dinitrotoluene	606-20-2	10
Diethylphthalate	84-66-2	10
4-Chlorophenyl-phenylether	7005-72-3	10
Fluorene	86-73-7	10
4-Nitroaniline	100-01-6	50
4,6-Dinitro-2-methylphenol	534-52-1	50
N-Nitrosodiphenylamine	86-30-6	10

Table C-5 (Cont)

Compound	CAS #	Limits of Quantification (μg/L)
Azobenzene	103-33-3	50
4-Bromophenyl-phenylether	101-55-3	10
Hexachlorobenzene	118-74-1	10
Pentachlorophenol	87-86-5	50
Phenanthrene	85-01-8	10
Anthracene	120-12-7	10
Di-*n*-butylphthalate	84-74-2	10
Fluoranthene	206-44-0	10
Benzidine	92-87-5	50
Pyrene	129-00-0	10
Butylbenzylphthalate	85-68-7	10
3,3′-Dichlorobenzidine	91-94-1	20
Benzo(*a*)anthracene	56-55-3	10
Bis(2-ethylhexyl)phthalate	117-81-7	10
Chrysene	218-01-9	10
Di-*n*-octyl phthalate	117-84-0	10
Benzo(*b*)fluoranthene	205-99-2	10
Benzo(*k*)fluoranthene	207-08-9	10
Benzo(*a*)pyrene	50-32-8	10
Indeno(1,2,3-*cd*)pyrene	193-39-5	10
Dibenzo(*a,h*)anthracene	53-70-3	10
Benzo(*g,h,i*)perylene	191-24-2	10

Table C-6. Volatile Organic Compounds Determined in Air (Pore Gas)

Compound	CAS #	Limits of Quantification (μg/tube)
Chloroform	67-66-3	1.0
1,1,1-Trichloroethane	71-56-6	1.0
Benzene	71-43-2	1.0
Carbon tetrachloride	56-23-5	1.0
Trichloroethene	79-01-6	1.0
Toluene	108-88-3	1.0
Tetrachloroethene	127-18-4	1.0
Chlorobenzene	108-90-7	1.0
Ethylbenzene	100-41-4	1.0
o-Xylene	95-47-6	1.0
m,p-Xylene (total)	108-38-3 and 106-42-3	1.0
1,2,4-Trimethylbenzene	95-63-6	1.0

Table C-7. EP Toxicity of Organic Contaminants

Contaminant	Maximum Concentration (mg/L)	Representative Detection Limits (mg/L)[a]
Endrin (1,2,3,4,10,10-hexachloro-6 7-*epoxy*-1,4,4*a*,5,6,7,8,8*a*-octahydro-1 4-*endo*, *endo*-5, 8-dimethanonaphthalene)	0.02	0.006
Lindane (α,α,β,α,α,β-hexachlorocyclohexane, gamma isomer)	0.4	0.0002
Methoxychlor (1,1,1-trichloro-2,2-bis(*p*-methoxyphenyl)ethane)	10.0	0.004
Toxaphene (technical chlorinated camphene, 67%–69% chlorine)	0.5	0.020
2,4-*D* (2,4-dichlorophenoxyacetic acid)	10.0	0.016
2,4,5-TP (Silvex) (2,4,5-trichlorophenoxypropionic acid)	1.0	0.005

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[a] Column: 30 m × 0.32-mm SPB-5 fused silica capillary. Detection limit was calculated as 4 times the gas chromatography background noise found when an electron capture detector was used.

refined for in-house preparation of quality control samples for volatile and semivolatile organic compounds in water.

Oil samples were received for the analysis of PCBs and organic solvents. The majority of these oils await disposal by the Laboratory's Waste Management Group (HSE-7) and include oil from decommissioned transformers. The remaining oil samples were environmental or industrial hygiene samples taken from areas of possible contamination.

Quality control samples for PCBs were prepared by diluting EPA standards or by preparing standards in hexane from the neat analyte. In the United States, the only PCBs that have been found in transformers have been PCBs 1242, 1254, and 1260. Samples submitted for analysis have contained only these PCBs, so they have been used to spike quality control samples. Vacuum pump oil was chosen for the oil base blank after an experiment with various brands of motor oil showed excessive matrix interferences.

5. Indicators of Accuracy and Precision. Accuracy is the degree of difference between average test results and true results, when the latter are known or assumed. Precision is the degree of mutual agreement among replicate measurements (frequently assessed by calculating the standard deviation of a set of data points). Accuracy and precision are evaluated from results of analysis of reference materials. These results (r) are normalized to the known quality in the reference material to permit comparison among reference materials of a similar matrix containing different concentrations of the analyte:

$$r = \frac{\text{Reported quantity}}{\text{Known quantity}} .$$

A mean value R for all normalized analyses of a given type is calculated as follows for a given matrix type (N is total number of analytical determinations):

$$R = \frac{\sum_i r_i}{N},$$

Standard deviations of R are calculated assuming a normal distribution of the population of analytical determinations (N):

$$s = \sqrt{\frac{\Sigma_i (R - r_i)^2}{(N-1)}}\ .$$

These calculated values are presented as the HSE-9 "Ratio ± Std Dev" in Tables C-8 through C-20. The mean value of R is a measure of the accuracy of a procedure. Values of R greater than unity indicate a positive bias in the analysis; values less than unity, a negative bias.

The standard deviation is a measure of precision. Precision is a function of the concentration of analyte; that is, as the absolute concentration approaches the limit of detection, precision deteriorates. For instance, the precision for some determinations is quite large because many standards approach the limits of detection of a measurement. We address this issue by calculating a new quality assurance parameter,

$$\left|\overline{X}_E - \overline{X}_c\right| < 1.96\sqrt{(S_E)^2 + (S_c)^2}\ ,$$

where X_E and X_c are the experimentally determined and certified or consensus mean elemental concentrations, respectively, and S_E and S_c are the standard deviations associated with X_E and X_c, respectively. An analysis will be considered under control when this condition is satisfied for a certain element in a given matrix. Details on this approach are presented elsewhere.[C72] The percentage of the tests for each parameter that fell within ±2 propagated standard deviations (under control), between ±2 and ±3 propagated standard deviations (warning level), or outside ±3 propagated standard deviations (out of control) is shown in Tables C-8 to C-23. A summary of the overall state of statistical control for analytical work done by HSE-9 is also provided in Tables C-21 to C-23.

A new table, C-24, has been added this year, summarizing our recovery information on organic surrogate compounds required for use in the EPA-CLP protocol. All mean recoveries are within the EPA limits, although the standard deviations are large. A summary of the overall state of statistical control for analytical work done by HSE-9 is provided in Table C-25.

For most radiochemical and inorganic analyses, more than 90% are within ±2 propagated standard deviations of the certified/consensus mean values (under control). Our performance on stable elements in biologicals improved significantly this year, but our radiochemical determinations in biologicals deteriorated. Our organic analyses in bulk materials remained under excellent control, and our organic determinations in water improved significantly over last year. However, our overall performance on organic measurements in soils deteriorated markedly over the previous year's marginal record. This area will be the focus of increased quality assurance/quality control efforts in the future.

New instrumentation has been purchased for the analysis of volatile organic compounds, and considerable improvement has been shown in this area. Analyses of semivolatile organic compounds continue to pose a challenge, but new extraction methods are being developed that show promise. Additional experienced personnel have been hired for the analysis of semivolatile compounds, currently the most complex organic analysis of the environmental protocols.

The analysis of any organic compound on silicate materials is difficult because of the tremendous number and types of matrix complications. In addition to the blind quality control samples, the analyst spikes samples for volatile and semivolatile compound analysis with a series of three to five surrogate compounds and checks for the percentage of recovery, as directed by EPA guidelines. If these recoveries are out of acceptable range, corrective action should be taken. Matrix spike samples are also prepared. A portion of the actual sample is spiked with target compounds, and recoveries are evaluated using EPA guidelines.

Data on analytical detection limits are given in Table C-26.

Table C-8. Summary of HSE-9 Quality Assurance Tests for 1989
(Stable Element Analyses in Biologicals)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Al	14	57	21	21	1.13 ± 0.58
As	3	100	—	—	0.79 ± 0.13
Br	20	95	5	—	1.26 ± 0.40
C	24	62	38	—	1.02 ± 0.01
Ca	21	100	—	—	0.99 ± 0.14
Cd	3	100	—	—	1.04
Cl	18	100	—	—	0.95 ± 0.05
Cs	16	100	—	—	1.27 ± 0.22
Cu	17	100	—	—	1.59 ± 0.91
H	24	75	4	21	1.06 ± 0.02
H_2O	1	—	—	100	0.91
In	21	95	5	—	0.53 ± 0.11
K	8	101	—	—	0.92 ± 0.04
Mg	18	89	11	—	0.98 ± 0.18
Mn	15	100	—	—	1.07 ± 0.06
N	24	92	8	—	0.98 ± 0.11
Na	18	94	6	—	1.28 ± 0.41
S	117	96	3	—	1.01 ± 0.21
U	12	83	—	17	0.90 ± 0.29
V	20	95	—	5	1.29 ± 0.54

Table C-9. Summary of HSE-9 Quality Assurance Tests for 1989
(Stable Element Analyses in Filters)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Al	6	50	33	17	1.51 ± 0.62
Be	187	96	4	1	1.02 ± 0.11
Br	1	100	—	—	0.72
Cd	32	100	—	—	1.02 ± 0.04
Cr	2	50	—	50	0.80 ± 0.21
Cu	1	100	—	—	1.12
Li	13	53	23	23	0.75 ± 0.13
Mn	3	100	—	—	1.04 ± 0.06
Ni	3	100	—	—	0.87 ± 0.11
Pb	140	93	6	—	0.96 ± 0.10
U	28	93	—	7	1.07 ± 0.44
Zn	32	100	—	—	0.98 ± 0.06

Table C-10. Summary of HSE-9 Quality Assurance Tests for 1989 (Stable Element Analyses in Bulk Materials)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Ag	21	100	—	—	1.14 ± 0.22
As	5	60	40	—	0.81 ± 0.29
Ba	16	100	—	—	1.13 ± 0.11
Cd	11	100	—	—	1.03 ± 0.09
Cr	22	100	—	—	1.01 ± 0.14
Fe	1	100	—	—	1.00
Flash point	10	100	—	—	1.00
Heat capacity	2	100	—	—	0.98 ± 0.02
Hg	3	100	—	—	1.09 ± 0.18
Ni	8	100	—	—	1.13 ± 0.12
Pb	23	100	—	—	0.98 ± 0.16
Se	17	100	—	—	0.90 ± 0.09
Tl	3	100	—	—	0.82 ± 0.03

Table C-11. Summary of HSE-9 Quality Assurance Tests for 1989 (Stable Element Analyses in Charcoal Tubes)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Al	1	—	100	—	0.84
As	8	100	—	—	0.80 ± 0.02
Ba	1	100	—	—	1.17
Be	12	75	25	—	0.76 ± 0.15
Cd	12	100	—	—	1.13 ± 0.19
Cr	1	100	—	—	0.95
Cu	25	100	—	—	1.00 ± 0.09
Fe	1	100	—	—	0.96
H_2O	1	100	—	—	0.93
Hg	8	88	13	—	1.16 ± 0.21
Li	5	100	—	—	0.82 ± 0.17
Mo	9	100	—	—	1.05 ± 0.17
Ni	23	95	4	–	0.92 ± 0.11
Pb	29	100	—	—	0.98 ± 0.13
S	161	77	10	12	0.98 ± 0.40
Sb	8	100	—	—	1.09 ± 0.03
Tl	18	89	11	—	0.98 ± 0.14
U	155	97	2	1	0.98 ± 0.09
W	8	100	—	—	1.25 ± 0.15

Table C-12. Summary of Additional HSE-9 Quality Assurance Tests for 1989 (Stable Element Analyses in Charcoal Tubes)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Br	2	100	—	—	1.03
Cl	3	100	—	—	1.20
F	2	100	—	—	0.78
NO_3	2	100	—	—	1.23

Table C-13. Summary of HSE-9 Quality Assurance Tests for 1989 (Stable Element Analyses in Water)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Ag	332	98	1	1	1.02 ± 0.26
Al	47	100	—	—	1.00 ± 0.10
As	303	94	4	1	1.03 ± 0.17
B	35	100	—	—	0.96 ± 0.06
Ba	283	100	—	—	1.01 ± 0.07
Be	231	99	1	—	1.05 ± 0.67
Br	7	100	—	—	1.09 ± 0.11
Ca	80	100	—	—	1.01 ± 0.08
Cd	417	96	1	3	1.05 ± 0.29
Cl	70	99	—	1	1.17 ± 1.43
CN	111	98	—	2	0.89 ± 0.08
Co	105	99	—	1	1.02 ± 0.08
COD	58	100	—	—	0.99 ± 0.08
Conductivity	80	100	—	—	0.97 ± 0.03
Cr	442	98	2	—	1.00 ± 0.10
Cr (VI)	23	100	—	—	0.95 ± 0.04
Cu	375	98	2	—	1.02 ± 0.09
F	87	95	2	2	1.31 ± 2.18
Fe	224	99	—	—	1.02 ± 0.11
Hardness	34	97	3	—	0.98 ± 0.06
Hg	225	97	3	—	0.98 ± 0.19
K	85	98	2	—	0.99 ± 0.11
Li	20	100	—	—	0.98 ± 0.05
Mg	91	94	4	1	1.02 ± 0.13
Mn	129	97	3	1	1.06 ± 0.10
Mo	60	95	5	—	1.08 ± 0.10
Na	86	98	1	1	1.27 ± 2.22
NH_3-N	53	100	—	—	1.01 ± 0.06
Ni	319	99	1	—	1.03 ± 0.09

Table C-13 (Cont)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
NO_3-N	81	100	—	—	1.01 ± 0.05
Oil/grease	2	100	—	—	0.98 ± 0.03
P	42	100	—	—	0.95 ± 0.14
Pb	496	98	1	1	1.03 ± 0.56
pH	364	100	—	—	1.00 ± 0.05
PO_4-P	31	97	—	3	0.93 ± 0.20
S	3	100	—	—	1.03 ± 0.08
Sb	67	100	—	—	1.01 ± 0.07
Se	301	98	1	—	1.05 ± 0.87
Si	68	100	—	—	1.03 ± 0.05
Sn	2	100	—	—	1.10 ± 0.20
SO_4	71	100	—	—	0.99 ± 0.06
Sr	24	100	—	—	0.98 ± 0.15
Total alkalinity	66	100	—	—	0.98 ± 0.06
TDS	38	95	3	3	1.00 ± 0.30
Ti	81	100	—	—	1.03 ± 0.07
Tl	218	97	1	2	1.03 ± 0.20
TOC (total organic carbon)	5	80	—	20	0.85 ± 0.38
TOX (total organic halides)	1	100	—	—	0.96
TSS (total suspended solids)	71	95	4		0.92 ± 0.06
Turbidity	2	100	—	—	1.70 ± 0.43
U	366	99	1	—	1.02 ± 0.10
V	52	87	8	6	1.11 ± 0.26
Zn	295	97	2	—	0.99 ± 0.08

Table C-14. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Biologicals)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
^{241}Am	3	100	—	—	1.12 ± 0.11
^{137}Cs	22	59	23	18	0.86 ± 0.19
^{238}Pu	8	100	—	—	1.01 ± 0.09
^{239}Pu	21	95	5	—	1.14 ± 0.23
^{90}Sr	3	—	—	100	0.53 ± 0.03

Table C-15. Summary of HSE-9 Quality Assurance Tests for 1989 (Radiochemical Analyses in Filters)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Alpha	36	100	—	—	0.90 ± 0.05
^{241}Am	8	76	13	13	1.16 ± 0.51
^{7}Be	7	58	29	14	0.70 ± 0.26
Beta	33	100	—	—	0.86 ± 0.03
^{144}Ce	1	—	—	100	0.14
^{60}Co	7	71	29	—	1.43 ± 0.21
^{134}Cs	7	100	—	—	1.03 ± 0.06
^{137}Cs	15	87	13	—	0.94 ± 0.18
^{54}Mn	1	100	—	—	0.79
^{239}Pu	10	70	20	10	1.10 ± 0.49
^{90}Sr	2	100	—	—	1.24
^{238}U	3	—	—	100	1.96 ± 0.03

Table C-16. Summary of HSE-9 Quality Assurance Tests for 1989 (Radiochemical Analyses in Silicates)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
^{241}Am	9	100	—	—	0.92 ± 0.06
^{137}Cs	73	92	3	5	0.96 ± 0.21
Gamma	39	100	—	—	1.08 ± 0.02
^{40}K	3	100	—	—	1.35 ± 0.07
^{239}Pu	4	100	—	—	0.92 ± 0.03
^{90}Sr	3	100	—	—	2.37 ± 1.52

Table C-17. Summary of HSE-9 Quality Assurance Tests for 1989 (Radiochemical Analyses in Water)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Alpha	660	100	—	—	0.99 ± 0.11
^{241}Am	86	100	—	—	0.97 ± 0.07
^{133}Ba	7	57	—	43	2.16 ± 1.08
Beta	659	100	—	—	0.98 ± 0.09
^{144}Ce	3	—	—	100	0.07 ± 0.01
^{57}Co	60	100	—	—	1.12 ± 0.12
^{60}Co	75	98	—	1	0.98 ± 0.29
^{134}Cs	79	100	—	—	0.94 ± 0.24
^{137}Cs	106	99	1	1	1.02 ± 0.18
Gamma	30	100	—	—	1.07 ± 0.14
^{3}H	319	96	4	—	0.98 ± 0.07
^{54}Mn	61	100	—	—	1.08 ± 0.06
^{22}Na	59	100	—	—	0.95 ± 0.03
^{238}Pu	56	100	—	—	0.93 ± 0.06
^{239}Pu	82	93	4	4	0.95 ± 0.08
^{226}Ra	17	100	—	—	0.96 ± 0.08
^{106}Ru	14	100	—	—	0.72 ± 0.31
^{90}Sr	15	94	7	—	0.85 ± 0.15
^{234}U	28	100	—	—	0.99 ± 0.08
^{235}U	42	100	—	—	1.01 ± 0.26
$^{235/238}$U	196	99	1	—	1.00 ± 0.06
^{238}U	3	100	—	—	1.07 ± 0.07
^{65}Zn	14	100	—	—	—

Table C-18. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Biologicals)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Bromochloromethane	1	100	—	—	0.85
Bromoform	1	100	—	—	0.88
o-Dichlorobenzene (1,2)	1	100	—	—	0.96
1,3-Dichloropropane	1	100	—	—	0.84
Ethylbenzene	1	100	—	—	0.88
Tetrachloroethylene	1	100	—	—	0.89
Toluene	1	100	—	—	1.00
Vinyl acetate	1	100	—	—	0.73

Table C-19. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Filters)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Anthracene	2	100	—	—	0.97 ± 0.16
Mixed aroclor	27	96	4	—	1.10 ± 0.74
Aroclor 1242	11	100	—	—	0.85 ± 0.11
Aroclor 1254	1	100	—	—	1.04
Aroclor 1260	15	93	7	—	1.26 ± 0.94
Pyrene	2	100	—	—	0.97 ± 0.01

Table C-20. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Bulk Materials)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Mixed aroclor	55	93	2	5	0.89 ± 0.20
Aroclor 1242	30	100	—	—	0.94 ± 0.15
Aroclor 1254	1	100	—	—	0.60
Aroclor 1260	34	91	6	3	0.88 ± 0.24

Table C-21. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Silicates)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Mixed aroclor	18	83	11	6	1.57
Mixed aroclor	2	100	—	—	1.57
Aroclor 1242	6	100	—	—	0.80 ± 0.13
Aroclor 1254	3	100	—	—	1.12 ± 0.15
Aroclor 1260	14	79	14	7	1.61

Table C-21 (Cont)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Benzene	3	33	33	33	0.42 ± 0.19
Bromochloromethane	1	100	—	—	—
2-Butanone	1	100	—	—	—
n-Butylbenzene	2	50	—	50	0.32
Carbon tetrachloride	1	100	—	—	—
Chlorobenzene	2	100	—	—	0.63 ± 0.02
Chloroform	2	—	—	100	0.37 ± 0.02
2,4-D	1	100	—	—	1.13
1,2-Dibromoethane	1	—	100	—	0.56
1,2-Dichloroethane	2	50	50	—	0.61 ± 0.02
1,2-Dichloropropane	1	—	100	—	0.53
Hexachlorobutadiene	2	50	50	—	0.57
Methoxychlor	1	100	—	—	1.04
4-Methyl-2-pentanone	1	100	—	—	—
Propylbenzene	2	50	—	50	0.36
Styrene	1	—	100	—	0.57
2,4,5-TP	1	100	—	—	0.95
1,1,2,2-Tetrachloroethane	2	—	—	100	0.28 ± 0.02
1,1,1,2-Tetrachloroethane	2	100	—	—	0.71
Tetrachloroethylene	1	100	—	—	0.64
Toluene	2	100	—	—	0.66 ± 0.05
Trichloroethene	2	50	50	—	0.65 ± 0.08
1,2,4-Trimethylbenzene	2	50	—	50	0.42
o-Xylene	2	100	—	—	0.63 ± 0.03
Mixed xylenes (*m* + *p*)	1	—	—	100	0.27

Table C-22. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Charcoal Tubes)

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Benzene	23	96	—	4	1.54 ± 2.07
Carbon tetrachloride	46	96	2	2	0.94 ± 0.10
Chlorobenzene	18	100	—	—	0.82 ± 0.10
Chloroform	30	86	13	—	0.87 ± 0.19
1,2-Dichloroethane	29	100	—	—	1.01 ± 0.07
Ethylbenzene	18	100	—	—	0.93 ± 0.12
Tetrachloroethylene	18	100	—	—	0.99 ± 0.13
Toluene	24	96	4	—	0.95 ± 0.11
1,1,1-Trichloroethane	19	100	—	—	0.95 ± 0.11
Trichloroethene	16	100	—	—	0.91 ± 0.03
1,2,4-Trimethylbenzene	16	101	—	—	1.04 ± 0.12
o-Xylene	8	100	—	—	0.92 ± 0.04

Table C-23. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Analyses in Water)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Acenaphthene	1	—	100	—	0.63
Aldrin	6	50	33	17	0.64 ± 0.27
Anthracene	1	—	00	—	0.57
Mixed aroclor	11	100	—	—	1.05 ± 0.27
Aroclor 1221	1	100	—	—	1.22
Aroclor 1242	7	100	—	—	1.13 ± 0.25
Aroclor 1248	5	80	—	20	0.85 ± 0.15
Aroclor 1254	4	75	—	25	1.72 ± 1.26
Aroclor 1260	3	100	—	—	0.87 ± 0.21
Benz(*a*)anthracene	2	50	50	—	0.63
Benzene	10	100	—	—	0.91 ± 0.20
Benzo(g,*h*,*i*)perylene	1	—	100	—	0.65
Benzo-*a*-pyrene	1	100	—	—	0.72
Benzo-*b*-fluoranthene	1	100	—	—	1.06
Benzo-*k*-fluoranthene	2	50	50	—	1.49
Bis(2-chloroethoxy)methane	2	50	50	—	0.74
Bis(2-chloroethyl)ether	2	100	—	—	0.71
Bis(2-chloroisopropyl)ether	1	—	—	100	0.55
Bis(2-ethylhexyl)phthalate	3	33	67	—	0.93
Bromochloromethane	5	100	—	—	0.97 ± 0.11
Bromodichloromethane	8	101	—	—	1.01 ± 0.20
Bromoform	10	100	—	—	1.20 ± 0.38
4-Bromophenylphenyl ether	1	100	—	—	0.77
2-Butanone	3	67	—	33	1.07
n-Butylbenzene	3	100	—	—	0.68 ± 0.05
Butylbenzyl phthalate	1	—	—	100	0.17
Carbon tetrachloride	11	100	—	—	0.85 ± 0.18
Chlordane	2	50	50	—	0.69 ± 0.14
4-Chloro-3-methylphenol	2	100	—	—	0.49 ± 0.02
Chlorobenzene	8	50	25	25	0.81 ± 0.21
Chlorodibromomethane	8	88	13	—	1.24 ± 0.42
Chloroform	7	71	—	29	1.66 ± 1.25
2-Chloronaphthalene	2	50	—	50	0.78
o-Chlorophenol	2	—	100	—	0.32 ± 0.01
4-Chlorophenylphenyl ether	1	100	—	—	0.75
p-Chlorotoluene	1	100	—	—	0.99
Chrysene	1	100	—	—	0.90
2,4-D	2	100	—	—	1.15
p,p'-DDD	4	100	—	—	0.84 ± 0.07
p,p'-DDE	4	75	25	—	0.91 ± 0.20
p,p'-DDT	4	75	—	25	0.88 ± 0.32

Table C-23 (Cont)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Di-*n*-butyl phthalate	2	—	—	100	0.20
Dibenzo(*a*,*h*)anthracene	1	100	—	—	0.72
1,2-Dibromoethane	3	100	—	—	0.91 ± 0.04
o-Dichlorobenzene (1,2)	9	89	11	—	0.90 ± 0.21
m-Dichlorobenzene (1,3)	8	100	—	—	0.82 ± 0.33
p-Dichlorobenzene (1,4)	7	86	—	14	0.83 ± 0.25
1,2-Dichloroethane	7	86	14	—	1.19 ± 0.31
2,4-Dichlorophenol	2	50	50	—	0.40 ± 0.01
1,3-Dichloropropane	2	100	—	—	1.04 ± 0.09
1,2-Dichloropropane	3	100	—	—	0.82 ± 0.03
Dieldrin	4	100	—	—	0.91 ± 0.12
Diethyl phthalate	2	—	50	50	—
Dimethyl phthalate	1	—	—	100	0.03
2,4-Dimethylphenol	2	50	50	—	0.41 ± 0.01
2,6-Dinitrotoluene	2	50	50	—	0.84
2,4-Dinitrotoluene	2	50	50	—	0.82
Endrin	1	100	—	—	1.16
Ethylbenzene	9	100	—	—	0.80 ± 0.17
Fluoranthene	1	100	—	—	0.87
Fluorene	1	100	—	—	0.76
Heptachlor	4	100	—	—	0.80 ± 0.21
Heptachlor epoxide	4	50	50	—	0.83 ± 0.24
Hexachlorobenzene	2	50	50	—	0.86
Hexachlorobutadiene	5	80	20	—	0.69 ± 0.06
Hexachloroethane	1	—	—	100	0.26
2-Hexanone	1	100	—	—	1.02
Isophorone	2	100	—	—	0.74
Lindane	4	50	25	25	0.77 ± 0.27
Methoxychlor	2	100	—	—	0.90 ± 0.10
4-Methyl-2-pentanone	3	100	—	—	0.98 ± 0.10
2-Methyl-4,6-dinitrophenol	2	100	—	—	0.87 ± 0.02
Methylene chloride	7	85	—	14	2.70 ± 3.91
Naphthalene	1	—	—	100	0.47
Nitrobenzene	1	—	100	—	0.56
2-Nitrophenol	2	100	—	—	0.44 ± 0.02
4-Nitrophenol	2	100	—	—	0.08
N-Nitrosodi-*n*-propylamine	2	100	—	—	0.51
Pentachlorophenol	2	100	—	—	0.62 ± 0.02
Phenanthrene	2	50	50	—	0.86
Phenol	2	—	—	100	0.15 ± 0.01
Propylbenzene	3	—	33	67	0.48 ± 0.01
Pyrene	2	50	50	—	0.91

Table C-23 (Cont)

Analysis	Number of Tests	<2σ (%)	2σ–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Styrene	3	100	—	—	0.86
2,4,5-TP	2	100	—	—	1.03 ± 0.03
1,1,2,2-Tetrachloroethane	3	7	33	—	0.90 ± 0.28
1,1,1,2-Tetrachloroethane	3	100	—	—	0.90 ± 0.02
Tetrachloroethylene	12	100	—	—	0.87 ± 0.12
Toluene	9	100	—	—	0.89 ± 0.20
1,2,4-Trichlorobenzene	2	50	50	—	0.73
1,1,1-Trichloroethane	6	83	17	—	1.15 ± 0.49
Trichloroethene	8	88	13	—	0.86 ± 0.20
2,4,6-Trichlorophenol	1	100	—	—	0.51
1,2,4-Trimethylbenzene	3	100	—	—	0.78 ± 0.04
Vinyl acetate	3	33	33	33	0.99 ± 0.42
o-Xylene	2	50	—	50	0.77 ± 0.31
m-Xylene	2	50	—	50	0.58 ± 0.19
Mixed xylenes (*m* + *p*)	1	100	—	—	0.77
2,4-Xylenol	2	50	50	—	0.41 ± 0.01

Table C-24. Summary of HSE-9 Quality Assurance Tests for 1989 (Organic Compound Surrogate Recoveries)

