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Environmental Surveillance at Los Alamos During 1988

Environmental Surveillance Group

Los Alamos
Los Alamos National Laboratory
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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 1988

by

ENVIRONMENTAL SURVEILLANCE GROUP

ABSTRACT

This report describes the environmental surveillance program conducted by Los Alamos National Laboratory during 1988. 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 1988 cover: external penetrating radiation; quantities of airborne emissions and liquid 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 insignificant and do not pose a threat to the public, Laboratory employees, or the environment.

I. EXECUTIVE SUMMARY

A. Monitoring Operations

The Laboratory maintains 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. More detailed, supplemental environmental studies are carried out to determine the extent of the potential problems, to provide the basis for any remedial actions, and to provide further information on surrounding environments. The monitoring program also 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.

Monitoring and sampling locations for various types of 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 particulates 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 1988. 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.

B. Estimated Doses and Risks from Radiation Exposure

1. Radiation Doses. Estimated individual radiation doses to the public attributable to Laboratory operations are compared with applicable standards in this report. Doses are expressed as a percentage 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 those 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 prior to 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 (effective dose equivalent) from all exposure pathways. In addition, exposure via the air pathway is further limited to 25 mrem/yr (whole body)

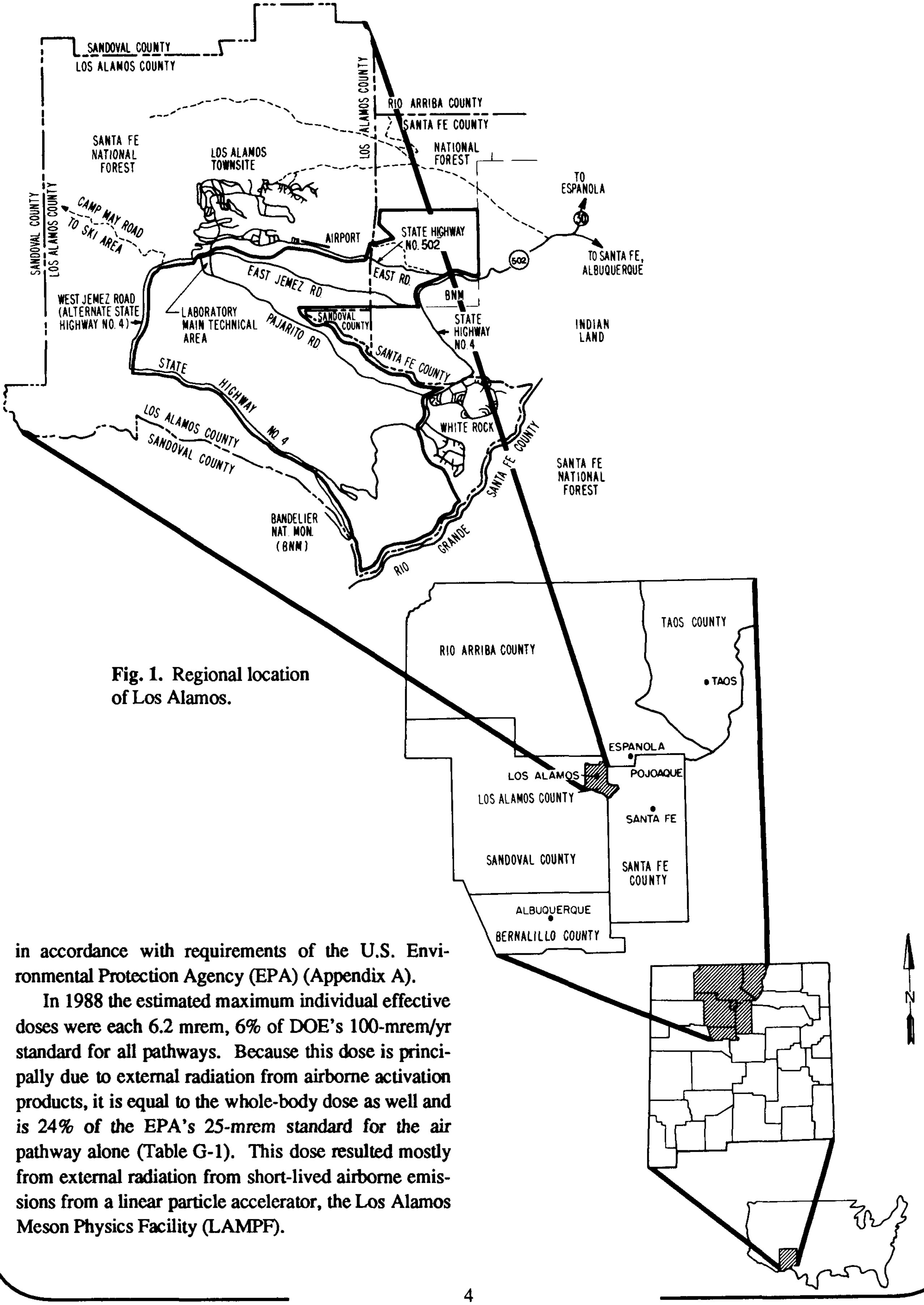

Fig. 1. Regional location of Los Alamos.

in accordance with requirements of the U.S. Environmental Protection Agency (EPA) (Appendix A).

In 1988 the estimated maximum individual effective doses were each 6.2 mrem, 6% 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 24% of the EPA's 25-mrem 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).

Table 1. Number of Sampling Locations

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

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[a] 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 sampled and analyzed as part of the monitoring program.

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 2% of the 336 mrem received from background radioactivity in Los Alamos during 1988.

2. Risk Estimates. Estimates of the added risk of cancer were calculated to provide a perspective for

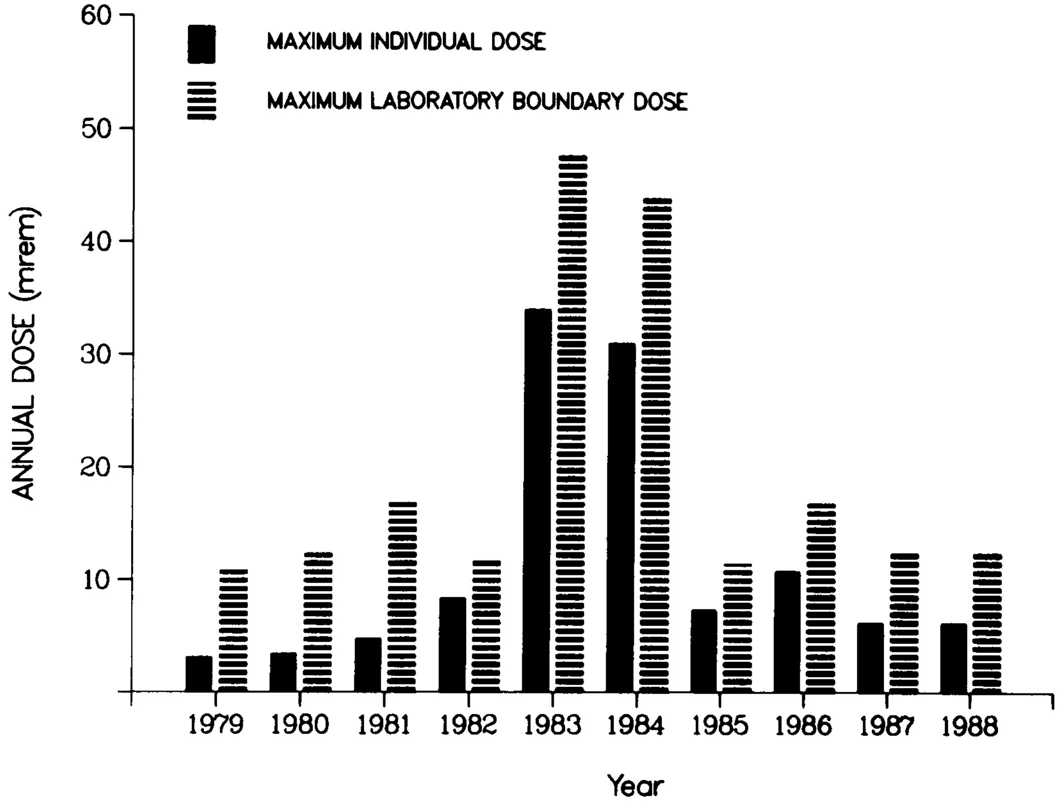

Fig. 2. Summary of estimated maximum individual and Laboratory boundary doses (excluding contributions from cosmic, terrestrial, and medical diagnostic sources) from Laboratory operations.