Analysis	Number of Tests	HSE-9 Mean (%) ± Std Dev	EPA-CLP Limits (%)
Pore Gas			
Bromobenzene	229	83 ± 16	None
Volatile Organic Compounds			
In Biological Materials			
1,2-Dichloroethane d4	1	95	None
Toluene d8	1	100	None
4-Bromofluorobenzene	1	118	None
In Sludges			
1,2-Dichloroethane d4	1	79	None
Toluene d8	1	92	None
4-Bromofluorobenzene	1	258	None
In Water			
1,2-Dichloroethane d4	181	99 ± 37	76–114
Toluene d8	181	94 ± 34	88–110
4-Bromofluorobenzene	181	109 ± 47	86–115
In Bulk Materials			
1,2-Dichloroethane d4	13	84 ± 39	None
Toluene d8	13	78 ± 37	None
4-Bromofluorobenzene	13	69 ± 35	None
In Soils			
1,2-Dichloroethane d4	281	112 ± 53	70–121
Toluene d8	281	104 ± 44	81–117
4-Bromofluorobenzene	281	121 ± 81	74–121
Semivolatile Organic Compounds			
In Water			
2-Fluorophenol	124	41 ± 21	21–100
Phenol-d5	124	31 ± 20	10– 94
Nitrobenzene-d5	122	62 ± 25	35–114
2-Fluorobiphenyl	122	63 ± 28	43–116
2,4,6-Tribromophenol	122	70 ± 33	10–123
p-Terphenyl-d14	122	88 ± 39	33–141
In Soils			
2-Fluorophenol	129	52 ± 31	25–121
Phenol-d5	129	58 ± 31	24–113
Nitrobenzene-d5	129	58 ± 34	23–120
2-Fluorobiphenyl	129	73 ± 40	30–115
2,4,6-Tribromophenol	128	65 ± 54	19–122

Table C-25. Overall Summary of HSE-9 Quality Assurance Tests for 1989

Analysis	Number of Tests	$<2\sigma$ (%)	2σ–3σ (%)	$>3\sigma$ (%)
Stable Elements				
Biological materials	414	93.9	3.4	2.7
Filters	448	93.5	4.5	2.0
Bulk materials	142	98.6	1.4	0
Silicate Materials	486	90.6	5.1	4.3
Water	7159	98.2	1.2	0.6
Charcoal tubes	9	100	0	0
Radiochemical Elements				
Water	2671	98.9	0.7	0.4
Filters	130	88.9	6.9	5.4
Biological materials	57	78	10	12
Silicate materials	131	95.5	1.5	3.0
Organic Compounds				
Water	340	81	11	8
Silicate materials	36	38	31	31
Bulk materials	120	94.2	2.5	3.3
Biological materials	8	100	0	0
Filters	58	96.6	3.4	0

Table C-26. Detection Limits for Analyses of Typical Environmental Samples

Parameter	Approximate Sample Volume or Weight	Count Time	Detection Limit Concentration	
Air Sample				
Tritium	3 m^3	50 min	1×10^{-10}	µCi/m^3
^{238}Pu	2.0×10^4 m^3	8×10^4 s	2×10^{-12}	µCi/m^3
^{239,240}Pu	2.0×10^4 m^3	8×10^4 s	3×10^{-12}	µCi/m^3
^{241}Am	2.0×10^4 m^3	8×10^4 s	2×10^{-12}	µCi/m^3
Gross alpha	6.5×10^3 m^3	100 min	4×10^{-10}	µCi/m^3
Gross beta	6.5×10^3 m^3	100 min	4×10^{-10}	µCi/m^3
Uranium (delayed neutron)	2.0×10^4 m^3	60 s	1	pg/m^3
Water Sample				
Tritium	0.005 L	50 min	7×10^{-7}	µCi/mL
^{137}Cs	0.5 L	5×10^4 s	4×10^{-8}	µCi/mL
^{238}Pu	0.5 L	8×10^4 s	1×10^{-10}	µCi/mL
^{239,240}Pu	0.5 L	8×10^4 s	1×10^{-10}	µCi/mL
^{241}Am	0.5 L	8×10^4 s	1×10^{-10}	µCi/mL
Gross alpha	0.9 L	100 min	3×10^{-9}	µCi/mL
Gross beta	0.9 L	100 min	3×10^{-9}	µCi/mL
Uranium (delayed neutron)	0.025 L	50 s	1	µg/L
Soil Sample				
Tritium	1 kg	50 min	0.003	pCi/g
^{137}Cs	100 g	5×10^4 s	0.1	pCi/g
^{238}Pu	10 g	8×10^4 s	0.02	pCi/g
^{239,240}Pu	10 g	8×10^4 s	0.02	pCi/g
^{241}Am	10 g	8×10^4 s	0.02	pCi/g
Gross alpha	2 g	100 min	1.4	pCi/g
Gross beta	2 g	100 min	1.3	pCi/g
Uranium (delayed neutron)	2 g	20 s	0.03	µg/g

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APPENDIX D

METHODS FOR DOSE CALCULATIONS

A. Introduction

Annual radiation doses are evaluated for three principal exposure pathways: inhalation, ingestion, and external exposure (which includes exposure from immersion in air containing photon-emitting radionuclides and direct and scattered penetrating radiation). Estimates are made of the following exposures:

1. maximum boundary organ doses and effective dose equivalents to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the individual is outdoors at the Laboratory boundary continuously (24 hours/day, 365 days/year).
2. maximum individual organ doses and effective dose equivalents to an individual at or outside the Laboratory boundary where the highest dose rate occurs and a person actually is present. It takes into account occupancy (the fraction of time that a person actually occupies that location), shielding by buildings, and self-shielding.
3. average organ doses and effective dose equivalents to nearby residents.
4. collective effective dose equivalent for the population living within an 80-km (50-mi) radius of the Laboratory.

Results of environmental measurements are used as much as possible in assessing doses to individual members of the public. Calculations based on these measurements follow procedures recommended by federal agencies to determine radiation doses.[D1,D2]

If the impact of Laboratory operations is not detectable by environmental measurements, individual and population doses attributable to Laboratory activities are estimated through modeling of releases.

Dose conversion factors used for inhalation and ingestion calculations are given in Table D-1. These factors are taken from the DOE[D3] and are based on factors in Publication 30 of the International Commission on Radiological Protection (ICRP).[D4]

Dose conversion factors for inhalation assume a 1-µm-activity median aerodynamic diameter, as well as the lung solubility category that will maximize the effective dose equivalent (for comparison with DOE's 100-mrem/yr Radiation Protection Standard [RPS]) if more than one category is given. Similarly, the ingestion dose conversion factors are chosen to maximize the effective dose if more than one gastrointestinal tract uptake is given (for comparison with DOE's 100-mrem/yr RPS for all pathways).

These dose conversion factors calculate the 50-year dose commitment for internal exposure. The 50-year dose commitment is the total dose received by an organ during the 50-year period following the intake of a radionuclide that is attributable to that intake.

External doses are calculated using the dose-rate conversion factors, also published by DOE.[D5] These factors, which are given in Table D-2 (Ref. D6), give the photon dose rate in millirem per year per unit radionuclide air concentration in microcuries per milliliter. The factors are used in the calculation of the population effective dose equivalent from external radiation for the 80-km (50-mi) area.

B. Inhalation Dose

Annual average air concentrations of ^{3}H, total uranium, ^{238}Pu, ^{239,240}Pu, and ^{241}Am, determined by the Laboratory's air monitoring network, are corrected for background by subtracting the average concentrations measured at regional stations. These net concentrations are then multiplied by a standard breathing rate of 8400 m^{3}/yr (Ref. D7) to determine total annual intake via inhalation, in microcuries per year, for each radionuclide. Each intake is multiplied by appropriate dose conversion factors to convert radionuclide intake into 50-year dose commitments. Following ICRP methods, doses are calculated for all organs that contribute more than 10% of the

Table D-1. Dose Conversion Factors for Calculating Internal Doses (rem/μCi intake)

Inhalation

	Target Organ						
Radionuclide	**Soft Tissue**	**Lung**	**Bone Surface**	**Red Marrow**	**Liver**	**Gonads**	**Effective Dose**
^{3}H	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}
^{234}U		1.1×10^{3}					1.3×10^{2}
^{235}U		1.0×10^{3}					1.2×10^{2}
^{238}U		1.0×10^{3}					1.2×10^{2}
^{238}Pu			8.1×10^{3}	6.7×10^{2}	1.8×10^{3}	1.0×10^{2}	4.6×10^{2}
^{239,240}Pu			9.3×10^{3}	7.4×10^{2}	2.0×10^{3}	1.2×10^{2}	5.1×10^{2}
^{241}Am			9.3×10^{3}	7.4×10^{2}	2.0×10^{3}	1.2×10^{2}	5.2×10^{2}

Ingestion

Radionuclide	Bone Surface	Red Marrow	Liver	Gonads	Kidney	Lungs	Breast	Thyroid
^{3}H	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}
^{7}Be		4.4×10^{-5}		2.1×10^{-4}				
^{90}Sr	1.6	7.0×10^{-1}						
^{137}Cs	4.8×10^{-2}	4.8×10^{-2}		5.2×10^{-2}		4.8×10^{-2}	4.4×10^{-2}	4.8×10^{-2}
^{234}U	4.1	2.7×10^{-1}			1.7			
^{235}U	3.7	2.5×10^{-1}			1.6			
^{238}U	3.7	2.5×10^{-1}			1.5			
^{238}Pu	67	5.6	15	8.5×10^{-1}				
^{239,240}Pu	78	5.9	16	9.6×10^{-1}				
^{241}Am	81	6.3	17	1.0				

Table D-1 (Cont)

	Target Organ					
Radionuclide	Soft Tissue	Lower Large Intestine Wall	Small Intestine Wall	Upper Large Intestine Wall	Remainder	Effective Dose
^{3}H	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}	6.3×10^{-5}
^{7}Be		4.4×10^{-4}	2.0×10^{-4}	2.7×10^{-4}		1.1×10^{-4}
^{90}Sr						1.3×10^{-1}
^{137}Cs		5.2×10^{-2}	5.2×10^{-2}	5.2×10^{-2}	5.6×10^{-2}	5.0×10^{-2}
^{234}U						2.6×10^{-1}
^{235}U		2.0×10^{-1}				2.5×10^{-1}
^{238}U						2.3×10^{-1}
^{238}Pu						3.8
^{239,240}Pu						4.3
^{241}Am						4.5

Table D-2. Dose Conversion Factors for Calculating External Doses ([mrem/yr]/[μCi/m^{3}])

Radionuclide[a]	Breast	Lung	Red Marrow	Bone Surface	Testes	Thyroid	Ovaries	Effective Dose
^{10}C								
^{11}C	5 540	4 450	4 560	5 210	5 980	4 520	3 980	5 110
^{13}N	5 540	4 450	4 560	5 210	5 980	4 520	3 980	5 110
^{16}N	31 500	25 300	27 400	26 900	33 800	30 600	22 200	29 300
^{14}O								
^{15}O	5 550	4 460	4 560	5 210	5 980	5 540	3 990	5 120
^{41}Ar	6 950	5 890	5 940	6 290	7 740	7 340	5 290	6 630

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[a] Dose conversion factors for ^{11}C, ^{13}N, ^{16}N, ^{15}O, and ^{41}Ar were taken from Ref. D5. Dose conversion factors for ^{10}C and ^{14}O were not given in Ref. D5 and were calculated with the computer program DOSFACTER II (Ref. D6).

total effective dose equivalent for each radionuclide (see Appendix A for definition of effective dose equivalent).

The dose calculated for inhalation of ^3H is increased by 50% to account for absorption through the skin.

This procedure for dose calculation conservatively assumes that a hypothetical individual is exposed to the measured air concentration continuously throughout the entire year (8760 hours). This assumption is made for the boundary dose, dose to the maximum exposed individual, and dose to the population living within 80 km (50 mi) of the site.

Organ doses and effective dose equivalent are determined at all sampling sites for each radionuclide. A final calculation estimates the total inhalation organ doses and effective dose equivalent by summing over all radionuclides.

C. Ingestion Dose

Results from foodstuffs sampling (Sec. VII) are used to calculate organ doses and effective dose equivalents from ingestion for individual members of the public. The procedure is similar to that used in the previous section. Corrections for background are made by subtracting the average concentrations from sampling stations not affected by Laboratory operations. The radionuclide concentration in a particular foodstuff is multiplied by the annual consumption rate[D2] to obtain total annual intake of that radionuclide. Multiplication of the annual intake by the radionuclide's ingestion dose conversion factor for a particular organ gives the estimated dose to the organ. Similarly, effective dose equivalent is calculated using the effective dose equivalent conversion factor (Table D-1).

Doses are evaluated for ingestion of ^3H, ^{90}Sr, ^{137}Cs, total uranium, ^{238}Pu, and $^{239,240}Pu$ in fruits and vegetables; ^3H, ^7Be, ^{22}Na, ^{54}Mn, ^{57}Co, ^{83}Rb, ^{134}Cs, ^{137}Cs, and total uranium in honey; and ^{90}Sr, ^{137}Cs, total uranium, ^{238}Pu, and $^{239,240}Pu$ in fish.

D. External Radiation

Environmental thermoluminescent dosimeter (TLD) measurements are used to estimate external radiation doses.

Nuclear reactions with air in the target areas at the Los Alamos Meson Physics Facility (LAMPF, TA-53) cause the formation of air activation products, principally ^{11}C, ^{13}N, ^{14}O, and ^{15}O. These isotopes are all positron emitters and have 20.4-minute, 10-minute, 71-second, and 122-second half-lives, respectively. Neutron reactions with air at the Omega West Reactor (TA-2) and LAMPF also form ^{41}Ar, which has a 1.8-hour half-life.

The radioisotopes ^{11}C, ^{13}N, ^{14}O, and ^{15}O are sources of photon radiation because of the formation of two 0.511-MeV (million-electron-volt) photons through positron-electron annihilation. The ^{14}O emits a 2.3-MeV gamma with 99% yield. The ^{41}Ar emits a 1.29-MeV gamma with 99% yield.

The TLD measurements are corrected for background to determine the contribution to the external radiation field from Laboratory operations. Background estimates at each site, which are based on historical data, consideration of possible nonbackground contributions, and, if possible, values measured at locations of similar geology and topography, are then subtracted from each measured value. This net dose is assumed to represent the dose from Laboratory activities that an individual would receive if he or she were to spend 100% of his time during an entire year at the monitoring location.

The individual dose is estimated from these measurements by taking into account occupancy and shielding. At off-site locations where residences are present, an occupancy factor of 1.0 was used.

Two types of shielding are considered: (1) shielding by buildings, and (2) self-shielding. Each shielding type is estimated to reduce the external radiation dose by 30%.[D8,D9]

Neutron doses from the critical assemblies at TA-18 were based on 1989 measurements. Neutron fields were monitored, principally with TLDs placed in cadmium-hooded, 23-cm (9-in.) polyethylene spheres.

At on-site locations at which above-background doses were measured, but at which public access is limited, doses based on a more-realistic estimate of exposure time are also presented. Assumptions used in these estimates are given in the text.

E. Population Dose

Calculation of collective effective dose equivalent estimates (in person-rem) are based on measured data to the extent possible. For background radiation, average measured background doses for Los Alamos, White Rock, and regional stations are multiplied by the appropriate population number. Tritium average doses are calculated from average measured concentrations in Los Alamos and White Rock above background (as measured by the regional stations).

These doses are multiplied by population data incorporating results of the 1980 census (Sec. II.E). The population data have been modified (increased from 155 077 in 1980 to 207 684 persons in 1989 within 80 km [50 mi] of the boundary) to account for population changes between 1980 and 1989. These changes are extrapolated from an estimate of the 1988 New Mexico population, by county, that was made by the U.S. Bureau of the Census.[D10]

Radionuclides emitted by LAMPF and, to a lesser extent, by the Omega West Reactor, contribute more than 95% of the population dose.

For ^{41}Ar, ^{11}C, ^{13}N, ^{14}O, and ^{15}O, atmospheric dispersion models are used to calculate an average dose to individuals living in the area in question. The air concentration of the isotope ($\chi[r,\theta]$) at location (r,θ), because of its emission from a particular source, is found using the annual average meteorological dispersion coefficient ($\chi[r,\theta]/Q$) (based on Gaussian plume dispersion models[D11]) and the source term Q. Source terms, obtained by stack measurements, are given in Table G-2.

The dispersion factors were calculated from 1989 meteorological data collected near LAMPF during the actual time periods when radionuclides were being released from the stacks. Dispersion coefficients used to calculate the χ/Q's were determined from measurements of the standard deviations of wind direction.[D12] The χ/Q includes the reduction of the source term because of radioactive decay.

The gamma dose rate in a semi-infinite cloud at time t, $\gamma_\infty(r,\theta,t)$, can be represented by the equation

$$\gamma_\infty(r,\theta,t) = (DCF)\,\chi(r,\theta,t) ,$$

where

$\gamma_\infty(r,\theta,t)$ = gamma dose rate (in mrem/yr) at time t, distance r, and angle θ;

DCF = dose rate conversion factor from the DOE[D5] ([mrem/yr]/[µCi/mL]); and

$\chi(r,\theta,t)$ = plume concentration (in µCi/mL).

The annual dose is multiplied by the appropriate population figure to give the estimated population dose.

F. Estimate of Maximum Individual Dose using AIRDOS-EPA/RADRISK

The EPA requires that compliance with regulation 40CFR 61, Subpart H, be demonstrated with the computer codes AIRDOS-EPA and RADRISK. These codes use measured radionuclide release rates and meteorological information to calculate transport and airborne concentrations of radionuclides released to the atmosphere. The programs estimate radiation exposures from inhalation of radioactive materials, external exposure to the radionuclides present in the atmosphere and deposited on the ground, and ingestion of radionuclides in produce, meat, and dairy products.

Calculations for Laboratory airborne releases use the radionuclide emissions given in Tables G-2 and G-6. Wind speed, wind direction, and stability class are continually measured at meteorology towers located at TA-54, TA-49, TA-59, East Gate, and TA-55. Emissions were modeled with the wind information most representative of the release point.

Chemical form was taken into account for tritium releases. The two chemical forms at the Laboratory are tritium oxide (HTO or T_2O) and gaseous tritium (HT or T_2). Tritium oxide is readily absorbed by the body and distributed in soft tissue, resulting in a whole-body exposure. In contrast, gaseous tritium exposure is mainly limited to lung tissue. Dose conversion factors for exposure to tritium oxide are five orders of magnitude higher than the factors for exposure to gaseous tritium. Gaseous tritium is a major fraction of the tritium releases at the Laboratory. The 1989 releases at TA-41 are more than 95% gaseous tritium; releases at TA-33, 40% gaseous tritium. Other tritium releases are assumed to be tritium oxide.

Doses were calculated assuming that individuals were at the exposure location for 365 days, 24 hours/day. Following the EPA procedure, these individuals were assumed to obtain all their foodstuffs at this same exposure location. To account for shielding by buildings, doses from external penetrating radiation were reduced by 30%, as recommended by the National Council on Radiation Protection and Measurements (NCRP)[D9] for photon radiation with energies equivalent to those found in terrestrial penetrating radiation.

G. Estimation of Risk from Ionizing Radiation

To compare the risk from the radiation dose from Laboratory operations with risks that are routinely experienced in everyday life, the risks of cancer mortality from exposure to ionizing radiation are estimated for exposures to natural background radiation, to medical procedures, and to Laboratory operations in 1989. These risk estimates are based on two reports recently published by the National Research Council's Committee on the Biological Effects of Ionizing Radiation, or BEIR Committee.

These calculations are for comparison purposes only. The low doses and dose rates from natural background radiation and from Laboratory operations are considerably below the range of data on which the BEIR Committee based its observations. The Committee itself did not calculate risks below a 10-rem exposure, stating that these risks are difficult to quantify and "that the lower limit of the range of uncertainty in the risk estimates extends to zero."[D13]

1. Risks from Whole-Body Radiation. Radiation exposures considered in this report are of two types: (1) whole-body exposures, and (2) individual organ exposures. The primary doses from nonradon natural background radiation and from Laboratory operations are whole-body exposures. With the exception of natural background radon exposures, discussed below, radiation doses and associated risks from those radionuclides that affect only selected body organs are less than a few percentage points of the dose and are negligible. Risks from whole-body radiation were estimated using the risk factors of the BEIR V report.[D13]

Risk factors are taken from the BEIR Committee's estimate (BEIR V report) of the risk from a single, instantaneous, high-dose rate exposure of 10 rem. The BEIR V report stated that this estimate should be reduced for an exposure distributed over time that would occur at a substantially lower dose rate. The committee discussed dose rate effectiveness factors (DREFs) ranging from 2 to 10 that should be applied to the nonleukemia part of the risk estimate.

For the risk estimates presented in this report, a DREF of 2 is used for the nonleukemia risk. Following the BEIR V report, no dose rate reduction was made for the leukemia risk. The risk is then averaged over male and female populations. The total risk estimator is 440 cancer fatalities per 10^9 person-mrem.

2. Risks from Exposure to Radon. Radon and radon decay product exposures are an important part of natural background radiation. These exposures differ from the whole-body radiation discussed above in that they principally involve only the localized exposure of the lung and not other organs in any significant way. Consequently, the risks from radon exposure were calculated separately.

Radon (principally ^{222}Rn) and radon decay product exposure rates are usually measured with a special unit, the working level (WL); 1 WL corresponds to a liter of air containing short-lived radon decay products whose total potential alpha energy is 1.3×10^5 MeV. An atmosphere having 100-pCi/L concentration of ^{222}Rn at equilibrium with its decay products corresponds to 1 WL. Cumulative exposure is measured in working-level months (WLMs). A WLM is equal to exposure to 1 WL for 170 hours.

The estimated national average radon effective dose that was given by the NCRP and used in the text is 200 mrem/yr. The NCRP derived this dose from an estimated national average radon exposure of 0.2 WLM/yr. Because the risk factors are derived in terms of WLM, for the purposes of risk calculation it is more convenient to use the radon exposure of 0.2 WLM/yr than to use the radon dose of 200 mrem/yr. Both the 0.2-WLM/yr and the 200-mrem/yr effective dose, however, correspond to the same radiation exposure.

Risks from radon were estimated using a risk factor of 350×10^{-6}/WLM. This risk factor was taken from the BEIR IV report.[D14]

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APPENDIX E

UNITS OF MEASUREMENT

Throughout this report, the International System of Units (SI) or metric system of measurements has been used, with some exceptions. For units of radiation activity, exposure, and dose, U.S. Customary Units (that is, curie [Ci], roentgen [R], rad, and rem) are retained because current standards are written in terms of these units. The equivalent SI units are the becquerel (Bq), coulomb per kilogram (C/kg), gray (Gy), and sievert (Sv), respectively. Table E-1 presents prefixes used in this report to define fractions or multiples of the base units of measurement. Table E-2 presents conversion factors for converting from SI units to U.S. Customary Units.

Table E-1. Prefixes Used with SI (Metric) Units

Prefix	Factor	Symbol
mega	1 000 000 or 10^{6}	M
kilo	1 000 or 10^{3}	k
centi	0.01 or 10^{-2}	c
milli	0.001 or 10^{-3}	m
micro	0.000001 or 10^{-6}	µ
nano	0.000000001 or 10^{-9}	n
pico	0.000000000001 or 10^{-12}	p
femto	0.000000000000001 or 10^{-15}	f
atto	0.000000000000000001 or 10^{-18}	a

Table E-2. Approximate Conversion Factors for Selected SI (Metric) Units

Multiply SI (Metric) Unit	By	To Obtain U.S. Customary Unit
Celsius (°C)	9/5, then add 32	Fahrenheit (°F)
centimeters (cm)	0.39	inches (in.)
cubic meters (m^3)	35	cubic feet (ft^3)
hectares (ha)	2.5	acres
grams (g)	0.035	ounces (oz)
kilograms (kg)	2.2	pounds (lb)
kilometers (km)	0.62	miles (mi)
liters (L)	0.26	gallons (gal.)
meters (m)	3.3	feet (ft)
micrograms per gram (µg/g)	1	parts per million (ppm)
milligrams per liter (mg/L)	1	parts per million (ppm)
square kilometers (km^2)	0.39	square miles (mi^2)

APPENDIX F

DESCRIPTIONS OF TECHNICAL AREAS AND THEIR ASSOCIATED PROGRAMS

Locations of the 51 technical areas (TAs) operated by the Laboratory in Los Alamos County are shown in Sec. II, Fig. 4. The main programs conducted at each of the 34 developed areas are listed in this appendix.

TA-2, Omega Site: Omega West Reactor, an 8-MW nuclear research reactor, is located here. It serves as a research tool by providing a source of neutrons for fundamental studies in nuclear physics and associated fields.

TA-3, South Mesa Site: In this main technical area of the Laboratory is the Administration Building that contains the Director's office and administrative offices and laboratories for several divisions. Other buildings house the central computing facility, administration offices, materials division, science museum, chemistry and materials science laboratories, physics laboratories, technical shops, cryogenics laboratories, a Van de Graaff accelerator, and the main cafeteria.

TA-6, Two-Mile Mesa Site: This is one of three sites (TA-22 and TA-40 are the other two) used in the development of special detonators to initiate high-explosive systems. Fundamental and applied research in support of this activity includes investigating phenomena associated with initiating high explosives and research in rapid shock-induced reactions.

TA-8, GT Site (or Anchor Site West): This is a nondestructive testing site operated as a service facility for the entire Laboratory. It maintains capability in all modern nondestructive testing techniques for ensuring quality of material, ranging from test weapons components to high-pressure dies and molds. Principal tools include radiographic techniques (x-ray machines to 1 000 000 V and a 24-MeV betatron), radioactive-isotope techniques, ultrasonic and penetrant testing, and electromagnetic test methods.

TA-9, Anchor Site East: At this site, fabrication feasibility and physical properties of explosives are explored. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied.

TA-11, K-Site: Facilities are located here for testing explosive components and systems under a variety of extreme physical environments. The facilities are arranged so that testing may be controlled and observed remotely and so that devices containing explosives or radioactive materials, as well as those containing nonhazardous materials, may be tested.

TA-14, Q-Site: This firing site is used for running various tests on relatively small explosive charges and for fragment impact tests.

TA-15, R-Site: This is the home of PHERMEX, a multiple-cavity electron accelerator capable of producing a very large flux of x rays for certain weapons development problems and tests. This site is also used for the investigation of weapons functioning and systems behavior in nonnuclear tests, principally by electronic recording means.

TA-16, S-Site: Investigations at this site include development, engineering design, pilot manufacture, environmental testing, and stockpile production liaison for nuclear weapons warhead systems. Development and testing of high explosives, plastics, and adhesives, and research on process development for manufacture of items using these and other materials are accomplished in extensive facilities.

TA-18, Pajarito Laboratory Site: The fundamental behavior of nuclear chain reactions with simple, low-power reactors called critical assemblies is studied here.

Experiments are operated by remote control and observed by closed-circuit television. The machines are housed in buildings known as kivas and are used primarily to provide a controlled means of assembling a critical amount of fissionable materials. This is done to study the effects of various shapes, sizes, and configurations. These machines are also used as a source of fission neutrons in large quantities for experimental purposes.

TA-21, DP-Site: This site has two primary research areas: DP-West and DP-East. DP-West is concerned with chemistry research; DP-East is the high-temperature chemistry and tritium site.

TA-22, TD Site: See TA-6.

TA-28, Magazine Area "A": This area is one of two storage areas for explosives.

TA-33, HP-Site: A major high-pressure tritium handling facility is located here. Laboratory and office space for Geosciences Division related to the Hot Dry Rock Geothermal Project are also located at this site.

TA-35, Ten Site: Nuclear safeguards research and development, which are conducted here, are concerned with techniques for nondestructive detection, identification, and analysis of fissionable isotopes. Research in reactor safety and laser fusion is also done here.

TA-36, Kappa Site: Various explosive phenomena, such as detonation velocity, are investigated here.

TA-37, Magazine Area "C": See TA-28.

TA-39, Ancho Canyon Site: Nonnuclear weapons behavior is studied here, primarily by photographic techniques. Investigations are also made into various phenomenological aspects of explosives, interactions of explosives, and explosions involving other materials.

TA-40, DF-Site: See TA-6.

TA-41, W-Site: Personnel at this site are engaged primarily in engineering design and development of nuclear components, including fabrications and evaluation of test materials for weapons.

TA-43, Health Research Laboratory: The Biomedical Research Group does research here in cellular radiobiology, biophysics, mammalian radiobiology, and mammalian metabolism. A large medical library, special counters used to measure radioactivity in humans and animals, and animal quarters for dogs, mice, and monkeys are also located in this building.

TA-46, WA-Site: Applied photochemistry, which includes development of technology for laser isotope separation and laser enhancement of chemical processes, is investigated here. Solar energy research, particularly in the area of passive solar heating for residences, is also done at this site.

TA-48, Radiochemistry Site: Laboratory scientists and technicians at this site study nuclear properties of radioactive materials by using analytical and physical chemistry. Measurements of radioactive substances are made, and "hot cells" are used for remote handling of radioactive materials.

TA-50, Waste Management Site: Personnel at this site have responsibility for treating and disposing of most industrial liquid waste received from Laboratory technical areas, for development of improved methods of solid-waste treatment, and for containment of radioactivity removed by treatment. Radioactive liquid waste from most technical areas is piped to this site for treatment.