comparing the significance of radiation exposures. Incremental cancer risk to residents of Los Alamos townsite due to 1988 Laboratory operations was estimated to be 1 chance in 83 000 000 (Table 2). This risk is <0.5% of the 1 chance in 30 000 cancer risk from natural background radiation and the 1 chance in 190 000 risk 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.

The TLD network monitoring radiation from airborne activation products released by LAMPF measured about 13 ± 3 mrem/yr (excludes background radiation from cosmic and terrestrial sources). This value is essentially the same as measured in 1987 despite a 19% decrease in the release of airborne radioactivity by LAMPF. This is probably due to the differences in wind patterns between the 2 yr.

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

Table 2. Added Individual Lifetime Cancer Mortality Risks Attributable to 1988 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	0.12	1 in 83 000 000
White Rock area	0.07	1 in 140 000 000
Natural Radiation		
Cosmic, terrestrial, self-irradiation, and radon exposure[a]		
Los Alamos	336	1 in 30 000[b]
White Rock	329	1 in 30 000
Medical X Rays (Diagnostic Procedures)		
Average whole-body exposure	53	1 in 190 000

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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 73 000 in Los Alamos and 1 chance in 77 000 in White Rock. The risk of lung cancer from radon exposure was estimated to be 1 chance in 50 000 for both locations. Risk estimates are derived from ICRP Publication 26 and NCRP Report 93 (ICRP 1977 and NCRP 1987).

emissions declined from 1987 (Table 3). This was principally due to a 19% decrease in releases of airborne activation products from LAMPF. Tritium releases increased due to increases at TAs-33 and -41.

Ambient air is routinely sampled for tritium, uranium, plutonium, americium, and gross beta activity at 25 sampling stations. Measurements of radioactivity in the air are compared with concentration guides based on DOE's Derived Air Concentrations. These guides are concentrations of radioactivity in air breathed continuously throughout the year that result in effective doses equal to DOE's RPS of 100 mrem/yr for off-site areas (Derived Concentration Guides for uncontrolled areas) and to the occupational RPS (see Appendix A) for on-site areas (Derived Air Concentration guides for controlled areas). Hereafter they are called guides for on-site and off-site areas.

Only the tritium air concentrations showed any measurable impact from radionuclides due to Laboratory operations. Annual average concentrations of tritium remained <0.1% of DOE's guides at all stations and posed no environmental or health problems in 1988. Annual average concentrations of longer-lived radionuclides in air were also <0.1% of the guides during 1988.

Table 3. Comparison of 1987 and 1988 Releases of Radionuclides from the Laboratory

Airborne Emissions

Radionuclide	Units	Activity Released 1987	Activity Released 1988	Ratio 1988:1987
^{3}H	Ci	3 180	11 000	3.5
^{32}P	μCi	48	57	1.2
^{41}Ar	Ci	232	264	1.1
Uranium	μCi	1 080	559	0.5
Plutonium	μCi	73	72	1.0
Gaseous mixed activation products	Ci	150 000	121 000	0.8
Mixed fission products	μCi	1 290	1 150	0.9
Particulate/vapor activation products	Ci	0.2	0.1	0.5
Total	Ci	153 412	132 264	0.9

Liquid Effluents

Radionuclide	Activity Released (mCi) 1987	Activity Released (mCi) 1988	Ratio 1988:1987
^{3}H	110 000	26 000	0.2
^{89,90}Sr	65	81	1.2
^{137}Cs	8.1	31	3.8
^{234}U	1.6	0.8	0.5
^{238,239,240}Pu	4.6	4.3	0.9
^{241}Am	3.6	3.7	1.0
Other	610.5	48	0.1
Total	110 693	26 169	0.2

E. Water, Soil, and Sediment Monitoring

Liquid effluents containing low levels of radioactivity were routinely released from one waste treatment plant and one sanitary sewage lagoon system. The dominant change from 1987 was a decrease in tritium discharge from TA-50's radioactive liquid-waste treatment facility due to decreased concentrations in the released waters (Table 3).