TA-51, Animal Exposure Facility: Here, animals are exposed to nonradioactive toxic materials to determine biological effects of high and low exposures.

TA-52, Reactor Development Site: A wide variety of activities related to nuclear reactor performance and safety is done at this site.

TA-53, Meson Physics Facility: The Los Alamos Meson Physics Facility (LAMPF), a linear particle accelerator, is used to conduct research in areas of basic physics, cancer treatment, materials studies, and isotope production. The Los Alamos Neutron Scattering Center (LANSCE) and the Proton Storage Ring (PSR) are also located on this site.

TA-54, Waste Disposal Site: This is a disposal area for solid radioactive and toxic wastes.

TA-55, Plutonium Processing Facilities: Processing of plutonium and research in plutonium metallurgy are done here.

TA-57, Fenton Hill Site: This is the location of the Laboratory's Hot Dry Rock geothermal project. Scientists at this site are studying the possibility of producing energy by circulating water through hot, dry rock located hundreds of meters below the earth's surface. The water is heated and then brought to the surface to drive electric generators.

TA-59, Occupational Health Site: Occupational health and environmental science activities are conducted at this site.

TA-60, East Jemez Road: This area contains physical support and infrastructure facilities, including the existing sanitary landfill.

TA-63: This area contains physical support facilities operated by Pan Am World Services, Inc.

TA-74, Los Alamos Airport: This area contains the DOE-owned airport that serves the county and Laboratory.

APPENDIX G

ENVIRONMENTAL DATA TABLES

Table G-1. Estimated Maximum Individual 50-Year Dose Commitments from 1989 Airborne Radioactivity[a]

Isotope	Critical Organ	Location[b]	Estimated Dose (mrem/yr)	Percentage of Radiation Protection Standard
^{3}H	Whole body	Royal Crest (station 11)	0.05	<0.1
^{11}C, ^{13}N, ^{14}O, ^{15}O, ^{41}Ar	Whole body	East Gate (station 6)	3.9	16
U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am	Bone surface	48th Street (station 7)	0.52	0.7

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[a] Estimated maximum individual dose is the dose from Laboratory operations (excluding dose contributions from cosmic, terrestial, medical diagnostics, and other non-Laboratory sources) to an individual at or outside the Laboratory boundary where the highest dose rate occurs and where a person actually resides. It takes into account shielding and occupancy factors.

[b] See Fig. 8 for station locations.

Table G-2. Airborne Radioactive Emissions from Laboratory Operations in 1989[a]

							Activation Products	
Location	^{238,239,240}Pu [b] (μCi)	^{235,238}U [c] (μCi)	Mixed Fission Products (μCi)	^{41}Ar [d] (Ci)	^{32}P (μCi)	^{3}H (Ci)	Gaseous[e] (Ci)	Particle/Vapor[f] (Ci)
TA-2				222				
TA-3	39.1	365	38.2			291		
TA-21	1.4	28.9	<0.1			452		
TA-33						1 770		
TA-35	0.7					18		
TA-41						11 600		
TA-43					17.6			
TA-46								
TA-48	1.5	0.3	435 000					
TA-50	0.5		9.8					
TA-53						8.2	156 000	0.1
TA-54	<0.1							
TA-55	2.2					266		
Rounded total	45.5	394	435 000	222	17.6	14 400	156 000	0.1

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[a] As reported on DOE form F-5821.1.

[b] Plutonium values contain indeterminate traces of ^{241}Am, a transformation product of ^{241}Pu.

[c] Does not include aerosolized uranium from explosives testing (Table G-6).

[d] Does not include 625 Ci of ^{41}Ar present in gaseous, mixed activation products.

[e] Includes the following constituents: ^{16}N, 1.3%; ^{10}C, 1.6%; ^{14}O, 0.8%; ^{15}O, 57.9%; ^{13}N, 13.3%; ^{11}C, 24.7%; ^{41}Ar, 0.4%.

[f] Includes 19 nuclides, dominated by ^{183}Os and ^{7}Be.

Table G-3. Thermoluminescent Dosimeter (TLD) Measurements

Station Location[b]	Annual Measurement[a] Coordinates	1989 Dose (mrem)
Uncontrolled Areas		
Regional Stations (28–44 km)		
1. Española	—	72 (5)[a]
2. Pojoaque	—	81 (5)
3. Santa Fe	—	87 (6)
4. Fenton Hill	—	108 (5)
Perimeter Stations (0–4 km)		
5. Barranca School	N180 E130	91 (5)
6. Arkansas Avenue	N170 E030	88 (6)
7. Cumbres School	N150 E090	108 (5)
8. 48th Street	N110 W010	98 (5)
9. Los Alamos Airport	N110 E170	85 (5)
10. Bayo Canyon	N120 E250	120 (5)
11. Exxon Station	N090 E120	126 (5)
12. Royal Crest Trailer Court	N080 E080	95 (5)
13. White Rock	S080 E420	109 (5)
14. Pajarito Acres	S210 E380	88 (5)
15. Bandelier Lookout Station	S280 E200	96 (5)
16. Pajarito Ski Area	N150 W200	107 (5)
Controlled Areas		
On-Site Stations		
17. TA-21 (DP West)	N095 E140	114 (4)
18. TA-6 (Two-Mile Mesa)	N025 E030	96 (5)
19. TA-53 (LAMPF)	N070 E090	94 (5)
20. Well PM-1	N030 E305	111 (5)
21. TA-16 (S-Site)	S035 W025	99 (5)
22. Booster P-2	S030 E220	97 (5)
23. TA-54 (Area G)	S080 E290	96 (5)
24. State Highway 4	N070 E350	133 (5)
25. Frijoles Mesa	S165 E085	94 (5)
26. TA-2 (Omega Stack)	N075 E120	117 (5)
27. TA-2 (Omega Canyon)	N085 E1210	146 (6)
28. TA-18 (Pajarito Site)	S040 E205	149 (5)
29. TA-35 (Ten Site A)	N040 E105	119 (5)
30. TA-35 (Ten Site B)	N040 E110	111 (5)
31. TA-59 (Occupational Health Lab)	N050 E040	114 (4)
32. TA-3 (Van de Graaff)	N050 E020	118 (6)
33. TA-3 (Guard Station)	N050 E020	112 (5)
34. TA-3 (Alarm Building)	N050 E020	126 (5)
35. TA-3 (Guard Building)	N050 E020	108 (5)
36. TA-3 (Shop)	N050 E020	111 (5)
37. Pistol Range	N040 E240	107 (5)
38. TA-55 (Plutonium Facility South)	N040 E240	93 (5)
39. TA-55 (Plutonium Facility West)	N040 E080	123 (5)
40. TA-55 (Plutonium Facility North)	N040 E080	110 (5)

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[a] Measurement (95% confidence increments).

[b] See Fig. 6.

Table G-4. Locations of Air Sampling Stations[a]

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate
Regional (28–44 km)		
1. Española	36°00′	106°06′
2. Pojoaque	35°52′	106°02′
3. Santa Fe	35°40′	106°56′
Perimeter (0–4 km)		
4. Barranca School	N180	E130
5. Arkansas Avenue	N170	E030
6. East Gate	N090	E210
7. 48th Street	N110	W010
8. Los Alamos Airport	N110	E170
10. Exxon Station	N090	E120
11. Royal Crest Trailer Park	N080	E080
12. White Rock	S080	E420
13. Pajarito Acres	S210	E380
14. Bandelier	S280	E200
On Site		
15. TA-21	N095	E140
16. TA-6	N025	E030
17. TA-53 (LAMPF)	N070	E090
18. Well PM-1	N030	E305
19. TA-52	N020	E155
20. TA-16	S035	W025
21. Booster P-2	S030	E180
22. TA-54	S080	E290
23. TA-49	S165	E085
24. TA-33	S245	E225
25. TA-2	N082	E110
26. TA-16-450	S055	W070
27–31. TA-54	S080	E290

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[a] See Fig. 8 for station locations.

Table G-5. Average Background Concentrations of Radioactivity in the Atmosphere

Radioactive Constituent	Units	EPA[a] 1987–1989	Laboratory[b] 1989	DOE Guide for Uncontrolled Area[c]
Gross beta	10^{-15} µCi/mL	10 ± 0	—	9 000
^{3}H	10^{-12} µCi/mL	—	0.7 ± 2.4	200 000
Uranium (natural)	pg/m^{3}	33 ± 9	241 ±115	100 000
^{238}Pu	10^{-18} µCi/mL	1.2 ± 0.0	3.2 ± 8.1[d]	30 000
$^{239,240}Pu$	10^{-18} µCi/mL	0.7 ± 0.1	2.1 ± 6.6[e]	30 000
^{241}Am	10^{-18} µCi/mL	—	1.7 ± 0.7[d]	30 000

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[a] EPA (1987–1989), Reports 49 through 58. Data are from the Santa Fe, New Mexico, sampling location and were taken from January 1987 through May 1989.

[b] Data are annual averages from the regional stations (Española, Pojoaque, Santa Fe) and were taken during calendar year 1989.

[c] See Appendix A. These values are presented for comparison.

[d] Minimum detectable limit is 2×10^{-18} µCi/mL.

[e] Minimum detectable limit is 3×10^{-18} µCi/mL.

Table G-6. Estimated Concentrations of Toxic Elements Aerosolized by Dynamic Experiments

Element	1989 Total Usage (kg)	Fraction Aerosolized (%)	Annual Average Concentration ($\mu g/m^3$) (4 km)[a]	(8 km)[a]	Applicable Standard ($\mu g/m^3$)
Uranium	237	10	2.3×10^{-5}	9.3×10^{-6}	9[b]
Beryllium	0	2	0	0	0.01[c]
Lead	22	100[d]	2.3×10^{-5}	9.3×10^{-9}	1.5[e]
Heavy metals	309	100[d]	3.3×10^{-4}	1.3×10^{-4}	10[e]

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[a] Distance downwind.

[b] DOE (1981).

[c] Standard for 30-day average, New Mexico Air Quality Control Regulation 201.

[d] No data are available; estimate was done assuming worst-case percentage was aerosolized.

[e] Standard for 3-month average (40 CFR 50.12).

Table G-7. Airborne Tritiated Water Concentrations for 1989

				Concentrations (pCi/m^3 [10^{-12} µCi/mL])			
Station Location[a]	**Total Air Volume (m^3)**	**No. of Monthly Samples**	**No. of Samples <MDL**[b]	**Maximum**[c]	**Minimum**[c]	**Mean**[c]	**Mean as a Percentage of Guide**[d]
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	90.8	12	11	8.0 (2.1)	−2.5 (1.9)	0.8 (2.5)	<0.1
2. Pojoaque	121.6	12	12	1.2 (1.2)	−1.6 (1.6)	0.3 (0.8)	<0.1
3. Santa Fe	114.7	12	11	11.1 (2.1)	−1.2 (1.2)	0.9 (3.3)	<0.1
Group Summary		36	34	11.1 (2.1)	−2.5 (1.9)	0.7 (2.4)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	115.1	12	7	19.4 (2.4)	0.4 (0.4)	4.0 (5.7)	<0.1
5. Arkansas Avenue	103.3	12	10	6.9 (1.2)	0.3 (0.1)	1.5 (1.8)	<0.1
6. Philomena's	106.5	12	1	9.1 (1.4)	0.4 (0.5)	4.2 (2.5)	<0.1
7. 48th Street	135.1	12	9	5.2 (1.0)	0.0 (0.5)	1.7 (1.6)	<0.1
8. Los Alamos Airport	109.4	12	4	33.6 (3.8)	0.4 (0.4)	6.9 (9.0)	<0.1
10. Exxon Station	82.9	12	3	25.1 (1.6)	0.1 (0.1)	6.3 (7.4)	<0.1
11. Royal Crest Trailer Park	91.3	12	2	47.8 (5.3)	0.3 (0.7)	7.3 (12.8)	<0.1
12. White Rock	132.2	12	8	5.2 (1.0)	0.6 (0.2)	2.0 (1.6)	<0.1
13. Pajarito Acres	93.9	12	8	25.5 (3.0)	0.6 (0.4)	4.5 (7.3)	<0.1
14. Bandelier	86.8	12	2	23.3 (2.5)	1.1 (0.6)	7.2 (6.6)	<0.1
Group Summary		120	54	47.8 (5.3)	0.0 (0.5)	4.6 (6.8)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	113.2	12	1	54.9 (5.7)	1.5 (0.7)	16.6 (16.5)	<0.1
16. TA-6	135.0	12	10	18.4 (2.5)	−0.1 (0.1)	2.3 (5.1)	<0.1
17. TA-53 (LAMPF)	116.7	12	3	12.9 (1.7)	1.4 (0.5)	3.4 (3.4)	<0.1
18. Well PM-1	127.3	12	7	35.0 (4.4)	0.4 (0.1)	4.6 (9.6)	<0.1
19. TA-52	94.0	12	5	7.7 (1.0)	0.8 (0.4)	3.5 (2.4)	<0.1
20. TA-16	113.2	12	10	15.4 (2.7)	−0.2 (0.5)	2.1 (4.4)	<0.1
21. Booster P-2	125.0	12	9	16.2 (2.1)	0.3 (0.1)	2.9 (4.3)	<0.1
22. TA-54	122.7	12	0	116.6 (13.0)	3.9 (0.6)	28.8 (32.8)	<0.1
23. TA-49	92.3	12	8	11.8 (1.3)	0.0 (0.3)	2.6 (3.4)	<0.1
24. TA-33	99.2	12	3	78.2 (8.0)	−0.9 (0.7)	18.3 (21.5)	<0.1
25. TA-2 (Omega)	99.1	12	1	116.2 (12.2)	1.1 (0.8)	22.8 (30.9)	<0.1
26. TA-16-450	124.7	12	8	23.3 (2.4)	0.2 (0.5)	3.2 (6.4)	<0.1
Group Summary		144	65	116.6 (13.0)	−0.9 (0.7)	9.3 (17.7)	<0.1

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[a] See Fig. 8 for map of local stations.

[b] Minimum detectable limit = 2 × 10^{-12} µCi/mL.

[c] Uncertainties are in parentheses (see Appendix B).

[d] Controlled area DOE Derived Air Concentration = 2 × 10^{-5} µCi/mL; uncontrolled area Derived Concentration Guide = 1 × 10^{-7} µCi/mL.

Table G-8. Airborne ^{239,240}Pu Concentrations for 1989

				Concentrations (aCi/m^3 [10^{-18} µCi/mL])			
Station Location[a]	Total Air Volume (m^3)	No. of Quarterly Samples	No. of Samples <MDL[b]	Minimum[c]	Maximum[c]	Mean[c]	Mean as a Percentage of Guide[d]
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	44 759	3	3	0.9 (2.8)	−8.0 (8.0)	−2.5 (4.8)	<0.1
2. Pojoaque	65 098	4	3	20.1 (2.8)	0.5 (0.8)	5.9 (9.5)	<0.1
3. Santa Fe	61 514	4	2	2.9 (1.2)	0.6 (1.0)	1.7 (1.1)	<0.1
Group Summary		11	8	20.1 (2.8)	−8.0 (8.0)	2.1 (6.6)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	71 141	4	2	6.1 (1.2)	0.6 (0.5)	3.1 (2.3)	<0.1
5. Arkansas Avenue	73 771	4	4	1.5 (0.7)	0.2 (0.7)	0.7 (0.6)	<0.1
6. Philomena's	70 151	4	3	2.5 (0.9)	0.7 (0.5)	1.3 (0.9)	<0.1
7. 48th Street	68 559	4	4	1.5 (0.8)	0.0 (0.6)	0.4 (0.7)	<0.1
8. Los Alamos Airport	74 147	4	3	2.0 (0.8)	0.2 (0.7)	1.2 (0.9)	<0.1
10. Exxon Station	67 227	4	3	2.3 (1.4)	0.4 (0.5)	1.6 (0.8)	<0.1
11. Royal Crest Trailer Park	60 324	4	4	1.8 (0.7)	−0.6 (0.6)	0.8 (1.1)	<0.1
12. White Rock	73 687	4	4	1.9 (0.8)	0.5 (0.8)	1.2 (0.7)	<0.1
13. Pajarito Acres	69 362	4	4	0.8 (0.5)	0.6 (0.6)	0.7 (0.1)	<0.1
14. Bandelier	65 079	4	4	0.5 (0.5)	0.0 (0.7)	0.2 (0.3)	<0.1
Group Summary		40	35	6.1 (1.2)	−0.6 (0.6)	1.1 (1.2)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	72 098	4	4	1.6 (1.0)	0.8 (0.6)	1.3 (0.4)	<0.1
16. TA-6	67 252	4	4	13.2 (9.9)	0.8 (0.5)	4.6 (5.8)	<0.1
17. TA-53 (LAMPF)	80 440	4	4	1.6 (0.7)	0.4 (0.6)	1.0 (0.5)	<0.1
18. Well PM-1	65 787	4	3	8.8 (10.8)	1.3 (0.8)	3.6 (3.5)	<0.1
19. TA-52	80 783	4	4	1.2 (0.6)	0.0 (0.5)	0.4 (0.5)	<0.1
20. TA-16	63 901	4	4	2.1 (1.8)	0.3 (0.5)	0.9 (0.8)	<0.1
21. Booster P-2	72 472	4	4	1.9 (0.9)	0.0 (0.6)	1.3 (0.9)	<0.1
22. TA-54	75 845	4	0	32.3 (3.9)	3.4 (0.9)	17.3 (15.6)	<0.1
23. TA-49	76 839	4	4	0.8 (0.8)	−1.3 (0.9)	0.0 (0.9)	<0.1
24. TA-33	75 894	4	4	0.3 (1.0)	−0.4 (0.5)	−0.1 (0.3)	<0.1
25. TA-2 (Omega)	60 178	4	3	2.6 (0.9)	1.2 (0.9)	2.2 (0.6)	<0.1
26. TA-16-450	77 757	4	4	0.8 (0.8)	−0.2 (0.2)	0.3 (0.4)	<0.1
Group Summary		48	42	32.3 (3.9)	−1.3 (0.9)	2.7 (6.3)	<0.1

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[a] See Fig. 8 for map of local stations.

[b] Minimum detectable limit = 3 × 10^{-18} µCi/mL.

[c] Uncertainties are in parentheses (see Appendix B).

[d] Controlled area DOE Derived Air Concentration = 2 × 10^{-12} µCi/mL; uncontrolled area Derived Concentration Guide = 2 × 10^{-14} µCi/mL.

Table G-9. Airborne ^{241}Am Concentrations for 1989

				Concentrations (aCi/m^3 [10^{-18} µCi/mL])			
Station Location[a]	**Total Air Volume (m^3)**	**No. of Quarterly Samples**	**No. of Samples <MDL[b]**	**Maximum[c]**	**Minimum[c]**	**Mean[c]**	**Mean as a Percentage of Guide[d]**
Regional Station (44 km), Uncontrolled Area							
3. Santa Fe	61 514	4	4	2.5 (1.6)	0.7 (0.8)	1.7 (0.7)	<0.1
Group Summary		4	4	2.5 (1.6)	0.7 (0.8)	1.7 (0.7)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
6. Philomena's	70 151	4	2	2.9 (1.1)	1.0 (0.7)	2.0 (1.0)	<0.1
8. Los Alamos Airport	74 148	4	2	2.9 (1.0)	0.7 (0.5)	1.9 (1.0	<0.1
12. White Rock	73 687	4	1	3.3 (1.1)	1.7 (1.3)	2.5 (0.7)	<0.1
Group Summary		12	5	3.3 (1.1)	0.7 (0.5)	2.1 (0.9)	<0.1
On-Site Stations, Controlled Areas							
16. TA-6	67 252	4	3	6.6 (1.4)	1.3 (1.2)	2.8 (2.5)	<0.1
17. TA-53 (LAMPF)	80 440	4	1	7.0 (1.3)	1.0 (0.7)	3.3 (2.6)	<0.1
20. TA-16	63 901	4	2	4.2 (1.5)	1.1 (1.0)	2.4 (1.5)	<0.1
21. Booster P-2	72 472	4	3	2.8 (1.1)	0.5 (0.8)	1.6 (1.0)	<0.1
22. TA-54	75 845	4	0	16.9 (2.1)	4.1 (1.0)	8.9 (5.9)	<0.1
Group Summary		20	9	16.9 (2.1)	0.5 (0.8)	3.8 (3.9)	<0.1

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[a] See Fig. 8 for map of local stations.

[b] Minimum detectable limit = 2×10^{-18} µCi/mL.

[c] Uncertainties are in parentheses (see Appendix B).

[d] Controlled area DOE Derived Air Concentration = 2×10^{-12} µCi/mL; uncontrolled area Derived Concentration Guide = 2×10^{-14} µCi/mL.

Table G-10. Airborne Uranium Concentrations for 1989

Station Location[a]	Total Air Volume (m^3)	No. of Quarterly Samples	No. of Samples <MDL[b]	Concentrations (pg/m^3) Maximum[c]	Minimum[c]	Mean[c]	Mean as a Percentage of Guide[d]
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	44 759	3	0	244.2 (24.4)	82.9 (8.3)	178.5 (84.7)	<0.1
2. Pojoaque	65 098	4	0	476.1 (19.2)	219.9 (10.2)	319.7 (122.8)	<0.1
3. Santa Fe	61 514	4	0	362.1 (36.2)	124.4 (6.5)	209.3 (106.4)	<0.1
Group Summary		11	0	476.1 (19.2)	82.9 (8.3)	241.1 (115.8)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	71 141	4	0	114.4 (5.0)	43.8 (4.4)	90.7 (33.0)	<0.1
5. Arkansas Avenue	73 771	4	0	63.0 (6.3)	30.7 (3.1)	41.5 (14.9)	<0.1
6. Philomena's	70 151	4	0	72.4 (7.2)	50.7 (2.3)	62.5 (8.9)	<0.1
7. 48th Street	68 559	4	0	67.3 (6.7)	34.9 (3.5)	48.4 (15.7)	<0.1
8. Los Alamos Airport	74 148	4	0	92.9 (9.3)	59.0 (5.9)	75.6 (18.5)	<0.1
10. Exxon Station	67 227	4	0	281.7 (12.2)	44.9 (4.5)	160.6 (117.0)	<0.1
11. Royal Crest Trailer Park	58 453	4	0	99.9 (10.0)	63.5 (3.1)	78.9 (15.2)	<0.1
12. White Rock	73 687	4	0	106.6 (10.7)	45.6 (4.6)	71.2 (28.3)	<0.1
13. Pajarito Acres	69 362	4	0	98.6 (4.4)	35.4 (3.6)	68.0 (34.8)	<0.1
14. Bandelier	65 079	4	0	80.0 (8.0)	28.1 (1.5)	44.5 (24.2)	<0.1
Group Summary		40	0	281.7 (12.2)	28.1 (1.5)	74.2 (50.1)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	72 098	4	0	100.0 (10.0)	71.5 (3.2)	82.0 (12.9)	<0.1
16. TA-6	67 252	4	0	87.4 (4.0)	39.0 (3.9)	65.7 (20.0)	<0.1
17. TA-53 (LAMPF)	80 440	4	0	92.4 (9.2)	49.9 (5.0)	71.8 (18.1)	<0.1
18. Well PM-1	65 787	4	0	80.3 (8.0)	43.9 (2.3)	59.2 (15.7)	<0.1
19. TA-52	80 783	4	0	131.6 (5.8)	42.0 (4.2)	77.6 (38.6)	<0.1
20. TA-16	63 901	4	0	117.1 (3.6)	32.6 (3.3)	75.4 (35.0)	<0.1
21. Booster P-2	72 472	4	0	153.2 (15.3)	36.5 (3.7)	86.9 (49.3)	<0.1
22. TA-54	75 845	4	0	186.5 (18.7)	48.9 (4.9)	93.3 (62.8)	<0.1
23. TA-49	76 839	4	0	66.0 (6.6)	27.7 (2.9)	44.6 (16.3)	<0.1
24. TA-33	75 894	4	0	76.6 (7.7)	42.4 (2.3)	52.8 (16.2)	<0.1
25. TA-2 (Omega)	60 178	4	0	108.5 (4.5)	29.4 (1.6)	64.4 (39.2)	<0.1
26. TA-16-450	77 757	4	0	66.4 (6.6)	25.2 (2.5)	42.4 (18.2)	<0.1
Group Summary		48	0	186.5 (18.7)	25.2 (2.5)	68.0 (32.4)	<0.1

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[a] See Fig. 8 for map of local stations.

[b] Minimum detectable limit = 1 pg/m^3.

[c] Uncertainties are in parentheses (see Appendix B).

[d] Controlled area DOE Derived Air Concentration = 2×10^8 pg/m^3; uncontrolled area Derived Concentration Guide = 1×10^5 pg/m^3.

Note: One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses can be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

Table G-11. Airborne Beryllium Concentrations for 1989

Station and Location[a]	Total Air Volume (m^3)	No. of Quarterly Samples	Concentrations (ng/m^3)		
			Maximum[b]	Minimum[b]	Mean[b]
Regional Stations (28–44 km), Uncontrolled Areas					
2. Pojoaque	53 366	3	0.04 (0.01)	0.03 (0.01)	0.03 (0.006)
Perimeter Stations (0–4 km), Uncontrolled Areas					
4. Barranca School	71 141	4	0.01 (0.01)	0.04 (0.01)	0.02 (0.004)
7. Los Alamos, 48th Street	68 559	4	0.01 (0.001)	0.01 (0.01)	0.03 (0.003)
10. Exxon Station	67 227	4	0.08 (0.01)	0.01 (0.01)	0.04 (0.007)
13. Pajarito Acres	69 362	4	0.2 (0.01)	0.01 (0.01)	0.01 (0.004)
Group Summary		16	0.08 (0.01)	0.01 (0.01)	0.02 (0.003)
On-Site Stations, Controlled Areas					
19. TA-52	80 783	4	0.02 (0.01)	0.01 (0.01)	0.01 (0.005)
20. TA-16	49 234	3	0.01 (0.00)	0.01 (0.01)	0.01 (0.003)
22. TA-54	37 676	2	0.07 (0.01)	0.01 (0.001)	0.04 (0.001)
26. TA-16-450	77 756	4	0.01 (0.00)	0.01 (0.01)	0.01 (0.003)
Group Summary		13	0.07 (0.01)	0.01 (0.01)	0.02 (0.003)

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[a] See Fig. 8 for map of local stations.

[b] Uncertainties are in parentheses (see Appendix B).

Table G-12. Emissions and Fuel Consumption during 1989 from the Steam Plants and TA-3 Power Plant

Pollutant	TA-3	TA-16	TA-21	Western Area	Total
Emissions (ton/yr)					
Particulate Matter					
1988	0.8	0.5	0.1	0.00	1.4
1989	0.6	0.4	0.1	0.00	1.1
Oxides of Nitrogen					
1988	7.0	21.2	5.6	0.13	33.9
1989	5.0	20.6	5.3	0.00	30.9
Carbon Monoxide					
1988	11.2	5.3	1.4	0.03	17.9
1989	7.8	5.1	1.3	0.00	14.2
Hydrocarbons					
1988	0.5	0.9	0.2	0.01	1.6
1989	0.3	0.9	0.2	0.00	1.4
Fuel Consumption (10^9 Btu/yr)					
1988	593	322	85	2	1002
1989	415	313	81	0	809

Table G-13. Quality of Effluent Released from the TA-50 Radioactive Liquid-Waste Treatment Plant in 1989

Radionuclide	Activity Released[a] (mCi)	Mean Concentration (µCi/mL)
^{3}H	16 000	7.0×10^{-3}
^{54}Mn	2.7	1.2×10^{-7}
^{56,60}Co	50	2.2×10^{-6}
^{75}Se	110	4.8×10^{-6}
^{83}Rb	230	1.0×10^{-5}
^{84}Rb	26	1.1×10^{-6}
^{85}Sr	100	4.4×10^{-6}
^{89}Sr	18	7.9×10^{-7}
^{90}Sr	1.1	4.8×10^{-8}
^{88}Y	1.9	8.3×10^{-8}
^{137}Cs	39	1.7×10^{-6}
^{234}U	0.5	2.2×10^{-8}
^{238}Pu	0.6	2.6×10^{-8}
^{239,240}Pu	2	8.8×10^{-8}
^{241}Am	4.1	1.8×10^{-7}
Total	16 585.9	

Nonradioactive Constituents	Mean Concentration (mg/L)
Cd [b]	1.1×10^{-2}
Ca	201
Cl	182
Total Cr [b]	3.2×10^{-2}
Cu [b]	0.15
F	10
Hg [b]	4.0×10^{-4}
Mg	0.8
Na	933
Pb [b]	2.3×10^{-2}
Zn [b]	0.11
CN	0.27
COD	44
NO_3-N	488
PO_4	0.29
TDS	4070
pH [b]	7.5–7.9

Total effluent volume = 2.28×10^{7} L.

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[a] As reported on DOE form F-5821.1.

[b] Constituents regulated by the National Pollutant Discharge Elimination System (NPDES) permit.

Table G-14. Quality of Effluent Released from the Los Alamos Meson Physics Facility (TA-53) Lagoons in 1989

Radionuclide	Activity Released[a] (mCi)	Mean Concentration (µCi/mL)
^{3}H	25 000	1.9×10^{-2}
^{7}Be	69	5.3×10^{-6}
^{22}Na	130	1.0×10^{-5}
^{54}Mn	140	1.1×10^{-5}
^{57}Co	54	4.2×10^{-6}
^{60}Co	15	1.2×10^{-6}
Total	25 408	

Total effluent volume = 1.3×10^{7} L.

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[a] As reported on DOE form F-5821.1.

Table G-15. Locations of Surface- and Ground-Water Sampling Stations

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]	Type[b]
Regional Surface Water				
Rio Chama at Chamita	30°05′	106°07′	—	SW
Rio Grande at Embudo	36°12′	105°58′	—	SW
Rio Grande at Otowi	35°52′	106°08′	—	SW
Rio Grande at Cochiti	35°37′	106°19′	—	SW
Rio Grande at Bernalillo	35°17′	106°36′	—	SW
Jemez River	35°40′	106°44′	—	SW
Perimeter Stations				
Los Alamos Reservoir	N105	W090	7	SW
Guaje Canyon	N300	E100	8	SW
Frijoles Canyon	S280	E180	9	SW
La Mesita Spring	N080	E550	10	GWD
Sacred Spring	N170	E540	11	GWD
Indian Spring	N140	E530	12	GWD
White Rock Canyon Stations				
Group I				
Sandia Spring	S030	E470	13	SWR
Spring 3	S110	E450	14	SWR
Spring 3A	S120	E445	15	SWR
Spring 3AA	S140	E440	16	SWR
Spring 4	S170	E110	17	SWR
Spring 4A	S150	E395	18	SWR
Spring 5	S220	E390	19	SWR
Spring 5AA	S240	E360	20	SWR
Ancho Spring	S280	E305	21	SWR
Group II				
Spring 5A	S230	E390	22	SWR
Spring 6	S300	E330	23	SWR
Spring 6A	S310	E310	24	SWR
Spring 7	S330	E295	25	SWR
Spring 8	S335	E285	26	SWR
Spring 8A	S315	E280	27	SWR
Spring 9	S270	E270	28	SWR
Spring 9A	S325	E265	29	SWR
Doe Spring	S320	E250	30	SWR
Spring 10	S370	E230	31	SWR
Group III				
Spring 1	N040	E520	32	SWR
Spring 2	N015	E505	33	SWR
Group IV				
Spring 3B	S150	E465	34	SWR

Table G-15 (Cont)

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]	Type[b]
White Rock Canyon Stations (Cont)				
Streams				
Pajarito	S180	E410	35	SWR
Ancho	S295	E340	36	SWR
Frijoles	S365	E235	37	SWR
Sanitary Effluent				
Mortandad	S070	E480	38	SWR
On-Site Stations				
Test Well 1	N070	E345	39	GWD
Test Well 2	N120	E150	40	GWD
Test Well 3	N080	E215	41	GWD
Test Well DT-5A	S110	E090	42	GWD
Test Well 8	N035	E170	43	GWD
Test Well DT-9	S155	E140	44	GWD
Test Well DT-10	S120	E125	45	GWD
Cañada del Buey	N010	E150	46	SW
Pajarito Canyon	S060	E215	47	SW
Water Canyon at Beta	S090	E090	48	SW
PCO-1	S054	E212	102	GWS
PCO-2	S081	E255	103	GWS
PCO-3	S098	E293	104	GWS
Effluent Release Areas				
Acid-Pueblo Canyons				
Acid Weir	N125	E070	49	SW
Pueblo 1	N130	E080	50	SW
Pueblo 2	N120	E155	51	SW
Pueblo 3	N085	E315	52	SW
Hamilton Bend Spring	N110	E250	53	S
Test Well 1A	N070	E335	54	GWS
Test Well 2A	N120	E140	55	GWS
Basalt Spring	N065	E395	56	S
DP–Los Alamos Canyons				
DPS-1	N090	E160	57	SW
DPS-4	N080	E200	58	SW
LAO-C	N085	E070	59	GWS
LAO-1	N080	E120	60	GWS
LAO-2	N080	E210	61	GWS
LAO-3	N080	E220	62	GWS
LAO-4	N070	E245	63	GWS
LAO-4.5	N065	E270	64	GWS

Table G-15 (Cont)

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]	Type[b]
Effluent Release Areas (Cont)				
Sandia Canyon				
SCS-1	N080	E040	65	SW
SCS-2	N060	E140	66	SW
SCS-3	N050	E185	67	SW
Mortandad Canyon				
GS-1	N040	E100	68	SW
MCO-3	N040	E110	69	GWS
MCO-4	N035	E150	70	GWS
MCO-5	N030	E160	71	GWS
MCO-6	N030	E175	72	GWS
MCO-7	N025	E180	73	GWS
MCO-7.5	N030	E190	74	GWS
Water Supply and Distribution System				
Los Alamos Well Field				
Well LA-1B	N115	E530	76	GWD
Well LA-2	N125	E505	77	GWD
Well LA-3	N130	E490	78	GWD
Well LA-4	N070	E405	79	GWD
Well LA-5	N076	E435	80	GWD
Well LA-6 (standby)	N105	E465	81	GWD
Guaje Well Field				
Well G-1	N190	E385	82	GWD
Well G-1A	N197	E380	83	GWD
Well G-2	N205	E365	84	GWD
Well G-3	N215	E350	85	GWD
Well G-4	N213	E315	86	GWD
Well G-5	N228	E295	87	GWD
Well G-6	N215	E270	88	GWD
Pajarito Well Field				
Well PM-1	N030	E305	89	GWD
Well PM-2	S055	E202	90	GWD
Well PM-3	N040	E255	91	GWD
Well PM-4	S030	E205	92	GWD
Well PM-5	N015	E155	93	GWD
Water Canyon Gallery	S040	W125	94	GWD

Table G-15 (Cont)

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]	Type[b]
Water Supply and Distribution System (Cont)				
Pajarito Well Field (Cont)				
Fire Station 1	N080	E015	95	D
Fire Station 2	N100	E120	96	D
Fire Station 3	S085	E375	97	D
Fire Station 4	N185	E070	98	D
Fire Station 5	S010	W065	99	D
Bandelier National Monument Headquarters	S270	E190	100	D
Fenton Hill (TA-57)	35°53′	106°40′	101	D

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[a] Regional surface-water sampling locations are given in Fig. 14; perimeter, White Rock Canyon, on-site, and effluent release area sampling locations are given in Fig. 15.

[b] SW = surface water, GWD = deep or main aquifer, GWS = shallow or alluvial aquifer, SWR = spring at White Rock Canyon, and D = water supply distribution system.

Table G-16. Radiochemical Quality of Surface Water from Regional Stations[a]

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	^{239,240}Pu (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Rio Chama						
Chamita	−0.1 (0.3)	66 (48)	3.0 (1.0)	0.021 (0.015)	−0.004 (0.004)	170 (70)
Rio Grande						
Embudo	0.1 (0.3)	−20 (75)	2.0 (1.0)	0.000 (0.010)	0.008 (0.011)	−20 (70)
Otowi	−0.3 (0.3)	88 (48)	3.0 (1.0)	−0.004 (0.004)	−0.004 (0.007)	−10 (70)
Cochiti	0.1 (0.3)	16 (74)	4.0 (1.0)	0.008 (0.008)	0.013 (0.007)	−10 (70)
Bernalillo	0.2 (0.3)	79 (47)	4.0 (1.0)	0.000 (0.010)	0.008 (0.006)	70 (70)
Jemez River						
Jemez	0.2 (0.3)	85 (81)	2.0 (1.0)	0.016 (0.014)	0.004 (0.007)	−20 (70)
Maximum	0.2 (0.3)	88 (48)	4.0 (1.0)	0.021 (0.015)	0.013 (0.007)	170 (70)
Limits of detection	0.7	40	1	0.009	0.03	50

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[a] Samples were collected in March 1989; counting uncertainties are in parentheses.

Table G-17. Chemical Quality of Surface Water from Regional Stations (mg/L)[a]

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hard-ness	pH[c]	Conduc-tivity (mS/m)
Rio Chama																
Chamita	12	47	8.6	2.5	24	<1	92	0.1	102	3	0.2	<0.1	270	158	8.1	41
Rio Grande																
Embudo	23	23	4.8	2.2	13	<1	74	0.1	23	3	0.3	0.2	136	82	8.0	20
Otowi	19	35	7.0	3.0	19	<1	81	<0.1	61	4	0.3	0.2	201	120	8.1	30
Cochiti	19	31	6.3	2.7	19	<1	92	<0.1	51	5	0.3	0.2	192	107	8.1	30
Bernalillo	20	33	6.4	3.9	27	<1	95	<0.1	53	11	0.3	<0.1	222	116	8.1	35
Jemez River																
Jemez	34	18	3.7	8.0	29	<1	65	0.2	23	23	0.4	<0.1	162	56	7.9	24

---

[a] Samples were collected in March 1989.

[b] Total dissolved solids.

[c] Standard units.

Table G-18. Radiochemical Quality of Surface and Ground Waters from Perimeter Stations[a]

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	$^{239,240}Pu$ (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Los Alamos Reservoir	0.2 (0.3)	188 (92)	2.0 (1.0)	–0.012 (0.015)	0.000 (0.010)	–50 (70)
Guaje Reservoir	0.2 (0.3)	–46 (35)	2.4 (0.2)	–0.005 (0.014)	–0.011 (0.011)	–260 (70)
Frijoles Canyon	0.4 (0.3)	–51 (54)	2.4 (0.2)	0.012 (0.012)	0.025 (0.012)	–120 (70)
La Mesita Spring	0.4 (0.3)	–34 (35)	10 (1.0)	–0.004 (0.009)	0.004 (0.012)	–110 (70)
Sacred Spring	–0.2 (0.3)	–37 (59)	3.4 (0.3)	0.009 (0.047)	–0.004 (0.008)	–60 (70)
Indian Spring	–0.3 (0.3)	–110 (42)	4.0 (0.4)	–0.004 (0.014)	0.004 (0.011)	–50 (70)
Maximum	0.4 (0.3)	188 (92)	10 (1.0)	0.009 (0.047)	0.025 (0.012)	–50 (70)
Limits of detection	0.7	40	1	0.009	0.03	50

---

[a] Samples were collected in March 1989; counting uncertainties are in parentheses.

Table G-19. Chemical Quality of Surface and Ground Waters from Perimeter Stations (mg/L)[a]

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hard-ness	pH[c]	Conduc-tivity (mS/m)
Los Alamos Reservoir	34	7	3.1	3.8	8	<1	27	0.1	4	7	0.1	<0.1	99	28	7.2	8.4
Guaje Canyon	54	6	2.0	2.4	6	<1	33	0.3	4	2	0.2	0.1	97	23	7.9	8.0
Frijoles Canyon	62	8	2.7	2.1	9	<1	42	0.3	4	3	0.2	0.1	119	30	7.9	10
La Mesita Spring	36	34	1.1	2.3	34	<1	120	0.2	16	7	0.3	2.2	198	83	8.2	30
Sacred Spring	49	25	0.3	3.0	24	<1	102	0.1	8	2	0.5	0.1	145	63	8.2	21
Indian Spring	58	33	2.4	2.8	30	<1	96	0.2	6	25	0.4	0.7	199	94	8.2	29
Maximum	62	34	3.1	3.8	34	<1	120	0.3	16	25	0.5	2.2	199	94	8.2	30

---

[a] Samples were collected in March 1989.

[b] Total dissolved solids.

[c] Standard units.

Table G-20. Radiochemical Quality of Surface and Spring Waters from White Rock Canyon[a]

Station	^3H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	$^{239,240}Pu$ (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Group I						
Sandia Spring	−0.1 (0.3)	28 (41)	1.5 (0.5)	−0.004 (0.004)	−0.004 (0.004)	10 (70)
Spring 3	−0.4 (0.3)	0 (45)	1.6 (0.8)	0.004 (0.012)	−0.004 (0.010)	50 (70)
Spring 3A	0.0 (0.3)	30 (55)	1.3 (0.9)	−0.013 (0.010)	0.013 (0.013)	370 (80)
Spring 4	−0.4 (0.3)	5 (55)	1.3 (0.8)	−0.012 (0.009)	0.000 (0.010)	−20 (70)
Spring 4A	−0.2 (0.3)	115 (58)	1.3 (0.3)	0.000 (0.010)	0.000 (0.010)	90 (70)
Spring 5	0.2 (0.3)	42 (42)	1.0 (0.9)	0.010 (0.014)	0.014 (0.011)	300 (70)
Ancho Spring	0.1 (0.3)	67 (64)	0.3 (0.3)	0.000 (0.010)	0.000 (0.010)	10 (70)
Maximum	0.2 (0.3)	115 (58)	1.6 (0.8)	0.010 (0.014)	0.014 (0.011)	370 (80)
Group II						
Spring 5A	−0.1 (0.3)	−34 (50)	1.8 (0.5)	−0.017 (0.015)	0.006 (0.017)	130 (70)
Spring 5B	0.2 (0.3)	23 (50)	0.9 (0.3)	0.015 (0.013)	0.025 (0.015)	20 (70)
Spring 6	0.2 (0.3)	−4 (41)	0.4 (0.2)	−0.005 (0.015)	0.005 (0.011)	60 (70)
Spring 6A	0.0 (0.3)	113 (59)	0.4 (0.3)	0.000 (0.010)	−0.011 (0.019)	170 (70)
Spring 7	0.0 (0.3)	28 (42)	2.1 (0.5)	0.020 (0.015)	0.000 (0.010)	−50 (70)
Spring 8	0.0 (0.3)	1 (45)	2.5 (0.9)	−0.004 (0.012)	0.008 (0.011)	−60 (70)
Spring 8A	−0.5 (0.3)	27 (41)	<0.5 (0.9)	0.020 (0.013)	−0.011 (0.000)	240 (70)
Spring 9	0.0 (0.3)	−53 (42)	0.3 (0.2)	0.000 (0.010)	0.000 (0.010)	−140 (70)
Spring 9A	0.0 (0.3)	−24 (42)	0.6 (0.5)	−0.009 (0.012)	0.009 (0.014)	−40 (70)
Doe Spring	−0.3 (0.3)	25 (63)	0.2 (0.2)	0.000 (0.010)	0.000 (0.010)	110 (70)
Maximum	0.3 (0.3)	113 (59)	2.5 (0.9)	0.026 (0.013)	0.025 (0.015)	240 (70)
Group III						
Spring 1	0.1 (0.3)	70 (46)	2.3 (0.5)	0.000 (0.010)	−0.009 (0.011)	−10 (70)
Spring 2	−0.3 (0.3)	186 (65)	4.2 (0.9)	0.010 (0.016)	0.000 (0.010)	190 (70)
Spring 2A	0.2 (0.3)	30 (63)	11 (1.1)	−0.004 (0.008)	−0.004 (0.004)	130 (70)
Maximum	0.2 (0.3)	186 (65)	4.2 (0.9)	0.010 (0.016)	0.000 (0.010)	190 (70)
Group IV						
Spring 3B	0.2 (0.3)	24 (41)	23 (4.7)	0.005 (0.015)	[illegible]	[illegible]

Table G-20 (Cont)

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	^{239,240}Pu (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Streams						
Pajarito	−0.2 (0.3)	−17 (57)	1.1 (0.5)	0.009 (0.014)	0.009 (0.009)	200 (70)
Ancho	−0.1 (0.3)	139 (59)	0.2 (0.2)	0.017 (0.015)	0.009 (0.009)	70 (70)
Maximum	0.2 (0.3)	139 (59)	23 (4.7)	0.017 (0.015)	0.009 (0.009)	200 (70)
Sanitary Effluent						
Mortandad	0.1 (0.3)	95 (63)	0.6 (0.3)	−0.021 (0.019)	0.007 (0.016)	−10 (70)

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[a] Samples were collected in October 1989; counting uncertainties are in parentheses. No sample was taken from Spring 5AA because it was dry. Springs 2A and 5B, which normally are not sampled because of high river levels, were included in 1989 because the flow in the Rio Grande was low.

Table G-21. Chemical Quality of Surface and Spring Waters from White Rock Canyon (mg/L)[a]

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hardness	pH[c]	Conductivity (mS/m)
Group I																
Sandia Spring	50	<5	4.5	3.7	14	<5	138	0.2	10	3	0.6	<0.1	216	131	8.1	27
Spring 3	54	20	1.5	2.6	14	<5	86	0.3	8	3	0.5	0.7	130	63	8.2	16
Spring 3A	58	20	1.6	3.0	15	<5	77	0.2	5	3	0.4	0.6	128	60	8.2	16
Spring 4	58	20	4.0	2.2	13	<5	86	0.2	10	6	0.8	1.2	162	81	7.6	21
Spring 4A	75	19	4.4	2.0	11	<5	81	0.3	8	4	0.5	1.1	100	73	7.7	20
Spring 5	74	19	1.0	2.4	12	<5	81	0.3	6	4	0.7	0.4	202	69	8.0	14
Ancho Spring	81	12	2.7	1.8	21	<5	62	0.4	4	2	0.4	0.4	138	45	7.8	12
Maximum	81	20	4.5	3.0	15	<5	138	0.4	10	6	0.8	1.2	216	131	8.2	27
Group II																
Spring 5A	63	23	2.7	3.0	18	<5	98	0.3	9	4	0.3	0.6	150	73	7.8	22
Spring 5B	66	23	5.0	2.4	15	<5	75	0.3	12	5	0.4	5.0	196	85	8.2	24
Spring 6	76	12	3.4	2.0	10	<5	61	0.5	4	2	0.5	0.4	126	49	7.8	14
Spring 6A	79	11	2.7	2.0	11	<5	51	0.5	3	1	0.3	0.5	158	40	8.0	12
Spring 7	80	13	3.0	2.3	14	<5	62	0.5	5	2	0.3	0.5	84	79	7.3	13
Spring 8	80	20	4.7	3.0	23	<5	113	0.4	14	3	0.4	1.2	110	84	6.8	21
Spring 8A	88	12	3.0	2.3	12	<5	64	0.4	3	2	0.5	<0.1	183	45	8.5	13
Spring 9	80	11	3.0	2.0	12	<5	62	0.4	4	2	0.4	<0.1	202	44	8.2	13
Spring 9A	79	10	2.9	1.4	11	<5	65	0.4	2	2	0.8	0.3	86	41	7.9	13
Doe Spring	83	12	3.0	1.7	12	<5	69	0.4	5	2	0.7	<0.1	164	46	8.2	13
Maximum	88	23	5.0	3.0	23	<5	113	0.5	14	4	0.8	5.0	202	85	8.5	24
Group III																
Spring 1	34	20	1.2	2.3	32	<5	122	—	9	3	0.9	0.2	226	59	8.2	20
Spring 2	37	20	1.0	1.7	59	<5	155	0.2	9	3	1.3	<0.1	372	57	8.1	31
Spring 2A	46	3	<0.5	1.2	62	<5	137	0.2	8	2	0.5	0.6	162	12	8.9	25
Maximum	46	20	1.2	2.3	32	<5	155	0.2	9	3	1.3	0.6	372	59	8.9	25

Table G-21 (Cont)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hard-ness	pH[c]	Conduc-tivity (mS/m)
Group IV																
Spring 3B	50	22	1.8	5.0	135	<5	311	0.2	16	3	0.6	2.0	446	62	7.6	61
Streams																
Pajarito	75	21	4.0	2.6	14	<5	83	0.3	7	4	0.5	0.7	158	74	8.2	20
Ancho	78	13	3.2	1.8	11	<5	65	0.4	4	2	0.4	<0.1	130	52	8.3	14
Maximum	78	21	4.0	2.0	14	<5	83	0.4	7	4	0.5	0.7	158	52	8.3	20
Sanitary Effluent																
Mortandad	97	29	9.0	16	97	<5	153	6.2	40	48	1.2	9.0	452	104	8.6	59

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[a] Samples were collected in October 1989. No sample was taken from Spring 5AA because it was dry. Springs 2A and 5B, which normally are not sampled because of high river levels, were included in 1989 because the flow in the Rio Grande was low.

[b] Total dissolved solids.

[c] Standard units.

Table G-22. Radiochemical Quality of Surface and Ground Waters from On-Site Stations[a]

Station	^{3}H (10^{-6} μCi/mL)	^{137}Cs (10^{-9} μCi/mL)	Total Uranium (μg/L)	^{238}Pu (10^{-9} μCi/mL)	^{239,240}Pu (10^{-9} μCi/mL)	Gross Gamma (counts/min/L)
Ground Water (Main Aquifer)						
Test well 1	Well inactive					
Test well 2	Well inactive					
Test well 3	−0.6 (0.3)	−62 (60)	2.7 (0.3)	0.004 (0.016)	−0.009 (0.011)	70 (70)
Test well DT-5A	−0.2 (0.3)	40 (38)	2.0 (1.0)	−0.008 (0.010)	0.008 (0.012)	60 (70)
Test well 8	0.1 (0.3)	30 (73)	2.0 (1.0)	0.019 (0.011)	0.028 (0.011)	60 (70)
Test well DT-9	−0.1 (0.3)	7 (46)	2.0 (1.0)	−0.005 (0.012)	−0.009 (0.011)	−50 (70)
Test well DT-10	−0.2 (0.3)	22 (8)	2.0 (1.0)	0.000 (0.010)	0.000 (0.010)	−90 (70)
Maximum	0.1 (0.3)	40 (38)	2.7 (0.3)	0.019 (0.011)	0.028 (0.011)	70 (70)
Surface Water						
Cañada del Buey	0.6 (0.3)	−100 (41)	2.5 (0.3)	0.014 (0.016)	0.005 (0.012)	160 (70)
Pajarito Canyon	−0.5 (0.3)	−19 (60)	5.9 (0.6)	−0.010 (0.010)	0.010 (0.017)	140 (70)
Water Canyon at Beta Hole	0.0 (0.3)	105 (70)	<1.0	0.004 (0.012)	0.004 (0.011)	80 (70)
Maximum	0.6 (0.3)	105 (70)	5.9 (0.6)	0.014 (0.016)	0.010 (0.017)	160 (70)
Observation Wells (Pajarito Canyon)						
PCO-1	−0.1 (0.3)	100 (48)	2.0 (1.0)	−0.009 (0.009)	0.000 (0.010)	40 (70)
PCO-2	0.1 (0.3)	75 (77)	2.0 (1.0)	0.005 (0.009)	0.011 (0.008)	190 (70)
PCO-3	0.6 (0.3)	14 (42)	2.0 (1.0)	0.006 (0.015)	−0.006 (0.015)	170 (70)
Maximum	0.6 (0.3)	100 (48)	2.0 (1.0)	0.006 (0.015)	0.011 (0.008)	190 (70)

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[a] Samples were collected March–April 1989; counting uncertainties are in parentheses.

Table G-23. Chemical Quality of Surface and Ground Waters from On-Site Stations (mg/L)[a]

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hard-ness	pH[c]	Conduc-tivity (mS/m)
Ground Water (Main Aquifer)																
Test well 1	Well inactive															
Test well 2	Well inactive															
Test well 3	110	17	4.3	2.1	17	<1	82	0.3	3	3	0.4	0.6	179	60	8.2	18
Test well DT-5A	74	10	3.6	3.2	11	<1	58	0.3	2	2	0.3	0.4	132	35	8.0	12
Test well 8	73	9	2.2	1.0	12	<1	54	0.3	2	1	0.3	0.3	132	35	8.0	12
Test well DT-9	72	10	2.2	1.3	12	<1	53	0.3	2	<1	0.3	0.4	126	38	8.0	12
Test well DT-10	73	10	3.0	1.0	11	<1	52	0.3	2	1	0.3	0.4	126	38	8.0	12
Maximum	110	17	4.3	3.2	17	<1	82	0.3	3	3	0.4	0.6	179	60	8.2	18
Surface Water																
Cañada del Buey	36	7	1.3	2.2	16	<1	34	0.1	5	10	0.9	0.1	109	22	7.6	11
Pajarito Canyon	58	77	32	4.8	113	<1	257	0.2	4	194	0.3	0.3	579	338	8.0	120
Water Canyon at Beta Hole	37	11	3.4	3.2	15	<1	52	0.2	5	8	0.2	0.1	125	45	7.8	14
Maximum	58	77	32	4.8	113	<1	257	0.2	5	194	0.9	0.3	579	338	8.0	120
Observation Wells (Pajarito Canyon)																
PCO-1	25	14	4.1	3.7	23	<1	57	<0.1	8	24	0.2	0.1	144	59	7.0	22
PCO-2	25	18	4.1	3.7	20	<1	59	<0.1	8	24	0.2	0.1	143	68	7.0	22
PCO-3	25	16	5.4	3.0	20	<1	62	<0.1	9	25	0.2	0.1	144	66	7.0	22
Maximum	25	18	5.4	3.7	23	<1	59	<0.1	9	25	0.2	0.1	144	68	7.0	22

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[a] Samples were collected in March and April 1989.

[b] Total dissolved solids.

[c] Standard units.

Table G-24. Radiochemical Quality of Surface and Ground Waters from Effluent Release Areas[a]

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	$^{239,240}Pu$ (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Acid-Pueblo Canyon						
Acid Weir	0.2 (0.3)	145 (84)	1.0 (1.0)	−0.008 (0.008)	0.082 (0.021)	100 (70)
Pueblo 1	0.3 (0.3)	0.4 (67)	1.0 (1.0)	0.009 (0.009)	0.009 (0.006)	10 (70)
Pueblo 2	0.0 (0.3)	30 (83)	1.0 (1.0)	−0.004 (0.009)	0.012 (0.013)	−40 (70)
Pueblo 3	0.4 (0.3)	44 (66)	1.0 (1.0)	0.005 (0.015)	0.014 (0.010)	−80 (70)
Hamilton Bend Spring	0.2 (0.3)	43 (81)	1.0 (1.0)	−0.017 (0.014)	0.009 (0.012)	−10 (70)
Test well 1A	0.4 (0.3)	−19 (34)	2.8 (0.3)	0.012 (0.010)	0.004 (0.007)	50 (70)
Test well 2A	0.6 (.03)	−52 (74)	1.0 (1.0)	0.009 (0.011)	−0.014 (0.010)	−30 (70)
Basalt Spring	0.1 (0.3)	716 (119)	2.0 (1.0)	0.004 (0.013)	−0.004 (0.012)	110 (70)
Maximum	0.6 (0.3)	716 (119)	2.8 (1.0)	0.012 (0.010)	0.082 (0.021)	110 (70)
Los Alamos Canyon						
DPS-1	1.2 (0.3)	−2.3 (34)	1.0 (1.0)	−0.012 (0.007)	0.004 (0.010)	70 (70)
DPS-4			Dry			
LAO-C	0.2 (0.3)	15 (52)	2.0 (1.0)	0.028 (0.013)	0.018 (0.009)	70 (70)
LAO-1	3.8 (0.5)	−61 (10)	1.0 (1.0)	−0.009 (0.009)	0.009 (0.014)	80 (70)
LAO-2	2.9 (0.5)	19 (32)	1.0 (1.0)	0.021 (0.016)	0.017 (0.010)	70 (70)
LAO-3	2.1 (0.4)	46 (30)	2.0 (1.0)	−0.017 (0.014)	0.004 (0.011)	60 (70)
LAO-4	2.9 (0.5)	96 (88)	1.0 (1.0)	0.012 (0.011)	0.008 (0.013)	90 (70)
LAO-4.5	2.8 (0.4)	−8.1 (31)	1.0 (1.0)	−0.009 (0.011)	0.000 (0.010)	30 (70)
Maximum	3.8 (0.5)	96 (88)	2.0 (1.0)	0.028 (0.013)	0.018 (0.014)	90 (70)
Sandia Canyon						
SCS-1	0.0 (0.3)	72 (73)	3.0 (1.0)	−0.015 (0.015)	0.005 (0.011)	150 (70)
SCS-2	0.7 (0.3)	−7 (42)	3.0 (1.0)	0.000 (0.010)	−0.004 (0.009)	100 (70)
SCS-3	0.3 (0.3)	1 (72)	3.0 (1.0)	−0.012 (0.007)	−0.004 (0.012)	120 (70)
Maximum	0.7 (0.3)	72 (73)	3.0 (1.0)	0.000 (0.010)	0.005 (0.011)	150 (70)

Table G-24 (Cont)

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	$^{239,240}Pu$ (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Mortandad Canyon						
GS-1	38 (4.0)	3130 (470)	4.0 (1.0)	7.36 (0.271)	28.4 (0.906)	2800 (300)
MCO-3	37 (4.0)	3000 (470)	4.0 (1.0)	7.82 (0.318)	29.9 (1.05)	2600 (300)
MCO-4	130 (10)	0.22 (46)	3.0 (1.0)	0.137 (0.034)	0.364 (0.054)	410 (80)
MCO-5	130 (10)	191 (103)	3.0 (1.0)	0.147 (0.024)	0.342 (0.038)	230 (80)
MCO-6	150 (20)	122 (46)	4.0 (1.0)	0.033 (0.012)	0.029 (0.010)	−20 (70)
MCO-7	150 (20)	8.1 (39)	4.0 (1.0)	0.003 (0.010)	0.030 (0.013)	−100 (70)
MCO-7.5	150 (20)	97 (90)	4.0 (1.0)	0.051 (0.018)	0.021 (0.010)	80 (70)
Maximum	150 (20)	3130 (470)	4.0 (1.0)	7.82 (0.318)	29.9 (1.05)	2800 (300)
Limits of detection	0.7	40	1	0.009	0.003	50

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[a] Samples were collected in April 1989; counting uncertainties are in parentheses.

Table G-25. Chemical Quality of Surface and Ground Waters from Effluent Release Areas (mg/L)[a]

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hardness	pH[c]	Conductivity (mS/m)
Acid-Pueblo Canyon																
Acid Weir	16	26	4.9	7.4	140	0	44	0.3	16	239	0.2	0.7	452	85	7.7	84
Pueblo 1	64	22	3.8	9.7	100	0	130	6.6	32	76	0.6	2.5	373	76	7.4	60
Pueblo 2	45	26	3.2	11	100	0	106	6.0	26	83	0.6	1.8	356	75	7.6	57
Pueblo 3	72	17	2.0	13	99	0	188	10.9	37	43	0.8	3.7	392	52	7.3	60
Hamilton Bend Spring	64	17	3.5	9.0	74	0	114	6.0	26	52	0.8	1.5	297	59	7.8	46
Test well 1A	42	27	8.0	4.0	20	9	127	1.8	25	38	0.5	2.7	288	88	8.4	46
Test well 2A	47	34	6.2	4.6	20	0	72	0.1	6	50	0.3	<0.1	169	100	8.0	32
Basalt Spring	44	34	6.2	4.6	20	0	92	0.3	18	17	0.5	3.0	204	108	8.2	30
Maximum	72	34	8.0	13	140	9	188	10.9	37	239	0.8	3.7	452	108	8.4	84
DP–Los Alamos Canyon																
DPS-1	23	48	3.4	8.2	125	0	140	0.2	14	140	0.8	<0.1	430	123	7.7	78
DPS-4									Dry							
LAO-C	34	11	3.2	5.6	26	0	34	0.2	32	4	0.2	0.1	131	29	7.1	19
LAO-1	35	15	3.3	3.0	34	0	41	0.3	6	47	0.2	<0.1	164	48	7.8	25
LAO-2	50	24	2.3	9.9	45	0	84	0.2	12	45	1.4	<0.1	220	47	7.3	34
LAO-3	39	23	3.9	12.0	70	0	88	0.2	12	73	1.4	0.4	265	67	7.1	45
LAO-4	38	21	3.8	7.3	31	0	57	0.2	8	50	0.9	<0.1	181	58	7.2	30
LAO-4.5	39	19	4.4	5.4	30	0	61	1.1	12	52	0.8	0.2	180	62	7.1	29
Maximum	50	48	4.4	12.0	125	0	140	1.1	32	140	1.4	0.4	430	123	7.8	78
Sandia Canyon																
SCS-1	78	17	2.7	11.0	100	0	99	4.3	53	53	0.6	4.1	349	54	7.6	52
SCS-2	66	21	3.2	8.9	140	0	89	2.4	71	72	0.6	4.0	412	65	8.0	60
SCS-3	75	16	4.0	4.9	54	0	80	1.7	32	33	0.5	2.9	269	57	8.0	35
Maximum	78	21	4.0	11.0	140	0	99	4.3	71	72	0.6	4.1	412	65	8.0	60

Table G-25 (Cont)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hardness	pH[c]	Conductivity (mS/m)
Mortandad Canyon																
GS-1	43	210	2.8	120	320	1	382	0.1	107	352	7.2	117	1780	446	8.0	300
MCO-3	43	200	3.0	117	300	28	372	0.1	102	294	6.4	111	1700	462	8.0	280
MCO-4	32	60	8.5	43	200	0	181	0.2	105	54	1.7	107	1060	182	7.5	150
MCO-5	32	56	7.7	50	220	0	172	0.2	100	66	1.6	106	1000	170	7.4	140
MCO-6	34	23	5.0	5.5	210	0	175	0.2	38	27	1.9	81	782	78	7.3	100
MCO-7	34	23	5.2	5.4	220	0	174	0.2	39	33	1.5	82	762	79	7.8	110
MCO-7.5	34	23	5.3	5.5	210	0	181	0.2	40	26	1.6	82	770	83	7.0	110
Maximum	43	210	8.5	120	320	28	382	0.2	107	352	7.2	117	1780	462	8.0	300

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[a] Samples were collected in April 1989.

[b] Total dissolved solids.

[c] Standard units.

Table G-26. Radiochemical Quality of Water from Supply Wells and the Distribution System[a]

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	^{239,240}Pu (10^{-9} µCi/mL)	Gross Alpha (10^{-9} µCi/mL)	Gross Beta (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Water Supply								
Los Alamos Field								
Well LA-1B	0.1 (0.3)	42 (60)	7.1 (0.7)	−0.008 (0.002)	0.000 (0.001)	18 (5.0)	2.8 (0.5)	160 (70)
Well LA-2	0.2 (0.3)	107 (59)	6.6 (0.7)	0.039 (0.034)	0.013 (0.022)	4 (1.0)	2.3 (0.5)	60 (70)
Well LA-3	0.3 (0.3)	−15 (61)	3.6 (0.4)	−0.007 (0.018)	0.007 (0.021)	0.9 (0.7)	1.7 (0.4)	190 (70)
Well LA-4	(Well inactive)							
Well LA-5	−0.3 (0.3)	−13 (50)	2.2 (0.2)	0.010 (0.015)	0.010 (0.015)	1.5 (0.8)	1.3 (0.4)	110 (70)
Guaje Field								
Well G-1	0.1 (0.3)	−15 (61)	2.1 (0.2)	0.008 (0.014)	0.008 (0.014)	0.1 (0.6)	2.5 (0.5)	−30 (70)
Well G-1A	−0.3 (0.3)	47 (45)	2.1 (0.2)	−0.005 (0.005)	0.000 (0.010)	0.7 (0.7)	2.2 (0.5)	50 (70)
Well G-2	0.4 (0.3)	147 (73)	2.6 (0.3)	0.000 (0.010)	0.006 (0.006)	0.4 (0.7)	2.7 (0.5)	140 (70)
Well G-3	(Well inactive)							
Well G-4	0.1 (0.3)	37 (52)	2.6 (0.3)	0.000 (0.010)	0.004 (0.007)	1.1 (0.7)	10 (1.0)	100 (70)
Well G-5	0.2 (0.3)	58 (60)	2.6 (0.3)	0.008 (0.006)	0.004 (0.004)	0.9 (0.7)	1.8 (0.4)	230 (80)
Well G-6	−0.1 (0.3)	42 (46)	2.2 (0.2)	0.008 (0.013)	0.025 (0.014)	0.6 (0.6)	1.6 (0.4)	120 (70)
Pajarito Field								
Well PM-1	0.1 (0.3)	−73 (60)	3.4 (0.3)	0.011 (0.011)	0.022 (0.011)	0.3 (0.7)	4.2 (0.6)	220 (80)
Well PM-2	−0.2 (0.3)	17 (51)	2.1 (0.2)	−0.004 (0.009)	−0.004 (0.012)	0.3 (0.5)	4.0 (0.6)	190 (70)
Well PM-3	0.1 (0.3)	22 (60)	3.3 (0.3)	−0.004 (0.014)	−0.008 (0.006)	1.3 (0.9)	3.8 (0.6)	190 (70)
Well PM-4	−0.1 (0.3)	91 (91)	1.0 (1.0)	0.000 (0.010)	−0.014 (0.008)	0.9 (0.6)	1.7 (0.4)	—
Well PM-5	0.2 (0.3)	−60 (35)	2.2 (0.2)	0.000 (0.010)	0.011 (0.017)	0.7 (0.7)	4.3 (0.6)	30 (70)
Water Canyon Gallery	−0.4 (0.3)	32 (60)	2.1 (0.2)	0.023 (0.012)	0.000 (0.010)	0.5 (0.6)	1.9 (0.4)	70 (70)
Water supply maximum	0.4 (0.3)	147 (73)	7.1 (0.7)	0.039 (0.034)	0.025 (0.014)	18 (5.0)	10 (1.0)	230 (80)

Table G-26 (Cont)

Station	^{3}H (10^{-6} µCi/mL)	^{137}Cs (10^{-9} µCi/mL)	Total Uranium (µg/L)	^{238}Pu (10^{-9} µCi/mL)	^{239,240}Pu (10^{-9} µCi/mL)	Gross Alpha (10^{-9} µCi/mL)	Gross Beta (10^{-9} µCi/mL)	Gross Gamma (counts/min/L)
Distribution System								
Fire Station 1	−0.2 (0.3)	−71 (45)	2.1 (0.2)	0.000 (0.010)	0.000 (0.010)	0.7 (0.6)	2.2 (0.4)	140 (70)
Fire Station 2	0.1 (0.3)	31 (51)	5.4 (0.5)	−0.011 (0.007)	0.004 (0.013)	4.0 (2.0)	3.0 (0.5)	50 (70)
Fire Station 3	0.1 (0.3)	78 (54)	2.9 (0.3)	0.009 (0.017)	0.009 (0.011)	0.7 (0.7)	6.5 (0.8)	200 (70)
Fire Station 4	0.0 (0.3)	40 (46)	2.7 (0.3)	0.000 (0.010)	−0.011 (0.008)	0.4 (0.7)	4.6 (0.6)	140 (70)
Fire Station 5	−0.2 (0.3)	100 (63)	2.1 (0.2)	−0.008 (0.008)	−0.004 (0.011)	1.0 (0.6)	1.8 (0.4)	80 (70)
Bandelier National Monument	0.5 (0.3)	−16 (51)	2.1 (0.2)	0.000 (0.010)	0.020 (0.013)	1.0 (0.6)	2.9 (0.5)	120 (70)
Distribution system maximum	0.1 (0.3)	100 (63)	5.4 (0.5)	0.009 (0.017)	0.009 (0.011)	4.0 (2.0)	6.5 (0.8)	200 (70)
Fenton Hill Supply TA-57	0.3 (0.3)	−37 (59)	4.3 (0.4)	0.000 (0.001)	0.005 (0.014)	3.0 (1.0)	5.0 (0.7)	10 (70)
Standby Well (LA-6)	0.0 (0.3)	—	3.0 (1.0)	0.033 (0.018)	−0.014 (0.008)	1.5 (0.9)	3.0 (0.5)	70 (70)

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[a] Collected in March 1989; counting uncertainties are in parentheses.

Table G-27. Chemical Quality for Parameters Covered by EPA's Primary and Secondary Standards for Water from Supply Wells and the Distribution System (mg/L)[a]

Station	Ag	As	Ba	Cd	Cr	F	Hg	NO_3-N	Pb	Se
Supply System										
Los Alamos Field										
Well LA-1B	<0.001	0.042	0.055	<0.001	0.024	2.9	<0.0002	0.5	0.002	<0.001
Well LA-2	<0.001	0.012	0.090	<0.001	0.021	1.8	<0.0002	0.5	<0.001	0.001
Well LA-3	<0.001	0.006	0.057	<0.001	0.008	0.7	<0.0002	0.5	<0.001	0.001
Well LA-5	<0.001	0.005	0.002	<0.001	0.004	0.4	<0.0002	0.4	0.006	<0.001
Guaje Field										
Well G-1	<0.001	0.003	0.002	<0.001	0.005	0.5	<0.0002	0.4	0.006	<0.001
Well G-1A	<0.001	0.015	0.001	<0.001	0.008	0.6	<0.0002	0.4	0.003	<0.001
Well G-2	<0.001	0.040	0.001	<0.001	0.011	0.9	—	0.4	0.003	0.001
Well G-3	Well inactive									
Well G-4	<0.001	0.003	0.002	<0.001	0.004	0.3	<0.0002	0.2	0.008	0.001
Well G-5	<0.001	0.002	0.015	<0.001	0.004	0.4	<0.0002	0.6	0.002	<0.001
Well G-6	<0.002	0.004	0.006	<0.001	0.005	0.3	—	0.6	0.001	<0.001
Pajarito Field										
Well PM-1	<0.001	0.002	0.083	<0.001	0.003	0.3	<0.0002	0.3	0.001	0.001
Well PM-2	<0.001	<0.001	0.025	<0.001	0.003	0.3	<0.0002	0.5	0.001	<0.001
Well PM-3	<0.001	0.003	0.088	<0.001	0.004	0.3	<0.0002	0.4	0.001	<0.001
Well PM-4	<0.001	0.001	0.022	<0.001	0.008	0.3	<0.0002	0.3	0.0002	<0.001
Well PM-5	<0.002	<0.001	0.033	0.006	0.005	0.3	<0.0002	0.3	0.015	<0.001
Water Canyon Gallery	<0.001	0.001	0.031	<0.001	0.002	0.1	<0.0002	0.3	0.003	<0.001
Water supply maximum	<0.001	0.042	0.090	0.006	0.024	2.9	<0.0002	0.6	0.015	0.001
Distribution System										
Fire Station 1	<0.001	<0.001	0.026	<0.001	0.007	0.3	<0.0002	0.3	0.004	<0.001
Fire Station 2	<0.001	0.018	0.054	<0.001	0.020	1.8	<0.0002	0.3	0.003	<0.001
Fire Station 3	<0.001	0.002	0.060	<0.001	0.006	1.1	<0.0002	0.4	0.006	0.001
Fire Station 4	<0.001	0.014	0.037	<0.001	0.009	0.9	<0.0002	0.4	0.003	0.001
Fire Station 5	<0.001	0.002	0.028	0.001	0.004	0.4	<0.0002	0.1	0.005	<0.001
Bandelier National Monument	<0.001	<0.001	0.026	<0.001	0.004	0.3	<0.0002	0.4	<0.006	<0.001
Distribution system maximum	<0.001	0.018	0.060	0.001	0.020	1.8	<0.0002	0.4	0.006	0.001
Fenton Hill supply, TA-57	<0.001	0.002	0.010	<0.001	0.002	0.1	<0.0002	0.2	<0.001	<0.001
Standby well (LA-6)	<0.001	0.156	0.026	<0.001	0.025	2.1	<0.0002	0.5	<0.001	0.001
EPA and NMEID primary maximum concentration levels	0.05	0.05	1.0	0.01	0.05	4.0	0.002	10	0.05	0.01

Table G-27 (Cont)

Station	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH[b]
Supply Wells								
Los Alamos Field								
Well LA-1B	16	0.035	0.010	0.004	38	0.008	427	8.5
Well LA-2	14	0.071	0.015	<0.002	15	0.004	214	8.5
Well LA-3	3	0.048	0.031	<0.002	7	0.002	124	8.4
Well LA-5	2	0.003	0.011	0.004	4	0.004	99	8.3
Guaje Field								
Well G-1	2	0.010	0.025	<0.002	5	0.003	147	8.4
Well G-1A	3	0.053	0.009	<0.002	5	0.018	150	8.4
Well G-2	2	0.002	0.007	<0.002	5	0.004	161	8.4
Well G-3	Well inactive							
Well G-4	2	0.066	0.160	0.003	4	0.012	134	8.3
Well G-5	3	0.001	0.004	<0.002	5	0.009	138	8.3
Well G-6	2	<0.005	0.021	<0.002	4	0.013	117	8.2
Pajarito Field								
Well PM-1	6	0.006	0.006	0.001	6	0.008	195	8.3
Well PM-2	2	0.002	0.003	0.002	4	0.003	127	8.2
Well PM-3	6	0.004	0.008	0.001	5	0.005	198	8.4
Well PM-4	2	<0.001	0.036	0.031	2	0.002	159	—
Well PM-5	2	0.002	0.450	<0.002	3	0.005	165	8.2
Water Canyon Gallery	2	0.001	0.002	0.017	5	0.019	74	7.8
Water supply maximum	16	0.071	0.450	0.017	38	0.019	427	8.5
Distribution System								
Fire Station 1	2	0.001	0.008	0.005	2	0.034	140	8.1
Fire Station 2	10	0.014	0.020	0.005	21	0.018	259	8.5
Fire Station 3	6	0.040	0.007	0.003	5	0.008	216	8.3
Fire Station 4	4	0.004	0.022	0.007	7	0.031	151	8.4
Fire Station 5	3	0.071	0.026	<0.002	3	0.122	128	8.0
Bandelier National Monument	2	0.009	0.030	0.002	3	0.108	137	8.1
Distribution system maximum	10	0.071	0.030	0.007	21	0.108	259	8.5
Fenton Hill supply, TA-57	59	0.001	0.110	<0.001	10	0.012	334	8.3
Standby well (LA-6)	4	<0.001	0.004	0.031	6	0.001	20	8.8
EPA and NMEID secondary maximum concentration levels	250	1.0	0.3	0.05	250	5.0	500	6.8–8.5

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[a] Samples were collected in April 1989.

[b] Standard units.

Table G-28. Chemical Quality of Water from Supply Wells and the Distribution System (mg/L)[a]

Station	Al	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	Total Hard- ness	Conduc- tivity (mS/m)
Supply Wells											
Los Alamos Field											
Well LA-1B	—	40	6	0.5	3.5	164	0	293	0.4	20	68
Well LA-2	—	33	7	0.4	2.8	76	0	131	0.2	19	34
Well LA-3	—	34	16	0.1	1.9	30	0	90	0.2	32	19
Well LA-4						Well inactive					
Well LA-5	—	42	12	0.1	1.8	27	0	74	0.2	31	15
Guaje Field											
Well G-1	—	88	14	0.7	3.0	24	0	80	0.4	42	16
Well G-1A	—	77	11	0.4	2.8	35	0	88	0.3	30	18
Well G-2	—	77	11	0.7	2.6	42	0	102	0.3	30	21
Well G-3						Well inactive					
Well G-5	—	63	21	4.5	2.0	13	0	79	0.3	69	16
Well G-6	—	56	15	2.1	2.6	21	0	75	0.2	45	16
Pajarito Field											
Well PM-1	—	82	26	7.2	4.0	22	0	118	0.3	90	26
Well PM-2	—	86	12	3.1	1.8	11	0	57	0.4	36	11
Well PM-3	—	83	27	6.2	4.3	22	0	118	0.3	94	26
Well PM-4	—	85	10	2.7	3.0	12	0	55	1.6	33	12
Well PM-5	—	94	13	4.4	2.0	14	0	68	0.4	48	14
Water Canyon Gallery	8.0	36	7	2.9	2.2	4.3	0	27	0.2	29	7
Water supply maximum	—	94	27	7.2	4.3	164	0	293	1.6	94	68
Distribution System											
Fire Station 1	<0.01	89	11	3.2	2.2	13	0	62	0.5	47	12
Fire Station 2	0.01	41	9	0.8	4.0	95	7	180	0.2	28	43
Fire Station 3	<0.01	90	23	7.4	5.3	18	0	119	0.4	95	26
Fire Station 4	0.01	65	13	1.8	3.1	29	4	98	0.3	43	21
Fire Station 5	0.03	86	13	3.7	2.3	10	0	60	0.4	50	13
Bandelier National Monument	—	83	14	3.5	3.1	10	0	62	0.3	51	13
Distribution system maximum	—	90	23	7.4	5.3	95	7	180	0.5	95	43
Fenton Hill Supply, TA-57	—	75	68	7.4	7.0	22	0	146	0.3	203	48
Standby well (LA-6)	—	35	3	0.4	1.6	71	0	140	0.8	7	30

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[a] Samples were collected in March 1989.

Table G-29. Transport of Radionuclides in Summer Run-Off from Los Alamos and Pueblo Canyons[a]

		Los Alamos Canyon at State Road 4				Pueblo Canyon at State Road 4		Los Alamos Canyon at Well LA-5	
		14:30		14:50		15:05		15:15	
Solution									
^{3}H	10^{-6} µCi/mL	0.5	(0.3)	0.7	(0.3)	0.4	(0.3)	0.6	(0.30)
^{137}Cs	10^{-9} µCi/mL	19	(48)	84	(57)	21	(37)	111	(64)
^{238}Pu	10^{-9} µCi/mL	0.012	(0.012)	0.013	(0.012)	−0.004	(0.004)	0.012	(0.007)
$^{239,240}Pu$	10^{-9} µCi/mL	0.020	(0.014)	0.036	(0.014)	0.013	(0.010)	0.029	(0.011)
Gross gamma	counts/min/L	160	(70)	320	(80)	−10	(70)	170	(70)
Suspended Sediments									
^{238}Pu	pCi/g	0.299	(0.016)	0.460	(0.024)	0.010	(0.002)	0.213	(0.014)
$^{239,240}Pu$	pCi/g	1.56	(0.066)	2.07	(0.090)	1.76	(0.076)	1.34	(0.059)
^{137}Cs	pCi/g	6.2	(0.9)	10.3	(1.6)	0.4	(0.1)	5.6	(0.9)
Gross gamma	counts/min/g	10	(1.0)	6.2	(0.7)	8.5	(0.9)	9.2	(1.0)
Total uranium	µg/g	5.4	(0.5)	6.7	(0.7)	5.4	(0.5)	6.0	(0.6)
Estimated discharge	(ft^3/s)	40		50		30		70	

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[a] Samples were collected September 5, 1989; counting uncertainties are in parentheses.

Table G-30. Number of Results above the Analytical LOQs for Organic Compounds in Surface and Ground Waters from Regional and On-Site Locations (Noneffluent and Effluent Areas)[a]

	Date (1989)	Type of Organic Compound				
		Volatile	Semivolatile	Pesticide	Herbicide	PCB
Number of Compounds Analyzed		65	68	13	4	4
Regional						
Rio Chama at Chamita	3-27	0	0	0	0	0
Rio Grande at Embudo	3-27	0	0	0	0	0
Rio Grande at Otowi	3-27	0	0	0	0	0
Rio Grande at Cochiti	3-27	0	0	0	0	0
Rio Grande at Bernalillo	3-27	0	0	0	0	0
Jemez River at Jemez	3-27	0	0	0	0	0
On Site (Noneffluent Areas)						
Pajarito Canyon						
PCO-1	3-27	0	0	0	0	0
PCO-2	3-27	1	0	0	0	0
PCO-3	3-27	0	0	0	0	0
On Site (Effluent Areas)						
Acid-Pueblo Canyon						
Acid-Weir	4-3	0	0	0	0	0
Pueblo 1	4-3	0	0	0	0	0
Pueblo 2	4-3	1	0	0	0	0
Pueblo 3	4-3	1	0	0	0	0
Hamilton Bend Spring	4-3	0	0	0	0	0
Test Well 2A	4-3	0	0	0	0	0
Basalt Spring	4-3	0	0	0	0	0
DP–Los Alamos Canyon						
DPS-1	4-17	0	0	0	0	0
LAO-C	4-17	0	0	0	0	0
LAO-1	4-17	0	0	0	0	0
LAO-2	4-17	0	0	0	0	0
LAO-3	4-17	0	0	0	0	0
LAO-4	4-17	0	0	0	0	0
LAO-4.5	4-17	0	0	0	0	0
Sandia Canyon						
SCS-1	3-27	0	0	0	0	0
SCS-2	3-27	0	0	0	0	0
SCS-3	3-27	0	0	0	0	0
Montandad Canyon						
GS-1	4-26	0	0	—	0	—
MCO-3	4-26	1	0	—	0	—
MCO-4	4-26	0	0	—	0	—
MCO-5	4-26	0	0	—	0	—
MCO-6	4-26	0	0	—	0	—
MCO-7	4-26	0	1	0	0	0
MCO-7.5	4-26	0	0	0	0	0

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[a] See Table 20 for values of analytical results reported above the LOQs and Appendix C for list of compounds analyzed in each set.

Table G-31. Locations of Soil and Sediment Sampling Stations

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]
Regional Sediments			
Chamita	36°05′	106°07′	—
Embudo	36°12′	106°58′	—
Otowi	35°52′	106°08′	—
Sandia	S060	E490	—
Pajarito	S185	E410	—
Ancho	S305	E335	—
Frijoles	S375	E235	—
Cochiti	35°37′	106°19′	—
Bernalillo	35°17′	106°36′	—
Jemez River	35°40′	106°44′	—
Perimeter Sediments[b]			
Guaje at SR-4	N135	E480	12
Bayo at SR-4	N100	E455	13
Sandia at SR-4	N025	E315	14
Mortandad at SR-4	S030	E350	15
Cañada del Buey at SR-4	S090	E360	16
Pajarito at SR-4	S105	E320	17
Potrillo at SR-4	S145	E295	18
Water at SR-4	S170	E260	19
Ancho at SR-4	S255	E250	20
Frijoles at National Monument Headquarters	S280	E185	21
Effluent Release Area Sediments			
Acid-Pueblo Canyon			
Acid Weir	N125	E070	22
Pueblo 1	N130	E085	23
Pueblo 2	N120	E145	24
Hamilton Bend Spring	N105	E255	25
Pueblo 3	N090	E315	26
Pueblo at SR-4	N070	E350	27
DP–Los Alamos Canyon			
DPS-1	N090	E160	28
DPS-4	N075	E205	29
Los Alamos at Bridge	N095	E020	30
Los Alamos at LAO-1	N080	E120	31
Los Alamos at GS-1	N075	E200	32
Los Alamos at LAO-3	N075	E215	33
Los Alamos at LAO-4.5	N065	E270	34
Los Alamos at SR-4	N065	E355	35
Los Alamos at Totavi	N065	E405	36
Los Alamos at LA-2	N125	E510	37
Los Alamos at Otowi	N100	E560	38

Table G-31 (Cont)

Station	Latitude or North-South Coordinate	Longitude or East-West Coordinate	Map Designation[a]
Effluent Release Area Sediments (Cont)			
Mortandad Canyon			
Mortandad near CMR Building	N060	E036	39
Mortandad west of GS-1	N045	E095	40
Mortandad at GS-1	N040	E105	41
Mortandad at MCO-5	N035	E155	42
Mortandad at MCO-7	N025	E190	43
Mortandad at MCO-9	N030	E215	44
Mortandad at MCO-13	N015	E250	45
Regional Soils			
Rio Chama	36°05′	106°07′	—
Embudo	36°12′	105°58′	—
Otowi	35°52′	106°08′	—
Near Santa Cruz	35°59′	105°54′	—
Cochiti	35°37′	106°19′	—
Bernalillo	35°17′	106°36′	—
Jemez	35°40′	106°44′	—
Perimeter Soils			
Los Alamos Sportsman Club	N240	E215	S1
North Mesa	N134	E168	S2
TA-8	N060	W075	S3
TA-49	S165	E085	S4
White Rock (east)	S055	E385	S5
Tsankawi	N020	E310	S6
On-Site Soils			
TA-21	N095	E140	S7
East of TA-53	N051	E218	S8
TA-50	N035	E095	S9
Two-Mile Mesa	N025	E030	S10
East of TA-54	S080	E295	S11
R-Site Road East	S042	E103	S12
Potrillo Drive	S065	E195	S13
S-Site	S035	W025	S14
Near test well DT-9	S150	E140	S15
Near TA-33	S245	E225	S16

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[a] Soil sampling locations are given in Figs. 14 and 17; sediment sampling locations, in Figs. 14 and 18.

[b] The three sediment stations on Potrillo, Water, and Ancho canyons located at State Road 4 are considered perimeter stations because all Laboratory facilities are located west of State Road 4. Eight additional sediment stations are located at the confluence of the Rio Grande and the following major canyons: Sandia, Cañada Ancha, Mortandad, Pajarito, Water, Ancho, Chaquihui, and Frijoles.

Table G-32. Radiochemical Analyses of Regional Soils and Sediments[a]

Location	^{3}H (10^{-6} µCi/mL)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	Gross Gamma (counts/min/g)
Soils						
Chamita	0.8 (0.3)	0.25 (0.10)	2.8 (0.3)	0.001 (0.001)	0.014 (0.002)	1.8 (0.4)
Embudo	1.0 (0.3)	0.88 (0.18)	2 (0.2)	0.001 (0.001)	0.016 (0.002)	1.7 (0.4)
Otowi	1.4 (0.3)	0.42 (0.08)	3.8 (0.4)	0.003 (0.003)	0.019 (0.002)	3.4 (0.5)
Near Santa Cruz Lake	1.4 (0.3)	0.09 (0.12)	3.3 (0.3)	0.003 (0.001)	0.001 (0.001)	3.4 (0.5)
Cochiti	0.5 (0.3)	0.38 (0.08)	2.4 (0.2)	0.002 (0.001)	0.010 (0.002)	2.3 (0.4)
Bernalillo	1.1 (0.3)	0.39 (0.13)	1.5 (0.2)	0.002 (0.001)	0.007 (0.001)	0.3 (0.4)
Jemez	0.5 (0.3)	0.14 (0.07)	2.2 (0.2)	0.000 (0.000)	0.006 (0.002)	10 (1.0)
Maximum	1.4 (0.3)	0.88 (0.18)	3.8 (0.4)	0.003 (0.003)	0.019 (0.002)	10 (1.0)
Sediments						
Rio Chama						
Chamita	—	0.20 (0.12)	1.8 (0.2)	0.002 (0.001)	0.004 (0.001)	1.2 (0.5)
Rio Grande						
Embudo	—	0.16 (0.63)	2.0 (0.2)	0.006 (0.001)	0.002 (0.001)	0.5 (0.4)
Otowi	—	0.28 (0.13)	1.2 (0.2)	0.000 (0.001)	0.000 (0.001)	−0.5 (0.4)
Sandia	—	−0.02 (0.10)	3.2 (0.3)	0.001 (0.001)	0.003 (0.001)	2.6 (0.4)
Pajarito	—	0.15 (0.06)	3.2 (0.3)	0.000 (0.001)	0.006 (0.001)	1.5 (0.4)
Ancho	—	−0.01 (0.06)	2.5 (0.2)	0.000 (0.001)	0.005 (0.001)	1.7 (0.4)
Frijoles	—	−0.05 (0.06)	3.2 (0.3)	0.000 (0.001)	0.003 (0.001)	2.6 (0.4)
Bernalillo	—	0.16 (0.06)	2.2 (0.2)	0.002 (0.001)	0.004 (0.001)	1.3 (0.4)
Jemez River						
Near Jemez	—	−0.08 (0.11)	2.9 (0.3)	0.002 (0.001)	0.005 (0.001)	2.6 (0.5)
Maximum	—	0.28 (0.13)	3.2 (0.3)	0.006 (0.001)	0.006 (0.001)	2.6 (0.5)

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[a] Samples were collected in May 1989; counting uncertainties are in parentheses.

Table G-33. Radiochemical Analyses of Perimeter Soils and Sediments[a]

Location	^{3}H (10^{-6} µCi/mL)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	Gross Gamma (counts/min/g)
Perimeter Soils						
Los Alamos Sportsman Club	3.8 (0.5)	0.33 (0.13)	3.1 (0.3)	0.008 (0.002)	0.011 (0.002)	1.9 (0.4)
North Mesa	2.5 (0.4)	0.29 (0.07)	3.1 (0.3)	0.000 (0.001)	0.004 (0.001)	2.5 (0.4)
TA-8	2.9 (0.4)	0.08 (0.13)	2.0 (0.2)	0.001 (0.001)	0.006 (0.002)	1.7 (0.4)
TA-49	1.5 (0.3)	1.19 (0.17)	4.3 (0.4)	0.002 (0.002)	0.048 (0.005)	3.5 (0.5)
White Rock	1.7 (0.3)	0.34 (0.14)	3.3 (0.3)	0.001 (0.001)	0.007 (0.001)	4.1 (0.6)
Tsankawi	2.6 (0.4)	0.33 (0.09)	5.8 (0.6)	0.003 (0.001)	0.014 (0.002)	6.2 (0.7)
Maximum	3.8 (0.5)	1.1 (0.17)	5.8 (0.6)	0.008 (0.002)	0.048 (0.005)	6.2 (0.7)
Perimeter Sediments						
Guaje at SR-4	—	0.12 (0.06)	1.9 (0.2)	0.000 (0.001)	0.002 (0.001)	1.1 (0.4)
Bayo at SR-4	—	0.11 (0.06)	2.0 (0.2)	0.001 (0.001)	0.001 (0.001)	1.5 (0.4)
Sandia at SR-4	—	0.15 (0.06)	2.7 (0.3)	0.001 (0.001)	0.002 (0.001)	2.8 (0.5)
Mortandad at SR-4	—	0.18 (0.12)	2.4 (0.2)	0.000 (0.001)	0.002 (0.001)	1.9 (0.4)
Cañada del Buey at SR-4	—	0.11 (0.06)	1.9 (0.2)	0.001 (0.001)	0.002 (0.001)	1.2 (0.4)
Pajarito at SR-4	—	0.07 (0.11)	2.6 (0.3)	−0.003 (0.001)	0.002 (0.001)	2.2 (0.4)
Potrillo at SR-4	—	0.18 (0.06)	2.2 (0.2)	0.002 (0.001)	0.000 (0.001)	1.6 (0.4)
Water at SR-4	—	0.14 (0.12)	2.0 (0.2)	0.001 (0.001)	0.002 (0.001)	2.4 (0.4)
Ancho at SR-4	—	0.12 (0.06)	2.0 (0.2)	0.001 (0.001)	0.002 (0.001)	2.5 (0.5)
Frijoles at Bandelier	—	0.01 (0.12)	2.2 (0.2)	0.004 (0.001)	0.002 (0.001)	1.6 (0.4)
Sandia at Rio Grande	—	0.11 (0.12)	1.8 (0.2)	0.003 (0.001)	0.003 (0.001)	1.3 (0.4)
Cañada Ancha at Rio Grande	—	0.10 (0.07)	1.6 (0.2)	0.000 (0.001)	0.001 (0.001)	0.8 (0.4)
Mortandad at Rio Grande	—	−0.01 (0.12)	1.4 (0.2)	0.001 (0.001)	0.000 (0.001)	0.4 (0.4)
Pajarito at Rio Grande	—	0.05 (0.07)	1.3 (0.1)	−0.001 (0.001)	0.002 (0.001)	0.9 (0.4)
Water at Rio Grande	—	−0.15 (0.11)	1.8 (0.2)	−0.001 (0.001)	0.002 (0.001)	1.4 (0.4)
Ancho at Rio Grande	—	0.04 (0.06)	1.2 (0.1)	0.004 (0.001)	0.002 (0.001)	1.3 (0.4)
Chaquihui at Rio Grande	—	−0.19 (0.12)	3.2 (0.3)	0.000 (0.001)	0.008 (0.001)	1.7 (0.4)
Frijoles at Rio Grande	—	0.22 (0.08)	2.4 (0.2)	0.001 (0.001)	0.008 (0.002)	2.0 (0.4)
Maximum	—	0.18 (0.12)	3.2 (0.3)	0.004 (0.001)	0.008 (0.002)	2.8 (0.5)

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[a] Samples were collected in May 1989; counting uncertainties are in parentheses.

Table G-34. Radiochemical Analyses of On-Site Soils and Sediments[a]

Location	^{3}H (10^{-6} µCi/mL)	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{241}Am (pCi/g)	Gross Gamma (counts/min/g)
On-Site Soils								
TA-21	4.2 (0.6)	—	0.04 (0.13)	3.5 (0.4)	0.005 (0.001)	0.013 (0.002)	—	2.7 (0.5)
East of TA-53	4.0 (2.0)	—	0.26 (0.08)	3.5 (0.4)	0.002 (0.001)	0.012 (0.002)	—	2.9 (0.5)
TA-50	3.6 (0.5)	—	0.09 (0.11)	3.7 (0.4)	0.000 (0.000)	0.016 (0.002)	—	3.8 (0.5)
Two-Mile Mesa	2.3 (0.4)	—	1.28 (0.20)	3.6 (0.4)	0.002 (0.001)	0.035 (0.003)	—	3.1 (0.5)
East of TA-54	—	—	0.20 (0.13)	4.0 (0.4)	0.004 (0.001)	0.010 (0.002)	—	2.3 (0.4)
R-Site Road	6.7 (0.9)	—	0.57 (0.10)	2.9 (0.3)	0.001 (0.001)	0.013 (0.002)	—	2.7 (0.5)
Potrillo Drive	120 (10)	—	0.28 (0.13)	3.6 (0.4)	0.004 (0.001)	0.008 (0.001)	—	3.8 (0.5)
S-Site	0.1 (0.3)	—	0.13 (0.06)	3.5 (0.4)	0.000 (0.001)	0.002 (0.001)	—	2.9 (0.5)
Near test well DT-9	0.1 (0.3)	—	0.20 (0.14)	3.6 (0.4)	0.002 (0.001)	0.004 (0.001)	—	4.3 (0.6)
Near TA-33	10 (1.0)	—	0.26 (0.26)	3.1 (0.3)	0.002 (0.001)	0.007 (0.002)	—	3.6 (0.5)
Maximum	120 (10)	—	1.28 (0.20)	4.0 (0.4)	0.005 (0.001)	0.035 (0.003)	—	3.8 (0.5)
Sediments from Effluent Release Areas								
Acid-Pueblo Canyon								
Acid Weir	—	0.40 (0.25)	0.41 (0.09)	2.8 (0.3)	0.053 (0.015)	9.32 (0.393)	0.310 (0.020)	1.7 (0.4)
Pueblo 1	—	0.20 (0.24)	0.20 (0.13)	2.5 (0.3)	0.002 (0.001)	0.007 (0.002)	0.002 (0.001)	3.4 (0.5)
Pueblo 2	—	0.25 (0.23)	0.18 (0.07)	2.8 (0.3)	0.003 (0.001)	0.674 (0.030)	0.032 (0.003)	3.2 (0.5)
Hamilton Bend Spring	—	0.05 (0.31)	0.15 (0.15)	3.0 (0.3)	0.000 (0.000)	0.152 (0.009)	0.006 (0.002)	2.7 (0.5)
Pueblo 3	—	−0.26 (0.39)	0.15 (0.06)	2.2 (0.2)	0.000 (0.000)	0.003 (0.001)	0.002 (0.001)	2.2 (0.4)
Pueblo at SR-4	—	−0.08 (0.33)	0.25 (0.14)	1.8 (0.2)	0.000 (0.001)	0.002 (0.001)	0.001 (0.001)	1.2 (0.4)
Maximum	—	0.40 (0.25)	0.41 (0.09)	3.0 (0.3)	0.053 (0.015)	9.32 (0.393)	0.310 (0.020)	3.4 (0.5)

Table G-34 (Cont)

Location	^{3}H (10^{-6} µCi/mL)	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{241}Am (pCi/g)	Gross Gamma (counts/min/g)
Sediments from Effluent Release Areas (Cont)								
DP–Los Alamos Canyon								
DP Canyon at DPS-1	—	—	0.30 (0.08)	2.0 (0.2)	0.003 (0.015)	0.043 (0.012)	0.370 (0.060)	2.1 (0.4)
DP Canyon at DPS-4	—	0.27 (0.37)	0.25 (0.14)	3.4 (0.3)	0.002 (0.001)	0.356 (0.017)	0.007 (0.001)	4.7 (0.6)
Los Alamos Canyon at Bridge	—	0.54 (0.44)	0.16 (0.07)	2.2 (0.2)	0.000 (0.001)	0.003 (0.001)	0.002 (0.001)	2.3 (0.4)
Los Alamos Canyon at LAO-1	—	0.02 (0.45)	0.36 (0.16)	4.5 (0.4)	0.004 (0.001)	0.467 (0.021)	0.006 (0.002)	4.8 (0.6)
Los Alamos Canyon at GS-1	—	0.49 (0.94)	1.8 (0.28)	3.4 (0.4)	0.017 (0.002)	0.192 (0.009)	0.103 (0.018)	4.6 (0.6)
Los Alamos Canyon at LAO-3	—	0.09 (0.50)	0.20 (0.13)	3.5 (0.4)	0.001 (0.001)	0.445 (0.021)	0.011 (0.002)	4.6 (0.6)
Los Alamos Canyon at LAO-4.5	—	0.14 (0.25)	2.5 (0.38)	4.0 (0.4)	0.019 (0.003)	0.221 (0.011)	0.138 (0.021)	5.9 (0.7)
Los Alamos Canyon at SR-4	—	0.12 (0.24)	1.5 (0.27)	3.1 (0.3)	0.008 (0.002)	0.124 (0.008)	0.062 (0.008)	4.1 (0.6)
Los Alamos Canyon at Totavi	—	0.03 (0.13)	0.28 (0.07)	2.0 (0.2)	0.001 (0.002)	0.011 (0.003)	0.002 (0.001)	1.7 (0.4)
Los Alamos Canyon at LA-2	—	0.14 (0.20)	0.19 (0.14)	1.7 (0.2)	0.001 (0.001)	0.002 (0.001)	0.002 (0.001)	2.4 (0.4)
Los Alamos Canyon at Otowi	—	0.16 (0.19)	0.11 (0.06)	1.6 (0.2)	0.007 (0.001)	0.002 (0.001)	0.002 (0.001)	1.5 (0.4)
Maximum		0.54 (0.44)	2.5 (0.38)	4.5 (0.4)	0.19 (0.003)	0.467 (0.021)	0.370 (0.050)	5.9 (0.7)
Mortandad Canyon								
Mortandad at CMR Building	—	−0.15 (0.18)	0.10 (0.13)	1.8 (0.2)	0.025 (0.003)	0.105 (0.002)	0.003 (0.001)	1.8 (0.4)
Mortandad west of GS-1	—	0.09 (0.46)	0.20 (0.07)	1.7 (0.2)	0.022 (0.003)	0.007 (0.002)	0.006 (0.001)	2.0 (0.4)
Mortandad at GS-1	—	—	0.30 (0.15)	2.6 (0.3)	−0.003 (0.006)	0.019 (0.011)	0.170 (0.040)	3.7 (0.5)
Mortandad at MCO-5	—	—	23.5 (3.5)	2.1 (0.2)	4.08 (0.173)	14.5 (0.537)	12.8 (0.80)	18 (2.0)
Mortandad at MCO-7	—	1.44 (0.28)	26.7 (4.0)	2.1 (0.2)	3.44 (0.150)	12.8 (0.473)	0.250 (0.050)	17 (2.0)
Mortandad at MCO-9	—	0.14 (0.21)	0.55 (0.11)	4.6 (0.5)	0.002 (0.002)	0.017 (0.004)	0.011 (0.002)	5.1 (0.6)
Mortandad at MCO-13	—	0.07 (0.20)	0.63 (0.18)	2.6 (0.3)	0.002 (0.002)	0.018 (0.005)	0.006 (0.001)	2.2 (0.4)
Maximum	—	—	26.7 (4.0)	4.6 (0.5)	4.08 (0.173)	14.5 (0.537)	12.8 (0.080)	18 (2.0)

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[a] Samples were collected in April and May 1989; counting uncertainties are in parentheses.

Table G-35. Radiochemical Analyses of Sediments from Reservoirs on the Rio Chama and Rio Grande[a]

Location	^{3}H (10^{-6} μCi/mL)	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	Total Uranium (μg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	^{241}Am (pCi/g)	Gross Gamma (counts/min/g)
Abiquiu Reservoir								
Upper	0.3 (0.3)	0.25 (0.26)	0.34 (0.09)	3.3 (0.3)	0.0007 (0.0001)	0.0041 (0.002)	—	2.3 (0.4)
Middle	−0.1 (0.3)	2.1 (0.35)	0.24 (0.13)	3.4 (0.3)	0.0003 (0.0001)	0.0036 (0.0001)	—	1.3 (0.4)
Lower	0.5 (0.3)	0.18 (0.27)	0.19 (0.08)	1.8 (0.2)	0.0002 (0.0001)	0.0033 (0.0002)	—	−1.3 (0.4)
Maximum	0.5 (0.3)	2.1 (0.35)	0.34 (0.09)	3.4 (0.3)	0.0003 (0.0001)	0.0041 (0.0002)	—	2.3 (0.4)
Cochiti Reservoir								
Upper	1.0 (0.3)	0.11 (0.37)	0.43 (0.10)	3.2 (0.3)	0.0007 (0.0001)	0.0129 (0.0005)	0.0041 (0.0010)	3.5 (0.5)
Middle	0.7 (0.3)	0.44 (0.39)	0.41 (0.12)	4.2 (0.4)	0.0051 (0.0004)	0.1330 (0.0070)	0.0371 (0.0031)	4.0 (0.5)
Lower	0.4 (0.3)	0.44 (0.39)	0.60 (0.13)	4.2 (0.4)	0.0017 (0.0001)	0.0020 (0.0003)	0.0087 (0.0014)	3.5 (0.5)
Maximum	1.0 (0.3)	0.44 (0.39)	0.60 (0.13)	4.2 (0.4)	0.0051 (0.0004)	0.1330 (0.0070)	0.0317 (0.0031)	4.0 (0.5)
Background (1974–1986)[b]	—	0.87	0.44	4.4	0.006	0.023	—	—

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[a] Samples were collected in June 1989; counting uncertainties are in parentheses.

[b] Background, upper limit (Purtymun 1987a).

Table G-36. Radiochemical Analyses of Sediments from an Active Waste Management Area (TA-54)[a]

Location	^{3}H (10^{-6} µCi/mL)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Gamma (counts/min/g)
Station Number						
1	1.8 (0.4)	0.31 (0.08)	4.3 (0.4)	0.000 (0.001)	0.011 (0.002)	4.5 (0.6)
2	1.9 (0.4)	0.05 (0.04)	4.3 (0.4)	0.007 (0.001)	0.012 (0.002)	4.6 (0.6)
3	1.7 (0.4)	0.20 (0.07)	2.9 (0.3)	0.008 (0.001)	0.014 (0.002)	2.5 (0.4)
4	1.7 (0.4)	0.10 (0.05)	4.3 (0.4)	0.001 (0.001)	0.016 (0.002)	5.1 (0.6)
5	2.0 (0.4)	0.32 (0.08)	4.6 (0.5)	0.002 (0.001)	0.016 (0.002)	5.7 (0.7)
6	1.6 (0.4)	−0.07 (0.04)	2.9 (0.3)	0.005 (0.001)	0.021 (0.002)	3.2 (0.5)
7	1.9 (0.4)	0.05 (0.05)	3.4 (0.3)	0.026 (0.002)	0.015 (0.002)	2.5 (0.4)
8	2.4 (0.4)	−0.06 (0.04)	2.7 (0.3)	0.007 (0.001)	0.010 (0.002)	1.8 (0.4)
9	2.1 (0.4)	0.05 (0.05)	2.8 (0.3)	0.011 (0.002)	0.150 (0.008)	2.9 (0.5)
Maximum concentration	2.4 (0.4)	0.32 (0.08)	4.6 (0.5)	0.026 (0.002)	0.150 (0.008)	5.7 (0.7)
Background (1974–1986)	7.2	0.44	4.4	0.006	0.023	7.9
Maximum concentration as a percentage of background	33	73	104	433	652	72
Analytical limits of detection	0.7	0.1	0.3	0.003	0.002	0.1

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[a] Samples were collected in August 1989; counting uncertainties are in parentheses.

Table G-37. Number of Results above the Analytical LOQs for Organic Compounds in Sediments from an Active Waste Management Area (TA-54)[a]

	Type of Organic Compound				
	Volatile	Semivolatile	Pesticide	Herbicide	PCB[b]
Number of Compounds Analyzed	65	68	22	3	4
Station					
1	3	1	0	0	0
2	3	0	0	0	0
3	4	0	0	0	0
4	4	0	0	0	0
5	2	0	0	0	0
6	2	0	0	0	0
7	2	0	0	0	0
8	4	1	0	0	0
9	2	0	0	0	0

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[a] Samples were collected in August 1989; see Table 23 for values of analytical results reported above LOQs and Appendix C for list of compounds analyzed in each set.

[b] Total mixed aroclors and three specific aroclors were reported for the PCB analyses.

Table G-38. Radionuclides in Local and Regional Produce[a]

	^{3}H (pCi/mL)	^{90}Sr (10^{-3} pCi/dry g)	Total Uranium (ng/dry g)	^{238}Pu (10^{-5} pCi/dry g)	$^{239,240}Pu$ (10^{-5} pCi/dry g)
Cochiti/Santo Domingo					
N	11	11	11	11	11
Mean	0.2	14	16	−9.5	4.4
Std dev	0.6	16	14	32	26
Minimum	−1.5 (0.3)	0.3 (1.8)	3.5 (0.5)	−110 (130)	−54 (120)
Maximum	0.8 (0.3)	4.8 (6.9)	46 (5.6)	4.5 (10)	55 (15)
Española					
N	8	8	8	8	8
Mean	0.0	19	56	1.7	2.0
Std dev	0.3	19	45	9.1	4.7
Minimum	−0.3 (0.3)	1.5 (2.4)	11 (1.5)	−1.3 (8.2)	−6.5 (6.5)
Maximum	0.5 (0.3)	53 (22)	130 (15)	1.6 (12)	10 (10)
San Ildefonso					
N	3	3	3	3	3
Mean	0.2	17	31	−5.0	−0.3
Std dev	0.3	17	−23	8.0	3.9
Minimum	0.1 (0.3)	1.3 (2.3)	−5.4 (0.5)	−14 (83)	−4.0 (6.3)
Maximum	0.4 (0.3)	34 (4.5)	−52 (4.5)	0.0 (1.9)	3.8 (6.0)
Los Alamos/White Rock					
N	7	7	7	7	7
Mean	−0.1	13	37	−3.2	−5.9
Std dev	0.6	9.6	27	50	24
Minimum	−1.3 (0.3)	1.2 (3.6)	8.2 (1.0)	−90 (52)	−52 (43)
Maximum	0.7 (0.3)	27 (19)	72 (7.2)	81 (42)	16 (34)
On Site					
N	2	2	2	2	2
Mean	0.1	6.8	7.7	2.3	1.3
Std dev	0.0	5.1	1.9	3.3	4.7
Minimum	0.1 (0.3)	3.2 (4.0)	6.3 (0.8)	0.0 (3.4)	−2.0 (2.0)
Maximum		10 (4.0)	9.1 (1.0)	4.2 (6.8)	4.7 (4.7)
Minimum detectable limit	0.7		30	20	10

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[a] Counting uncertainties are in parentheses.

Table G-39. Radionuclides in Fish[a]

	^{90}Sr (10^{-3} pCi/dry g)	^{137}Cs (10^{-3} pCi/dry g)	Total Uranium (ng/dry g)	^{238}Pu (10^{-5} pCi/dry g)	^{239}Pu (10^{-5} pCi/dry g)
Catfish					
Abiquiu					
N	7	7	7	5	5
Mean	33	62	9.0	0.5	3
Std dev	14	71	1.6	5	2
Minimum	16 (5.5)	−0.3 (9.9)	6.4 (0.6)	−4 (3)	0 (6)
Maximum	55 (5.2)	160 (140)	12 (1.2)	7 (6)	5 (4)
Cochiti					
N	9	9	9	5	5
Mean	24	−1400	8.6	1	−0.2
Std dev	9.2	1800	4.1	4	3
Minimum	11 (4.8)	−5600 (5200)	3.7 (0.4)	−4 (6)	−4 (4)
Maximum	35 (7.2)	−190 (470)	15 (1.5)	7 (6)	3 (3)
Crappie					
Abiquiu					
N	10	10	10	5	5
Mean	82	−4	2.2	6	−0.4
Std dev	28	74	0.60	5	3
Minimum	36 (7.8)	−150 (120)	1.5 (0.2)	3 (10)	−5 (6)
Maximum	120 (7.5)	100 (100)	3.2 (0.3)	14 (10)	3 (6)
Cochiti					
N	10	10	10	5	5
Mean	87	−44	3.4	10	8
Std dev	18	160	0.6	3	7
Minimum	43 (6.5)	−45 (200)	2.5 (0.2)	9 (9)	−3 (9)
Maximum	10 (16)	180 (180)	4.4 (0.4)	17 (8)	16 (10)
Minimum detectable limit		10	3	30	20

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[a] Counting uncertainties are in parentheses.

Table G-40. Locations of Beehives

Station	North-South Coordinate	East-West Coordinate
Regional Stations (28–44 km), Uncontrolled Areas		
1. Chimayo	—	—
13. San Pedro	—	—
16. El Rancho	—	—
17. San Juan	—	—
Perimeter Stations (0–4 km), Uncontrolled Areas		
2. Northern Los Alamos County	N180	W020
3. Pajarito Acres	S210	E380
On-Site Stations, Controlled Areas		
4. TA-21 (DP Canyon)	N095	E180
5. TA-50 (Upper Mortandad Canyon)	N040	E095
6. TA-53 (LAMPF)	N050	E220
7. Lower Mortandad Canyon	N020	E185
8. TA-8 (Anchor Site W)	S020	W065
9. TA-33 (HP-Site)	S260	E265
10. TA-54 (Area G)	N050	E220
11. TA-9 (Anchor Site E)	S005	W040
12. TA-15 (R-Site)	S020	E065
14. Near TA-49, Frijoles Mesa	S160	E105
15. TA-16 (S-Site)	S055	W080

Table G-41. Selected Radionuclides in Local and Regional Honey[a]

Station	^{3}H (pCi/L)	^{7}Be (pCi/L)	^{22}Na (pCi/L)	^{54}Mn (pCi/L)	^{57}Co (pCi/L)	^{83}Rb (pCi/L)	^{137}Cs (pCi/L)
El Rancho	300 (300)	190 (140)	130 (100)	80 (110)	120 (83)	−3.5 (110)	250 (120)
San Pedro	500 (300)	−11 (97)	−96 (92)	140 (97)	38 (71)	12 (71)	110 (73)
San Juan	1 600 (300)	120 (130)	25 (120)	17 (110)	30 (82)	33 (110)	100 (86)
Pajarito Acres	200 (300)	−10 (97)	37 (90)	100 (92)	170 (75)	49 (72)	100 (83)
TA-5	1 000 (300)	120 (140)	47 (110)	58 (110)	−61 (82)	49 (110)	150 (110)
TA-8	1 600 (300)	230 (140)	190 (110)	150 (110)	220 (81)	150 (110)	220 (100)
TA-9	100 (300)	−90 (98)	37 (92)	81 (95)	160 (74)	47 (81)	100 (73)
TA-15	600 (300)	86 (130)	86 (120)	88 (110)	130 (76)	−64 (110)	420 (130)
TA-16	500 (300)	36 (88)	−130 (91)	140 (98)	12 (70)	18 (70)	28 (71)
TA-21	3 900 (500)	−56 (98)	130 (92)	150 (95)	150 (74)	−62 (81)	12 (71)
TA-33	38 000 (4 000)	76 (130)	75 (110)	48 (110)	280 (85)	−75 (110)	−41 (85)
TA-49	1 100 (300)	−5.5 (88)	93 (93)	69 (93)	180 (75)	26 (71)	14 (71)
TA-50	1 300 (300)	−36 (87)	−160 (92)	−36 (94)	100 (73)	85 (72)	96 (82)
TA-53	61 000 (6 000)	180 (140)	2 900 (460)	100 (110)	310 (89)	98 (110)	97 (100)
TA-54	200 (300)	62 (97)	57 (90)	130 (95)	160 (75)	−81 (72)	−12 (71)

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[a] Data are from 1988; counting uncertainties are in parentheses.

Table G-42. Selected Trace Metals in Local and Regional Honey[a]

Station	Arsenic (ng/g)	Beryllium (ng/g)	Boron (µg/g)	Cadmium (ng/g)	Chromium (ng/g)	Lead (µg/g)	Mercury (ng/g)	Selenium (ng/g)
San Pedro	19	<2	12	9.3	90	0.1	<1	<0.1
San Juan	117	<2	20	8.6	150	0.1	<1	<0.1
Pajarito Acres	15	<2	7	9.4	120	0.1	3	<0.1
El Rancho	24	<2	2.5	9.5	140	0.1	<1	<0.1
TA-5	81	<2	3.9	9.3	110	0.1	3	<0.1
TA-8	18	<2	4.8	26	270	0.1	3	<0.1
TA-9	81	<2	6.3	6.5	110	0.1	3	<0.1
TA-15	98	<2	6.0	8.0	150	0.1	2	<0.1
TA-16	81	<2	3.5	6.4	120	<0.1	6	<0.1
TA-21	22	<2	11	13	290	0.1	<1	<0.1
TA-33	9	<2	8.2	10	200	0.1	3	<0.1
TA-49	80	<2	6.9	8.5	330	<0.1	<1	<0.1
TA-50	25	<2	3.5	9.5	94	<0.1	<1	<0.1
TA-53	30	<2	10	16	230	0.1	<1	<0.1
TA-54	19	<2	5.1	12	220	<0.1	<1	<0.1

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[a] Data are from 1988; uncertainty of the results is ±10%. The density of honey is about 1860 g/L.

Table G-43. Selected Radionuclides in Local and Regional Bees[a]

Station	^{3}H (pCi/L)	^{7}Be (pCi/g)	^{22}Na (pCi/g)	^{54}Mn (pCi/g)	^{57}Co (pCi/g)	^{83}Rb (pCi/g)	^{137}Cs (pCi/g)	Uranium (ng/g)
El Rancho	400 (300)	0.056 (0.24)	−0.011 (0.032)	0.068 (0.028)	0.27 (0.068)	−0.024 (0.05)	−0.019 (0.028)	45 (0.4)
San Pedro	300 (300)	−0.26 (0.54)	0.057 (0.079)	−0.0023 (0.079)	0.39 (0.16)	−0.0075 (0.14)	0.015 (0.062)	20 (0.2)
San Juan	−200 (300)	2.1 (0.90)	0.16 (0.074)	0.11 (0.082)	0.35 (0.11)	−0.20 (0.035)	0.014 (0.027)	10 (0.2)
Pajarito Acres	10 000 (1 000)	0.26 (0.34)	−0.048 (0.034)	0.12 (0.042)	0.43 (0.077)	−0.056 (0.074)	0.035 (0.012)	21 (0.3)
TA-5	30 000 (3 000)	−0.19 (0.34)	−0.067 (0.036)	0.056 (0.036)	0.32 (0.065)	−0.13 (0.074)	0.027 (0.011)	—
TA-8	700 (300)	0.21 (0.34)	−0.073 (0.036)	0.045 (0.035)	0.41 (0.075)	−0.062 (0.075)	0.026 (0.011)	20 (0.2)
TA-9	300 (300)	−0.17 (0.23)	−0.015 (0.026)	0.071 (0.027)	0.12 (0.051)	0.024 (0.044)	0.054 (0.031)	55 (0.5)
TA-15	2 300 (400)	0.83 (0.76)	0.048 (0.074)	0.048 (0.077)	0.5 (0.12)	−0.22 (0.17)	0.011 (0.022)	110 (0.7)
TA-16	6 800 (800)	−0.059 (0.53)	−0.072 (0.064)	0.063 (0.058)	0.39 (0.14)	0.050 (0.10)	0.13 (0.071)	23 (0.3)
TA-21	6 700 (800)	−0.34 (0.22)	0.054 (0.028)	0.034 (0.026)	0.18 (0.057)	−0.090 (0.048)	0.033 (0.028)	44 (0.4)
TA-33	4 900 (600)	−0.34 (0.35)	−0.03 (0.034)	0.035 (0.035)	0.31 (0.064)	0.088 (0.065)	0.023 (0.012)	71 (0.5)
TA-49	600 (300)	−0.29 (0.22)	−0.031 (0.03)	0.025 (0.026)	0.17 (0.056)	−0.033 (0.046)	0.013 (0.031)	48 (0.4)
TA-50	63 000 (6 000)	−0.23 (0.24)	−0.05 (0.031)	0.0080 (0.026)	0.21 (0.063)	−0.024 (0.050)	0.020 (0.028)	34 (0.3)
TA-53	110 000 (10 000)	0.21 (0.40)	18 (2.7)	0.53 (0.090)	0.67 (0.11)	−0.82 (0.14)	0.02 (0.012)	22 (0.3)
TA-54	130 000 (10 000)	0.10 (0.24)	−0.06 (0.031)	0.060 (0.028)	0.20 (0.059)	−0.056 (0.046)	0.021 (0.032)	61 (0.5)

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[a] Data are from 1988; counting uncertainties are in parentheses.

Table G-44. Selected Trace Metals in Local and Regional Bees[a]

Station	Arsenic (ng/g)	Beryllium (ng/g)	Boron (µg/g)	Cadmium (ng/g)	Chromium (ng/g)	Lead (µg/g)	Mercury (ng/g)	Selenium (ng/g)
San Pedro	<1	<2	13	40	96	0.3	27	<1
San Juan	<1	<2	11	25	81	0.3	<3	<1
Pajarito Acres	170	<2	3.4	30	1.8	0.7	<3	<1
El Rancho	170	<2	<0.1	<1	1.8	0.7	<3	<1
TA-5	100	<2	53	6	700	0.6	<3	<1
TA-8	170	<2	12	40	510	0.3	<3	<1
TA-9	180	<2	—	150	1.7	0.8	<3	
TA-15	100	<2	28	40	740	1	<3	<1
TA-16	11	<2	11	120	100	0.5	<3	<1
TA-21	90	<2	5.3	20	710	0.4	<3	—
TA-33	25	<2	<0.1	25	140	0.3	<3	—
TA-49	70	<2	4.3	<1	320	0.2	<3	—
TA-50	45	<2	—	66	150	0.3	<3	<1
TA-53	25	<2	7.3	15	120	3	<3	—
TA-54	90	75	10	15	235	0.5	<3	—

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[a] Data are from 1988; uncertainty of the results is ±10%.

Table G-45. Hazardous Waste Management Facilities at Los Alamos National Laboratory

Technical Area	Facility Type	<90-Day Storage	Inclusion in Part B Permit Application or Interim Status	NMEID Application Closure
TA-54, Area L	Tank treatment		Permitted	
	Container storage		Interim status	
	Landfill[a]		Neither	FY 1991
	Oil storage tanks		Neither	FY 1990
TA-54, Area G	Landfill[a]		Neither[b]	
TA-50-1	Batch treatment		Permitted	
	Container storage		Permitted	
TA-50-37	Controlled-air incinerator		Permitted	
	Container storage (feed bay)	Yes	Neither	
	Container storage (room 117)		Permitted	
TA-3-102	Container storage	Yes	Neither	
TA-3-40	Container storage	Yes	Neither	
TA-14 (2 units)	Miscellaneous unit		Interim status	
TA-15	Miscellaneous unit		Interim status	
TA-36	Miscellaneous unit		Interim status	
TA-39-6	Miscellaneous unit		Interim status	
TA-39-57	Miscellaneous unit		Interim status	
TA-22-24	Container storage		Neither	Closed
TA-40-2	Container storage		Neither	Closed
TA-40 (detonation pit)	Miscellaneous unit		Neither	FY 1990
TA-16 (6 units)	Miscellaneous unit		Interim status	
TA-16, Area P	Landfill[a]		Neither	FY 1991
TA-46 (not in use)	Tank storage	Yes	Neither	
TA-16	Surface impoundment		Neither	FY 1990
TA-54, Area H	Landfill[a]		Neither	FY 1990
TA-35-85	Surface impoundment		Neither	FY 1990
TA-35-125	Surface impoundment		Neither	FY 1990
TA-3-39	Container storage	Yes		
TA-3-30	Container storage	Yes		
TA-3-66	Container storage	Yes		
TA-16 (burn ground)	Container storage	Yes		
TA-3-38 (paint shop)	Container storage	Yes		

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[a] Interim status was terminated in November 1985. These landfills are in the process of being closed in accordance with New Mexico Hazardous Waste Management Regulations.

[b] May be added to Part B when mixed-waste regulatory issues are settled.

Table G-46. Resource Conservation and Recovery Act (RCRA) Interactions among the Laboratory, the U.S. Environmental Protection Agency (EPA), and New Mexico's Environmental Improvement Division (NMEID) in 1989

January 5, 1989	NMEID disapproves the TA-16 surface-impoundment closure plan and requests revised closure plan within 30 days.
February 3, 1989	DOE and the Laboratory hold negotiation meeting with NMEID on the draft RCRA permit.
February 6, 1989	The Laboratory submits revised TA-16 surface-impoundment closure plan to NMEID.
February 1989	The Laboratory submits Solid Waste Management Units (SWMUs) report to the EPA Region VI, with a copy to NMEID (the report is used in determining investigative and corrective-action schedules for permit negotiations with the EPA).
February 14, 1989	DOE requests a determination from NMEID on the operation of the Batch Waste Treatment Plant at TA-50 and the discharge of treated waste into the Industrial Waste Treatment Plant at TA-50.
	DOE and the Laboratory hold negotiation meeting with NMEID on the draft RCRA permit.
February 21, 1989	NMEID sends facsimile letter to DOE regarding the settlement agreement for the August 30, 1988, compliance order.
February 1989	The Laboratory sends SWMU report, orthogonal/topographic maps, and Environmental Restoration Task Listing to EPA for negotiation on Hazardous and Solid Waste Amendments (HSWA) portion of permit.
February 24, 1989	NMEID sends revised draft RCRA permit closure plans.
	DOE responds to NMEID's letter of February 21, 1989, regarding settlement agreement for compliance order.
February 28, 1989	NMEID responds to DOE requests of February 14, 1989. The state's interpretation is pending because of NMEID's legal review and because DOE's interpretation of the regulations may not be consistent with NMEID's.
March 1, 1989	The Laboratory, DOE, and contract personnel from Roy F. Weston, Inc., meet with the EPA (Steve Slaten and Rich Mayer) to explain the Environmental Restoration Program and the Laboratory's rationale that this is the approach to take in addressing the HSWA permit requirements (continuing releases).
March 3, 1989	DOE sends proposed sequence of RCRA closures to NMEID.

Table G-46 (Cont)

March 7, 1989	NMEID responds to DOE's January 11 response to the Notice of Violation dated November 23, 1988. NMEID states that the DOE's January 11 response adequately addresses the Notice of Violation, but requests that the Laboratory submit a ground-water monitoring waiver.
March 13, 1989	DOE sends letter to NMEID requesting clarification of the state's on-again, off-again authority over mixed waste.
March 1989	DOE submits the Laboratory's ground-water monitoring waiver to NMEID.
March 28, 1989	DOE and the Laboratory hold negotiation meeting with NMEID on draft RCRA permit.
June 18, 1989	NMEID holds public hearing on the RCRA portion of the Laboratory's draft hazardous waste permit.
August 7, 1989	EPA holds public hearing on the HSWA portion of the Laboratory's draft hazardous waste permit.
	EPA and NMEID conduct RCRA compliance inspection August 7–11, 1989.
August 15, 1989	EPA conducts additional inspection to look at land disposal restriction compliance.
October 11, 1989	NMEID issues a Notice of Violation resulting from the August 7, 1989, inspection. Ten violations were noted.
November 8, 1989	NMEID issues the RCRA permit, with modifications.
November 13, 1989	The Laboratory responds to the October 11, 1989, Notice of Violation, stating that all violations have been corrected.
December 8, 1989	NMEID notifies the Laboratory that the October 11, 1989, Notice of Violation has been adequately addressed.
December 1989	The Laboratory files an appeal against the permit requirement for radiation monitoring at the incinerator.

Table G-47. Types of Discharges and Parameters Monitored at the Laboratory under its NPDES Permit NM0028355

EPA Identification No.	Type of Discharge	Number of Outfalls	Monitoring Required	Sampling Frequency
01A	Power plant	1	Total suspended solids, free available chlorine, pH, flow	Monthly
02A	Boiler blowdown	2	pH, total suspended solids, flow, copper, iron, phosphorus, sulfite, total chromium	Weekly
03A	Treated cooling water	36	Total suspended solids, free available chlorine, phosphorus, pH, flow	Weekly
04A	Noncontact cooling water	28	pH, flow	Weekly
050 051	Radioactive waste treatment plant	2	Ammonia, chemical oxygen demand, total suspended solids, cadmium, chromium, copper, iron, lead, mercury, zinc, pH, flow	Weekly
05A	High explosive	19	Chemical oxygen demand, pH, flow, total suspended solids	Weekly
06A	Photo waste	13	Cyanide, silver, pH, flow	Weekly
128	Printed circuit board	1	pH, chemical oxygen demand, total suspended solids, iron, copper, silver, flow	Weekly
SS	Sanitary waste	10	Biochemical oxygen demand, flow, pH, total suspended solids, fecal coliform bacteria	Variable frequency, from three per month to once quarterly

Table G-48. NPDES Permit Monitoring of Effluent Quality at Sanitary Sewage Treatment Outfalls

Discharge Location (Outfall)	Permit Parameters	Number of Deviations	Range of Deviation
TA-3 (01S)	BOD[a]	1	46.7
	TSS[b]	2	50.8–65.0
	Fecal coliform bacteria[c]	1	1 890 000
	pH[d]	0	—
TA-9 (02S)	BOD	0	—
	TSS	0	—
	pH	0	—
TA-16 (03S)	BOD	0	—
	TSS	0	—
	pH	0	—
TA-18 (04S)	BOD	0	—
	TSS (90)	0	—
	pH	0	—
TA-21 (05S)	BOD	0	—
	TSS	1	60.0
	pH	0	—
TA-35 (10S)	BOD	0	—
	TSS (90)	0	—
	pH	0	—
TA-41 (06S)	BOD	0	—
	TSS	0	—
	Fecal coliform bacteria	0	—
	pH	0	—
TA-46 (07S)	BOD	0	—
	TSS	0	—
	pH	0	—
TA-46 (12S)	BOD	0	—
	TSS	0	—
	pH	0	—
TA-53 (09S)	BOD	1	—
	TSS (90)	0	—
	pH	0	—

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[a] Biochemical oxygen demand (BOD) permit limits are 30 mg/L (20-day average) and 45 mg/L (7-day average).

[b] Total suspended solids (TSS) permit limits are 30 mg/L (20-day average) and 45 mg/L or 90 mg/L (7-day average), dependent on the specific outfall.

[c] Fecal coliform bacteria limits are 1000 organisms/100 mL (20-day average) and 2000 organisms/100 mL (7-day average).

[d] Range of permit pH limits is between 6.0 and 9.0 standard units.

Table G-49. Limits Established by NPDES Permit NM0028355 for Industrial Outfall Discharges

Discharge Category	Permit Parameter	Daily Average	Daily Maximum	Unit of Measurement
Power plant	TSS	30.0	100.0	mg/L
	Free Cl	0.2	0.5	mg/L
	pH	6–9	6–9	standard unit
Boiler blowdown	TSS	30	100	mg/L
	Fe	10	40	mg/L
	Cu	1	1	mg/L
	P	20	40	mg/L
	SO_3	35	70	mg/L
	Cr	Report	Report	mg/L
	pH	6–9	6–9	standard unit
Treated cooling water	TSS	30.0	100.0	mg/L
	Free Cl	0.2	0.5	mg/L
	P	5.0	5.0	mg/L
Noncontact cooling water	pH	6–9	6–9	standard unit
Radioactive waste treatment plant	COD[a]	18.8	37.5	lb/day
	COD[b]	94.0	156.0	lb/day
	TSS[a]	3.8	12.5	lb/day
	TSS[b]	18.8	62.6	lb/day
	Cd[a]	0.01	0.06	lb/day
	Cd[b]	0.06	0.3	lb/day
	Cr[a]	0.02	0.08	lb/day
	Cr[b]	0.19	0.38	lb/day
	Cu[a]	0.13	0.13	lb/day
	Cu[b]	0.63	0.63	lb/day
	Fe[a]	0.13	0.13	lb/day
	Fe[b]	1.0	2.0	lb/day
	Pb[a]	0.01	0.03	lb/day
	Pb[b]	0.06	0.15	lb/day
	Hg[a]	0.007	0.02	lb/day
	Hg[b]	0.003	0.09	lb/day
	Zn[a]	0.13	0.37	lb/day
	Zn[b]	0.62	1.83	lb/day
	pH[a]	6–9	6–9	standard unit
	pH[b]	6–9	6–9	standard unit
High explosive	COD	150.0	250.0	mg/L
	TSS	30.0	45.0	mg/L
	pH	6–9	6–9	standard unit

Table G-49 (Cont)

Discharge Category	Permit Parameter	Daily Average	Daily Maximum	Unit of Measurement
Photo waste	CN	0.2	0.2	mg/L
	Ag	0.5	1.0	mg/L
	pH	6–9	6–9	standard unit
Printed circuit board	COD	1.9	3.8	lb/day
	TSS	1.25	2.5	lb/day
	Fe	0.05	0.1	lb/day
	Cu	0.05	0.1	lb/day
	Ag	Report	Report	lb/day
	pH	6–9	6–9	standard unit

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[a] Limitations for outfall 050 located at TA-21-257; COD = chemical oxygen demand.

[b] Limitations for outfall 051 located at TA-50-1.

Table G-50. NPDES Permit Monitoring of Effluent Quality at Industrial Outfalls[a]

Discharge Category	Outfall No.	Number of Outfalls	Permit Parameter	Number of Deviations	Range of Deviations	Number of Outfalls with Deviations
Power plant	01A	1	TSS[b]	0	—	0
			Free Cl	0	—	0
			pH	0	—	0
Boiler blowdown	02A	2	pH	0	—	0
			TSS	2	127.0–265.0	1
			Cu	0	—	0
			Fe	0	—	0
			P	0	—	0
			SO_3	0	—	0
			Cr	0	—	0
Treated cooling water	03A	36	TSS	0	—	0
			Free Cl	1	1.2	1
			P	0	—	0
			pH	0	—	0
Noncontact cooling water	04A	28	pH	0	—	0
Radioactive waste treatment plant	051 and 050	2	COD[c]	0	—	0
			TSS	0	—	0
			Cd	0	—	0
			Cr	0	—	0
			Cu	0	—	0
			Fe	0	—	0
			Pb	0	—	0
			Hg	0	—	0
			Zn	0	—	0
			pH	0	—	0
High explosive	05A	19	COD	0	—	0
			TSS	1	249.0	1
			pH	0	—	0
Photo waste	06A	13	CN	0	—	0
			Ag	0	—	0
			TSS	0	—	0
			pH	0	—	0

Table G-50 (Cont)

Discharge Category	Outfall No.	Number of Outfalls	Permit Parameter	Number of Deviations	Range of Deviations	Number of Outfalls with Deviations
Printed circuit board	128	1	pH	0	—	0
			COD	0	—	0
			Ag			
			Fe	0	—	0
			Cu	0	—	0
			TSS	0	—	0
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[a] Limits set by the NPDES permit are presented in Table G-49.

[b] Total suspended solids.

[c] Chemical oxygen demand.

Table G-51. Federal Facility Compliance Agreement (FFCA): Schedule for Upgrading the Laboratory's Waste-Water Outfalls

Outfalls	Date	Status or Target Date
Outfall 02A (Boiler Blowdown)		
Final design complete	December 1988	Completed
Advertisement of construction contract	February 1989	Completed
Award of construction contract	April 1989	Completed
Construction completion	September 1989	Completed
In compliance with final limits	October 1989	Completed
Outfall 04S (TA-18 Sanitary Treatment Plant)		
Final design complete	October 1989	Completed
Advertisement of construction contract	December 1989	September 1990
Award of construction contract	February 1990	December 1990
Construction completion	January 1992	January 1992
Special facilities completion and facility startup	June 1992	June 1992
In compliance with final limits	July 1992	July 1992
Outfall 05A (High-Explosive Discharge)		
Final design complete	December 1988	Completed
Advertisement of construction contract	February 1989	Completed
Award of construction contract	April 1989	Completed
Construction completion	August 1989	Completed
In compliance with final limits	October 1989	Completed
Outfall 09S (TA-53 Lagoons)		
Final design complete	October 1989	Completed
Advertisement of construction contract	December 1989	September 1990
Award of construction contract	February 1990	December 1990
Construction completion	January 1992	January 1992
Special facilities completion and facility startup	June 1992	June 1992
In compliance with final limits	July 1992	July 1992

Table G-52. Federal Facility Compliance Agreement (FFCA): Interim Compliance Limits

Effluent Characteristic	Discharge Limitation[a] Daily Average (lb/day)	 Daily Average (mg/L)	 Daily Maximum (mg/L)
Industrial Outfalls			
Outfall 05A (High Explosive)			
Flow	N/A	N/A	N/A
Chemical oxygen demand	N/A	650.0	1000
Total suspended solids	N/A	60.0	90
Outfall 02A (Boiler Blowdown)			
Flow	N/A	N/A	N/A
Total suspended solids	N/A	180.0	250.0
Total iron	N/A	20.0	60.0
Total copper	N/A	2.0	2.0
Total phosphorous	N/A	30.0	60.0
Sulfite (as SO_3)	N/A	45.0	80.0
Total chromium	N/A	Report	Report
Sanitary Waste-Water Outfalls			
Outfall 04S (Located at TA-18)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	2.5	60.0	90.0
Total suspended solids	2.5	60.0	150.0
pH[b]		5.5 minimum	11.0 maximum
Outfall 10S (Located at TA-35)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	23.2	115	185
Total suspended solids	26.1	130	170
Outfall 09S (Located at TA-53)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	42.0	70.0	160.0
Total suspended solids	54.0	90.0	150.0
pH[b]		5.5 minimum	11.0 maximum

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[a] Flows must be monitored and reported (in millions of gallons per day).

[b] The pH must be between 6.0 and 9.0 standard units.

Table G-53. Status of Environmental Documentation[a] Prepared for Proposed Laboratory Projects by Group HSE-8

1. **Burn Facility at TA-11**
   ADM approved by the Laboratory Environmental Review Committee (LERC), October 1989
2. **Infrastructure Support Facilities (ISFs) Gas Line Replacement**
   ADM approved by LERC, June 1989
3. **ISF Gas Line Replacement, Phase I**
   ADM approved by LERC, June 1989
4. **Oralloy Area Renovation, TA-3**
   ADM approved by LERC, April 1989
5. **Sandia Canyon Landfill Utilization, TA-61**
   ADM approved by LERC, April 1989
6. **Utilities Restoration, Los Alamos and Pueblo Canyons**
   ADM approved by LERC, April 1989
7. **Waste Incinerator Facility, TA-36**
   ADM approved by LERC, July 1989
8. **Scintillation Vial Crusher, TA-50**
   ADM approved by LERC, July 1989
   EA preparation directed by DOE, January 1990
9. **Animal Exposures to Compounds One and Two, Revision 1, TA-51**
   ADM revision submitted to DOE, October 1989
10. **Weapons Engineering Tritium Facility, TA-16**
    ADM revision approved by LERC, March 1987
    EA preparation directed by DOE, June 1989
11. **Materials Science Laboratory, TA-3**
    ADM approved by LERC, June 1989
    EA preparation directed by DOE, November 1989
12. **Special Nuclear Materials Research and Development (SNMs R&D) Laboratory, TA-55**
    EA approved by LERC, April 1988
    EIS preparation directed by DOE, September 1989

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[a] Action Description Memorandum (ADM), Environmental Assessment (EA), and Environmental Impact Statement (EIS).

Table G-54. Summary of Estimated Emissions of Toxic Air Pollutants at Los Alamos in 1989

Pollutant	Emissions (lb/yr)	Pollutant	Emissions (lb/yr)
Kerosene	15 256	Methyl chloride	17
Acetone	10 872	*N*-Butyl alcohol	16
Gasoline	7 269	Dimethyl acetamide	15
Methyl alcohol	4 437	Ammonium chloride fume	14
Ammonia	3 816	Oil mist	13
Methyl ethyl ketone (MEK)	3 180	Boron oxide	13
VM&P naphtha	2 162	Carbon disulfide	13
Hydrogen chloride	1 832	Carbon tetrachloride	12
Nitric acid	1 674	Formamide	12
Methyl acetate	1 500	Methyl isobutyl ketone	11
Xylene	1 347	Formaldehyde	9
Trichloroethylene	1 229	Cyclohexane	9
Nitric oxide	1 049	Acrylonitrile	7
Nitrogen oxide	1 049	2,4,6-Trinitrotoluene (TNT)	7
2-Butoxyethanol	1 014	Naphthalene	7
Stoddard solvent	941	*tert*-Butyl alcohol	7
Isopropyl alcohol	829	Methyl isobutyl carbinol	7
Methylene chloride	702	Formic acid	7
Turpentine	579	Methyl *N*-butyl ketone	6
Soft wood	525	Boron trifluoride	6
Nitrous oxide	450	Diethylene triamine	6
Chloroform	443	Hydrogen fluoride as fluorine	6
Hexane (*N*-hexane)	435	Isobutyl acetate	6
Toluene (toluol)	268	Isobutyl alcohol	5
Welding fumes	253	Isopropyl ether	5
Acetonitrile	223	Aluminum oxide	4
Tetrahydrofuran	194	Tin	4
Sulfuric acid	121	Dipropylene glycol methyl ether	4
Dioxane	119	Zinc chloride fume	4
sec-Butyl alcohol	109	Potassium hydroxide	3
N-Butyl acetate	100	Heptane (*N*-heptane)	3
Fluoride compounds, as fluorine	99	Glutaraldehyde	3
Acetic acid	96	Dichlorofluoromethane	2
Fluorine	82	2-Nitropropane	2
Ethyl acetate	81	Acetic anhydride	2
Ethylene dichloride	66	Acrylamide	2
Pyridine	65	Sodium hydroxide	2
Dimethylformamide	53	Cyclohexanone	2
Ethylene glycol vapor	50	Nitrobenzene	1
N-Amyl acetate	38	1,1-Dichloroethane	1
Trichloroacetic acid	37	Aluminum	1
Hydrogen peroxide	29	Sodium bisulfite	1
Propyl alcohol	23	Hydrogen bromide	1
Phenol	22	Magnesium oxide fume	1
Lithium hydride	21	Hydrogen sulfide	1
Styrene, monomer	19	Chromic acid	1
Phosphoric acid	19	Barium soluble compounds, as barium	1
Ethyl ether	18	Vinyl acetate	1

Table G-55. Los Alamos, New Mexico,[a] Climatological Summary (1911–1989), Temperature and Precipitation Means[b] and Extremes

	Temperature (°F)[c]										
	Normals			Extremes							
Month	Mean Maximum	Mean Minimum	Average	High Average	Year	Low Average	Year	High Daily Maximum	Date	Low Daily Minimum	Date
January	39.7	18.5	29.1	37.6	1986	20.9	1930	64	1/12/81	–18	1/13/63
February	43.0	21.5	32.2	37.4	1934	23.0	1939	69	2/25/86	–14	2/01/51
March	48.7	26.5	37.6	45.8	1972	32.1	1948	73	3/11/89	–3	3/11/48
April	57.6	33.7	45.6	54.3	1954	39.7	1973	80	4/23/50	5	4/09/28
May	67.0	42.8	54.9	60.5	1956	50.1	1957	89	5/29/35	24	5/01/76[c]
June	77.8	52.4	65.1	69.4	1980	60.4	1965	95	6/22/81	28	6/03/19
July	80.4	56.1	68.2	71.4	1980	63.3	1926	95	7/11/35	37	7/07/24
August	77.4	54.3	65.8	70.3	1936	60.9	1929	92	8/10/37	40	8/16/47
September	72.1	48.4	60.2	65.8	1956	56.2	1965	94	9/11/34	23	9/29/36
October	62.0	38.7	50.3	54.7	1963	42.8	1984	84	10/01/80	15	10/19/76
November	48.7	27.1	37.9	44.4	1949	30.5	1972	72	11/01/50	–14	11/28/76
December	41.4	20.3	30.8	38.4	1980	24.6	1931	64	12/27/80	–13	12/09/78
Annual	59.6	36.7	48.1	52.0	1954	46.2	1932	95	6/22/81[c]	–18	1/13/63

Table G-55 (Cont)

	Precipitation (in.)[d]										Mean Number of Days Per Year		
	Precipitation[e]					Snow						Max.	Min.
Month	Mean	Maximum	Year	Daily Maximum	Date	Mean	Maximum	Year	Daily Maximum	Date	Precip. ≥0.10 in.	Temp. ≥90°F	Temp. ≤32°F
January	0.85	6.75	1916	2.45	1/12/16	10.7	64.8	1987	22.0	1/15/87	2	0	30
February	0.68	2.78	1987	1.05	2/20/15	7.3	48.5	1987	20.0	2/19/87	2	0	26
March	1.01	4.11	1973	2.25	3/30/16	9.7	36.0	1973	18.0	3/30/16	3	0	24
April	0.86	4.64	1915	2.00	4/12/75	5.1	33.6	1958	20.0	4/12/75	2	0	13
May	1.13	4.47	1929	1.80	5/21/29	0.8	17.0	1917	12.0	5/02/78	3	0	2
June	1.12	5.67	1986	2.51	6/10/13	0	—	—	—	—	3	0	0
July	3.18	7.98	1919	2.47	7/31/68	0	—	—	—	—	8	1	0
August	3.93	11.18	1952	2.26	8/01/51	0	—	—	—	—	9	0	0
September	1.63	5.79	1941	2.21	9/22/29	0.1	6.0	1913	6.0	9/25/13	4	0	0
October	1.52	6.77	1957	3.48	10/05/11	1.7	20.0	1984	9.0	10/31/72	3	0	7
November	0.96	6.60	1978	1.77	11/25/78	5.0	34.5	1957	14.0	11/22/31	2	0	22
December	0.96	3.21	1984	1.60	12/06/78	11.4	41.3	1967	22.0	12/06/78	3	0	30
Annual	17.83	30.34	1941	3.48	10/05/11	50.8	178.4	1987	22.0	1/15/87	43	2	154
Season							153.2	1986–87		12/06/78			

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[a] Latitude 35°52′ north, longitude 106°19′ west; elevation 2249 m.

[b] Means are based on standard 30-year period: 1951–1980.

[c] Most-recent occurrence.

[d] Metric conversions: 1 in. = 2.5 cm; °F = 9/5 °C + 32.

[e] Includes water equivalent of frozen precipitation.

Table G-56. Los Alamos Climatological Summary for 1989

	Temperature (°F)[a]						
	Means			Extremes			
Month	Mean Maximum	Mean Minimum	Average	High	Date	Low	Date
January	38.5	17.0	27.8	50	19	0	8
February	43.4	21.9	32.6	64	25	–4	6
March	58.0	31.7	44.8	73	11	14	5
April	66.5	38.9	52.7	79	21	19	10
May	73.3	46.2	59.7	84	23	30	1
June	78.3	51.7	65.0	92	19	42	4
July	81.3	55.4	68.4	93	2	51	22,23
August	76.6	52.2	64.4	86	5	47	8
September	73.2	47.6	60.4	83	1	34	14
October	61.4	36.6	49.0	75	1	18	30
November	52.4	27.1	39.7	66	11	10	29
December	40.8	17.7	29.2	56	5	–3	22
Annual	62.1	37.1	49.6	93	7/2/89	–4	2/6/89

Table G-56 (Cont)

	Precipitation (in.)[a]						Number of Days		
	Water Equivalent			Snow				Max.	Min.
Month	Total	Daily Maximum	Date	Total	Daily Maximum	Date	Precip. ≥0.10 in.	Temp. ≥90°F	Temp. ≤32°F
January	1.20	0.75	27	16.6	11.5	27	2	0	31
February	0.99	0.55	5	16.3	10.0	5	4	0	25
March	0.91	0.63	20	7.3	6.5	20	2	0	15
April	0.21	0.18	12	T	T	10	1	0	71
May	1.07	0.75	9	0	0	–	2	0	1
June	0.51	0.18	14	0	0	–	2	1	0
July	3.71	0.70	25	0	0	–	11	8	0
August	3.16	0.91	1	0	0	–	7	0	0
September	2.14	0.67	19	0	0	–	5	0	0
October	1.73	0.62	4	0	0	–	3	0	9
November	0.04	0.04	30	0.6	0.6	30	0	0	24
December	0.50	0.27	30	10.7	4.5	30	2	0	30
Annual	16.17	0.91	8/1/89	51.5	11.5	1/27/89	41	9	142

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[a] Metric conversions: 1 in. = 2.5 cm; °F = 9/5 °C + 32.

Table G-57. Los Alamos Precipitation for 1989 (in.)[a]

	S-Site (Site 1)[b]	North Community (Site 2)	TA-59 (Site 3)	Bandelier (Site 4)	East Gate (Site 5)	Area G (Site 6)	White Rock Y (Site 7)	White Rock (Site 8)
January	1.37	1.45	1.20	1.29	1.12	1.15	1.05	1.29
February	1.33	1.49	0.99	1.15	1.00	0.63	0.94	0.70
March	1.04	0.96	0.91	0.88	0.63	0.67	0.60	0.68
April	0.23	0.16	0.21	0.03	0.19	0.06	0.11	0.10
May	0.43	1.54	1.07	0.94	1.53	1.34	2.39	1.65
June	0.91	0.69	0.51	0.29	0.45	0.40	0.26	0.55
July	5.38	4.50	3.71	4.26	3.35	1.90	2.72	1.70
August	3.55	3.05	3.16	2.72	2.15	2.49	1.74	1.37
September	1.43	3.42	2.14	0.88	1.39	1.16	1.08	1.59
October	1.83	1.89	1.73	1.60	1.87	1.83	1.94	1.93
November	0.03	0.08	0.04	0.04	0.06	0.02	0.04	0.05
December	0.42	0.44	0.50	0.55	0.42	0.37	0.35	0.55
Annual	17.95	19.67	16.17	14.63	14.16	12.02	13.22	12.16

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[a] Metric conversion: 1 in. = 2.5 cm.

[b] See Fig. 28 for site locations.

Table G-58. 1989 Weather Highlights

Key for Abbreviations:

SMDH	Set maximum daily high-temperature record.
TMDH	Tied maximum daily high-temperature record.
SMDL	Set minimum daily low-temperature record.
TMDL	Tied minimum daily low-temperature record.
SMDP	Set maximum daily precipitation record.
TMDP	Tied maximum daily precipitation record.
SMDS	Set maximum daily snowfall record.

January

Snowy.
Snowfall = 16.6 in. (normal = 10.7 in.).
SMDP on the 4th: 0.34 in.
SMDS on the 27th: 11.5 in.
Snowstorm on the 27th closes the Laboratory, schools, and businesses in Los Alamos during the afternoon.
Strong winds with peak gusts of 68 and 53 mph on the 5th and 6th, respectively.

February

Snowy.
Snowfall = 16.3 in. (normal = 7.3 in.).
SMDP on the 5th: 0.55 in.
SMDS on the 5th: 10.0 in.
SMDL on the 6th: −4°F.
Strong winds with peak gusts of 51 and 64 mph on the 20th and 27th, respectively.

March

Very warm, second warmest March on record.
Mean temperature = 44.8°F (normal = 37.6°F).
Only 15 days with minimum temperature ≤32°F (normal = 24 days).
SMDH on the 8th: 67°F.
SMDH on the 9th: 72°F. Also highest for entire month of March.
SMDH on the 10th: 71°F.
SMDH on the 11th: 73°F. Also highest for entire month of March.
SMDH on the 12th: 70°F.
TMDP on the 20th: 0.63 in.
SMDS on the 20th: 6.5 in.
Northern lights visible during the evening on the 12th.
Strong winds with peak gust of 62 mph on the 14th.

Table G-58 (Cont)

April

Very warm, second warmest April on record.

Mean temperature = 52.7°F (normal = 45.6°F).

Only 7 days with minimum temperature ≤32°F (normal = 13 days).

Dry.

Precipitation = 0.21 in. (normal = 0.86 in.).

SMDH on the 7th: 75°F. Also warmest for so early in the season.

SMDH on the 8th: 74°F.

SMDH on the 20th: 78°F.

SMDH on the 21st: 79°F. Also warmest for so early in the season.

TMDH on the 24th: 72°F.

Strong dust devil at Royal Crest Trailer Court on the 20th; boat picked up and damaged.

Haze on the 21st and 22d.

Strong winds with gusts of 50 and 55 mph on the 1st and 3d, respectively.

May

Very warm, third warmest May on record.

Mean temperature = 59.7°F (normal = 54.9 F).

TMDH on the 6th: 78°F.

SMDH on the 7th: 81°F. Also warmest for so early in the season.

SMDH on the 8th: 83°F. Also warmest for so early in the season.

SMDP on the 9th: 0.75 in.

Hailstorm on the 9th, with 0.75- and 0.5-in.-diameter hail reported at White Rock and North Community, respectively. Some damage to cars, accidents in White Rock. Accumulation up to 2 in.; 76-mph wind gust recorded at East Gate.

SMDH on the 23d: 84°F.

Strong thunderstorm winds on the 27th of 76 and 66 mph at Area G and Bandelier sites, respectively.

Strong winds with gusts of 55 and 52 mph on the 3d and 4th, respectively.

Spring (March–May)

Warmest spring on record: 52.4°F (previous warmest was in 1972, with 50.2°F).

June

Dry.

Precipitation = 0.51 in. (normal = 1.12 in.).

SMDH on the 19th: 92°F. Also warmest for so early in the season.

Strong thunderstorm winds on the 8th, with peak gust of 62 mph.

Hazy on the 20th, 21st, 24th, 27th, and 28th.

Table G-58 (Cont)

July

Hot first week.
Month had 8 days with high temperature ≥90°F (normal = 1 day).
Second most 90°F days for July (the most was 11 days in 1980).
Third most 90°F days for any month (the most was 11 days in July 1980; second most, 9 days in June 1980).
TMDH on the 1st: 90°F.
SMDH on the 2d: 93°F (also the warmest day since 95°F on June 21, 1981).
TMDH on the 3d: 91°F.
TMDH on the 8th: 90°F.
Strong thunderstorm on the 14th: 1.90 in. of rain in 3 hours at S-Site (10-year return), with 0.75- to 1-in.-diameter hail falling in North Community.
TMDH on the 18th: 91°F.
Flash flooding in Albuquerque on the 25th. One person was killed.

August

SMDL on the 22d: 45°F.

Summer (June–August)

Second highest total of days with high temperature ≥90°F: 9. The highest was 22 in 1980.

September

SMDL on the 13th: 39°F.
SMDL on the 14th: 34°F.

October

TMDL on the 30th: 18°F.

November

Very dry, with warm daytime temperatures.
Mean high temperature = 52.4°F (normal = 48.7°F).
Precipitation = 0.04 in. (normal = 0.96 in.).
Snowfall = 0.6 in. (normal = 5.0 in.).
TMDL on the 20th: 60°F.
Strong winds with peak gust of 52 mph on the 26th.

December

SMDL on the 22d: −3°F.
SMDS on the 30th: 4.5 in.

Annual

1989 mean temperature = 49.6°F (normal = 48.1°F).
Warmest year since 1981.
1989 precipitation = 16.17 in. (normal = 17.83 in.).
Least precipitation since 1980.
1989 snowfall = 51.5 in. (normal = 50.8 in.).
1988–1989 winter season snowfall = 52.6 in.

Table G-59. Analyses of Surface-Water Quality at Fenton Hill, December 1989[a]

Station	Location	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hard-ness	Specific Conduc-tance (µmho)	pH[c]
F	Sulphur Creek	52	49	5	8.3	20	<5	34	0.1	114	17	0.3	1.2	302	148	294	7.5
J	Jemez River	65	22	4	2.7	27	<5	78	0.2	11	5	1.0	0.1	228	72	163	8.2
N	San Antonio Creek	68	24	3	2.9	19	<5	63	0.2	13	3	1.4	0.0	190	71	146	7.5
Q	Rio Guadalupe	35	81	7	3.2	25	<5	206	0.1	14	7	0.9	0.1	232	234	364	8.2
R	Jemez River	54	84	7	12.7	93	<5	196	0.1	13	85	1.2	0.0	570	241	276	8.7
S	Jemez River	60	75	7	15.9	119	<5	197	0.1	18	125	1.4	0.0	532	217	649	8.5
T	Rio Cebolla	46	26	2	2.8	13	<5	71	0.1	6	2	0.6	0.1	208	77	142	7.7
U	Redondo Creek	37	17	2	3.2	10	<5	44	0.1	11	10	0.2	0.0	216	50	117	7.8
V	Sulphur Creek	49	56	7	11	27	<5	<5	0.1	275	63	0.4	0.0	582	170	468	2.4
LF-1	Lake Fork (6085 m)[d]	Dry															
LF-2	Lake Fork (7285 m)[d]	Dry															
LF-3	Lake Fork (8500 m)[d]	61	14	2	2.7	15	<5	54	0.1	5	3	1.3	0.5	200	44	135	7.4
LF-4	Lake Fork (9420 m)[d]	57	18	2	3.3	17	<5	67	0.2	6	4	1.2	0.4	152	55	148	7.8

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[a] Analysis units are milligrams per liter, except as noted.

[b] Total dissolved solids.

[c] Standard units.

[d] Number represents distance below lower pond (GTP-3) in Lake Fork Canyon.

Table G-60. Analyses of Ground-Water Quality at Fenton Hill, December 1989[a]

Station	Location	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	SO_4	Cl	F	NO_3-N	TDS[b]	Total Hardness	Specific Conductance (µmho)	pH[c]
JS-2,3	Jemez Village (spring)	76	17	3	1.2	18	<5	69	0.2	5	4	0.5	0.1	114	58	137	7.6
JS-4,5	Jemez Village (spring)	72	2	5	1.0	19	<5	85	0.2	4	3	0.5	0.1	184	29	146	7.4
FH-1	Fenton Hill (well)	73	80	7	5.9	23	<5	148	0.2	12	53	0.1	0.6	350	230	422	7.4
JF-1	Jemez Canyon (hot spring)	49	262	23	70.0	641	<5	0	0.2	39	810	2.8	0.8	300	750	3339	7.3
JF-5	Soda Dam (hot spring)	49	424	27	191.0	1130	<5	1240	0.1	43	1600	3.4	0.4	451	1117	5555	6.4
RV-2	San Antonio (hot spring)	81	5	0	1.9	27	<5	47	0.2	28	2	3.4	0.1	270	36	114	8.0
RV-4	Spruce (hot spring)	70	10	2	1.4	58	<5	118	0.2	21	7	0.5	0.0	240	36	279	8.5
RV-5	McCauley (hot spring)	58	12	5	1.1	24	<5	82	0.1	7	3	1.0	0.1	162	50	154	8.4
Loc. 4	La Cueva (well)	87	12	2	2.1	21	<5	75	0.3	4	3	0.2	0.1	231	40	135	7.7
Loc. 6	La Cueva (spring)	75	26	6	3.9	21	<5	100	0.3	5	3	0.4	0.3	91	93	211	7.1
Loc. 27	La Cueva (well)	58	28	5	6.7	18	<5	91	0.4	21	4	0.5	0.1	214	93	207	7.0
Loc. 31	Lake Fork (spring)	59	17	2	3.0	14	<5	67	0.2	5	3	1.0	0.2	190	53	133	7.2
Loc. 39	Lake Fork (tank)	28	13	2	2.1	8	<5	38	0.0	16	3	1.2	0.2	120	43	105	6.7
Loc. 42	La Cueva (well)	52	16	6	4.8	12	<5	34	0.3	8	2	0.5	0.0	64	67	166	6.9
Loc. 47	La Cueva (well)	65	12	6	5.9	320	<5	78	0.0	27	2	3.3	0.0	592	34	955	8.3
Loc. 48	La Cueva (well)	67	31	5	2.2	27	<5	89	0.2	40	15	0.8	0.1	212	81	280	7.0
Loc. 53	Sulphur Creek (well)	67	52	5	6.4	16	<5	148	0.4	17	4	0.4	0.5	212	131	298	7.0
Loc. 54	Sulphur Creek (well)	69	82	12	8.6	49	<5	267	0.3	23	4	0.5	0.0	344	209	507	7.1
Loc. 55	Sulphur Creek (well)	92	87	10	20.8	63	<5	222	0.4	191	5	0.5	0.0	564	222	261	7.1
FH-2	Fenton Hill (well)[d]	74	27	2.7	3.3	13	<5	105	0.4	7	5	0.1	<0.1	212	82	235	—
FH-2	Fenton Hill (well)[d]	70	24	2.9	3.5	13	<5	105	0.3	7	7	0.1	<0.1	200	87	240	74

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[a] Analysis units are milligrams per liter, except as noted.

[b] Total dissolved solids.

[c] Standard units.

[d] A special pumping test of FH-2 was conducted in 1989. The first sample was taken September 7, 1989. Four samples were collected during a 23-minute interval: after pumping 1, 3, 10, and 23 minutes. Samples were analyzed for 68 volatile and 72 semivolatile organic compounds. Results were below limits of detection (see Appendix C for compounds and limits of detection). A second sample was taken September 21, 1989.

Table G-61. Trace Metals in Surface and Ground Waters, Fenton Hill, December 1989[a]

Station	Location	As	B	Ba	Cu	Fe	Li	Se	Hg	Total Uranium (μg/L)
Surface Water										
F	Sulphur Creek	<0.05	<0.1	0.03	<0.05	0.03	<0.1	<0.01	0.0003	<2
J	Jemez River	0.09	<0.1	<0.03	<0.05	0.01	0.1	<0.01	0.0003	2
N	San Antonio Creek	<0.05	<0.1	0.03	<0.05	0.02	0.7	<0.01	0.0002	2
Q	Rio Guadalupe	<0.05	<0.1	0.12	<0.05	<0.01	1.1	<0.01	0.0002	6
R	Jemez River	0.07	0.7	0.09	<0.05	0.02	0.7	<0.01	<0.0002	3
S	Jemez River	0.10	1.0	0.07	<0.05	0.02	1.1	<0.01	<0.0002	2
T	Rio Cebolla	<0.05	<0.1	0.03	<0.05	0.04	<0.1	<0.01	<0.0002	<2
U	Redondo Creek	<0.05	<0.1	<0.03	<0.05	0.03	<0.1	<0.01	<0.0002	<2
V	Sulphur Creek	<0.05	<0.1	<0.03	<0.05	<0.01	<0.1	<0.01	<0.0002	<2
LF-1	Lake Fork Canyon					Dry				
LF-2	Lake Fork Canyon					Dry				
LF-3	Lake Fork Canyon	<0.05	<0.1	<0.03	<0.05	0.08	<0.1	<0.01	0.0002	<2
LF-4	Lake Fork Canyon	<0.05	<0.1	<0.03	<0.05	0.02	<0.01	<0.01	0.0002	<2
Ground Water										
JS-2,3	Jemez Village (spring)	<0.05	<0.1	0.03	<0.05	0.03	<0.1	<0.01	<0.0002	2
JS-4,5	Jemez Village (spring)	<0.05	0.6	0.04	<0.05	—	<0.1	<0.01	<0.0002	2
FH-1	Fenton Hill (well)	<0.05	7.0	0.10	<0.05	0.02	<0.1	<0.01	<0.0002	2
JF-1	Jemez Canyon (hot spring)	<0.05	14	0.24	<0.05	0.10	5.4	0.02	<0.0002	2
JF-5	Soda Dam (hot spring)	<0.08	<0.1	0.40	<0.05	0.07	0.12	<0.05	<0.0002	2
RV-2	San Antonio (hot spring)	<0.05	0.2	<0.03	<0.05	0.02	<0.1	<0.01	<0.0002	2
RV-4	Space (hot spring)	<0.05	<0.1	<0.03	<0.05	<0.01	0.6	<0.01	<0.0002	2
RV-5	McCauley (hot spring)	<0.05	<0.1	<0.03	<0.05	<0.01	1.1	0.02	<0.0002	2
Loc. 4	La Cueva (well)	<0.05	<0.1	0.03	<0.05	0.04	<0.1	0.01	<0.0002	2
Loc. 6	La Cueva (well)	<0.05	<0.1	0.06	<0.05	0.08	<0.1	<0.01	<0.0002	2
Loc. 27	La Cueva (well)	<0.05	<0.1	0.13	<0.05	<0.01	<0.1	<0.01	<0.0002	<2
Loc. 31	Lake Fork (spring)	<0.05	<0.1	<0.03	<0.05	<0.01	<0.1	<0.01	<0.0002	2
Loc. 39	Lake Fork (tank)	<0.05	<0.1	<0.03	<0.05	<0.01	<0.1	<0.01	<0.0002	2
Loc. 42	La Cueva (well)	<0.05	0.4	0.05	<0.05	<0.01	<0.1	<0.01	<0.0002	2
Loc. 47	La Cueva (well)	0.05	0.6	0.35	<0.05	0.04	0.1	<0.01	<0.0002	16
Loc. 48	La Cueva (well)	0.05	<0.1	0.06	0.14	<0.01	<0.1	<0.01	0.0003	<2

Table G-61 (Cont)

Station	Location	As	B	Ba	Cu	Fe	Li	Se	Hg	Total Uranium (µg/L)
Ground Water (Cont)										
Loc. 53	Sulphur Creek (well)	<0.05	<0.1	<0.03	<0.05	0.07	0.6	0.02	<0.0002	2
Loc. 54	Sulphur Creek (well)	<0.05	<0.1	0.14	<0.05	<0.01	<0.1	<0.01	<0.0002	<2
Loc. 55	Sulphur Creek (well)	<0.05	<0.1	0.13	<0.05	<0.01	<0.1	<0.01	<0.0002	2

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[a] Analysis units are milligrams per liter, except as noted. Analyses were performed on samples from the 11 surface-water and 19 ground-water stations listed above for the following constituents, and concentrations were all found to be below limits of detection:

Ag < 0.05 mg/L;
Cd < 0.001 mg/L;
Cu < 0.005 mg/L;
Pb < 0.001 mg/L; and
Tl < 0.002 mg/L.

Table G-62. Summary of Radiochemical Analyses of Sediments from TA-49

Station	^3H (10^{-6} mCi/mL)	^{137}Cs (pCi/g)	Total Uranium (µg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Gamma (counts/min/L)
A-1	0.4 (0.3)	0.31 (0.08)	4.2 (0.4)	0.002 (0.002)	0.006 (0.002)	3.9 (0.5)
A-2	0.1 (0.3)	0.59 (0.15)	3.2 (0.3)	0.009 (0.002)	0.074 (0.005)	3.4 (0.5)
A-3	0.8 (0.3)	0.27 (0.08)	3.1 (0.3)	0.015 (0.010)	0.902 (0.033)	3.6 (0.5)
A-4	0.7 (0.3)	0.86 (0.17)	2.7 (0.2)	0.002 (0.001)	0.016 (0.002)	3.0 (0.5)
A-4A	0.4 (0.3)	0.44 (0.09)	3.5 (0.3)	0.001 (0.001)	0.020 (0.002)	3.8 (0.5)
A-5	0.6 (0.3)	0.49 (0.15)	3.2 (0.3)	0.001 (0.001)	0.014 (0.002)	4.1 (0.6)
A-6	0.7 (0.3)	1.7 (0.27)	3.8 (0.4)	0.003 (0.001)	0.058 (0.004)	4.5 (0.6)
A-7	0.5 (0.3)	0.16 (0.11)	3.3 (0.3)	0.001 (0.001)	0.002 (0.001)	3.7 (0.5)
A-8	0.3 (0.5)	0.30 (0.09)	2.7 (0.3)	0.003 (0.001)	0.006 (0.001)	4.8 (0.6)
A-9	0.1 (0.3)	0.20 (0.11)	3.3 (0.3)	0.002 (0.001)	0.008 (0.002)	4.3 (0.6)
A-10	0.8 (0.3)	0.47 (0.11)	2.4 (0.2)	0.002 (0.001)	0.011 (0.002)	4.5 (0.6)
A-11	0.0 (0.3)	0.39 (0.13)	0.9 (0.1)	0.001 (0.001)	0.004 (0.002)	1.2 (0.4)
Sediment background (1974–1986)[a]		0.44	4.4	0.006	0.023	

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[a] See Purtymun (1987a).

Table G-63. Trace Metals in Solution Extracted from Sediments at TA-49 (mg/L)

	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Maximum extraction procedure toxic threshold	5.0	100	1.0	5.0	5.0	2.0	1.0	5.0
Limits of detection	0.002	0.5	0.01	0.04	0.05	0.002	0.001	0.005
Stations								
A-1	BLD[a]	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-2	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-3	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-4	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-4A	0.003	BLD	BLD	BLD	BLD	BLD	BLD	0.005
A-5	0.002	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-6	0.002	BLD	BLD	0.08	BLD	BLD	BLD	BLD
A-7	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-8	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-9	0.009	BLD	BLD	0.05	BLD	BLD	BLD	0.008
A-10	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
A-11	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD
Maximum	0.009	BLD	BLD	BLD	BLD	BLD	BLD	0.008

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[a] BLD = below limits of detection.

Table G-64. Number of Results above the Analytical LOQ for Organic Compounds in Sediments from TA-49[a]

	Type of Organic Compound				
	Volatile	Semivolatile	Pesticide	Herbicide	PCB[b]
Number of Compounds Analyzed	65	68	22	5	—
Stations					
A-1	0	0	0	0	0
A-2	1	1	0	0	0
A-3	4	1	0	0	0
A-4	1	0	0	0	0
A-4A	0	1	0	0	0
A-5	2	0	0	0	0
A-6	2	0	0	0	0
A-7	4	1	0	0	0
A-8	3	0	0	0	0
A-9	2	0	0	0	0
A-10	2	1	0	0	0
A-11	2	1	0	0	0

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[a] Samples were collected June 22, 1989; see Table 38 for listing of results reported above LOQ.

[b] Mixed aroclor; LOQ is 0.12 mg/kg.

GLOSSARY

activation products	Radioactive products generated as a result of neutrons and other subatomic particles interacting with materials such as air, construction materials, or impurities in cooling water. These "activation products" are usually distinguished, for reporting purposes, from "fission products."
alpha particle	A charged particle (identical to the helium nucleus) composed of two protons and two neutrons that are emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.
background radiation	Ionizing radiation from sources other than the laboratory. This background may include cosmic radiation; external radiation from naturally occurring radioactivity in the earth (terrestrial radiation), air, and water; internal radiation from naturally occurring radioactive elements in the human body; and radiation from medical diagostic procedures.
beta particle	A charged particle (identical to the electron) that is emitted during decay of certain radioactivity atoms. Most beta particles are stopped by ≤ 0.6 cm of aluminum.
controlled area	Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and radioactive materials.
cosmic radiation	High-energy particulate and electromagnetic radiations that originate outside the earth's atmosphere. Cosmic radiation is part of natural background radiation.
curie (Ci)	A special unit of radioactivity. One curie equals 3.70×10^{10} nuclear transformations per second.
dose	A term denoting the quantity of radiation energy absorbed.
dose, absorbed	The energy imparted to matter by ionizing radiation per unit mass of irradiated material. (The unit of absorbed dose is the rad.)
dose, effective	The hypothetical whole-body dose that would give the same risk of cancer mortality and/or serious genetic disorder as a given exposure and that may be limited to just a few organs. The effective dose equivalent is equal to the sum of individual organ doses, each weighted by degree of risk that the organ dose carries. For example, a 100-mrem dose to the lung, which has a weighting

factor of 0.112, gives an effective dose that is equivalent to (100 × 0.12) = 12 mrem.

dose, equivalent	A term used in radiation protection that expresses all types of radiation (alpha, beta, and so on) on a common scale for calculating the effective absorbed dose. It is the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)
dose, maximum boundary	The greatest dose commitment, considering all potential routes of exposure from a facility's operation, to a hypothetical individual who is in an uncontrolled area where the highest dose rate occurs. It assumes that the hypothetical individual is present 100% of the time (full occupancy), and it does not take into account shielding (for example, by buildings).
dose, maximum individual	The greatest dose commitment, considering all potential routes of exposure from a facility's operation, to an individual at or outside the Laboratory boundary where the highest dose rate occurs. It takes into account shielding and occupancy factors that would apply to a real individual.
dose, population	The sum of the radiation doses to individuals of a population. It is expressed in units of person-rem. (For example, if 1000 people each received a radiation dose of 1 rem, their population dose would be 1000 person-rem.)
dose, whole body	A radiation dose commitment that involves exposure of the entire body (as opposed to an organ dose that involves exposure to a single organ or set of organs).
exposure	A measure of the ionization produced in air by x or gamma radiation. (The unit of exposure is the roentgen).
external radiation	Radiation originating from a source outside the body.
fission products	Atoms created by the splitting of larger atoms into smaller ones, accompanied by release of energy.
gallery	An underground collection basin for spring discharges.
gamma radiation	Short-wavelength electromagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength (high energy), gamma radiation can cause ionization. Other electromagnetic radiation (such as microwaves, visible light, radiowaves) have longer wavelengths (lower energy) and cannot cause ionization.

gross alpha	The total amount of measured alpha activity without identification of specific radionuclides.
gross beta	The total amount of measured beta activity without identification of specific radionuclides.
ground water	A subsurface body of water in the zone of saturation.
half-life, radioactive	The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains (1/2 × 1/2), after three half-lives, one-eighth (1/2 × 1/2 × 1/2), and so on.
internal radiation	Radiation from a source within the body as a result of deposition of radionuclides in body tissues by processes, such as ingestion, inhalation, or implantation. Potassium-40, a naturally occurring radionuclide, is a major source of internal radiation in living organisms.
Laboratory	Los Alamos National Laboratory.
Maximum Contaminant Level (MCL)	Maximum permissible level of a contaminant in water that is delivered to the free-flowing outlet of the ultimate user of a public water system (see Appendix A and Table A-3). The MCLs are specified by the EPA.
mrem	Millirem (10^{-3} rem). See rem definition.
perched water	A ground-water body above an impermeable layer that is separated from an underlying main body of ground water by an unsaturated zone.
person-rem	The unit of population dose, which expresses the sum of radiation exposures received by a population. For example, two persons, each with a 0.5-rem exposure, receive 1 person-rem, and 500 people, each with an exposure of 0.002 rem, also receive 1 person-rem.
rad	A special unit of absorbed dose from ionizing radiation. A dose of 1 rad equals the absorption of 100 years of radiation energy per gram of absorbing material.
radiation	The emission of particles or energy as a result of an atomic or nuclear process.
Radiation Protection Standard (RPS)	A standard for external and internal exposure to radioactivity as defined in DOE Order 5480.1A, Chap. XI (see Appendix A and Table A-2 in this report).

rem	The unit of radiation dose equivalent that takes into account different kinds of ionizing radiation and permits them to be expressed on a common basis. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the necessary modifying factors.
roentgen (R)	A unit of radiation exposure that expresses exposure in terms of the amount of ionization produced by x rays in a volume of air. One roentgen (R) is 2.58×10^{-4} coulombs per kilogram of air.
terrestrial radiation	Radiation emitted by naturally occurring radionuclides, such as ^{40}K; the natural decay chains ^{235}U, ^{238}U, or ^{232}Th; or cosmic-ray-induced radionuclides in the soil.
thermoluminescent dosimeter (TLD)	A material (the Laboratory uses lithium fluoride) that, after being exposed to radiation, luminesces upon being heated. The amount of light the material emits is proportional to the amount of radiation (dose) to which it was exposed.
tritium	A radionuclide of hydrogen with a half-life of 12.3 years. The very low energy of its radioactivity decay makes it one of the least hazardous radionuclides.
tuff	Rock of compacted volcanic ash and dust.
uncontrolled area	An area beyond the boundaries of a controlled area (see definition of "controlled area" in this glossary).
uranium	
uranium, depleted	Uranium consisting primarily of ^{238}U and having less than 0.72 wt% ^{235}U. Except in rare cases occurring in nature, depleted uranium is manmade.
uranium, total	The amount of uranium in a sample, assuming that the uranium has the isotopic content of uranium in nature (99.27 wt% ^{238}U, 0.72 wt% ^{235}U, and 0.0057 wt% ^{234}U).
water year	October through September.
Working Level Month (WLM)	A unit of exposure to ^{222}Rn and its decay products. Working Level (WL) is any combination of the short-lived ^{222}Rn decay products in 1 L of air that will result in the emission of 1.3×10^5 MeV potential alpha energy. At equilibrium, 100 pCi/L of ^{222}Rn corresponds to 1 WL. Cumulative exposure is measured in Working Level Months, which is 170 WL-h.