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 are above natural terrestrial and worldwide fallout levels. These on-site waters are not a source of industrial, agricultural, or municipal water supplies. The radiochemical quality of water from regional, perimeter, and on-site areas that have received no direct discharge showed no significant effects from Laboratory releases. Lack of a hydrologic connection to the deep aquifer was confirmed by lack of radioactive or chemical contamination in that aquifer.

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 on sediments at levels slightly higher than attributable to natural terrestrial sources or worldwide fallout. The low levels of cesium, plutonium, and strontium in Mortandad Canyon are due to liquid effluents from a waste treatment plant. No above-background radioactivity on sediments or in water has been measured in locations beyond the Laboratory boundary in Mortandad Canyon. However, small amounts of radioactivity on sediments in Pueblo Canyon (from pre-1964 effluents) and Los Alamos Canyon (from 1952 to current treated effluents) have been transported to the Rio Grande. Theoretical estimates, confirmed by measurements, show the incremental effect on Rio Grande sediments is insignificant when compared with background concentrations in soils and sediments.

Environmental monitoring is done at 1 active and 11 inactive waste management areas at the Laboratory. The general public is excluded from these controlled-access sites. Surface run-off has transported some low-level contamination from the active disposal area and several of the inactive areas into controlled-access canyons. Leachate extracts (following EPA guidelines) from the surface contamination indicate the presence of no constituents in excess of EPA criteria for hazardous waste determination.

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

Two unplanned releases of radioactive or hazardous materials occurred during 1988. Both involved the release of tritium from a tritium-handling facility at TA-33. In each case, the resulting radiation dose to a member of the public was estimated to be <1% of the RPS.

1. February 22 Tritium Release at TA-33. On February 22, 1988, 5800 Ci of tritium were released from the tritium-handling facility at TA-33. The release was in the form of elemental tritium gas, and 1% was assumed to be subsequently oxidized to tritiated water. Air samples collected at six air-sampling stations were within their normal range and <0.1% of the DOE's Derived Concentration Guide (DCG) for tritium in off-site areas. The whole body is the organ receiving the dose that is the largest fraction of its radiation limit. The largest whole-body dose was calculated to be 0.18 mrem, which is 0.7% of the EPA's radiation limit of 25 mrem/yr to the whole body from the air pathway.

2. October 4 Tritium Release at TA-33. On October 4, 1988, 200 Ci of elemental tritium gas were released at TA-33, and 1% of the tritium was assumed to be subsequently oxidized after released. Air samples collected from the Laboratory's routine air-sampling network were within their normal range and were <0.1% of the DOE's DCG for tritium. The whole body is the organ receiving the dose that is the largest fraction of its radiation limit. The maximum whole-body dose was calculated to be <0.1 mrem, or <0.4% of the EPA's 25-mrem/yr (whole-body) radiation limit.

H. Environmental Compliance Activities

1. Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) regulates hazardous wastes from generation to ultimate disposal. The EPA has transferred full authority (with the exception of the Hazardous and Solid Waste Amendment of 1984) for administering RCRA to New Mexico's Environmental Improvement Division (NMEID). In 1988, the Laboratory had numerous interactions with NMEID and prepared documentation to comply with RCRA requirements. One compliance and one follow-up inspection were conducted during 1988. Two Notices of Violations were issued. Four meetings were held with the NMEID and one with the EPA and NMEID to discuss the draft hazardous waste permit that is scheduled for public hearing in early summer. Two closure plans and additional information on a third were submitted to the NMEID. The Laboratory has revised RCRA Parts A and B permit applications, originally submitted in 1985. The latest revisions were submitted November 1988.

2. Clean Water Act. Regulations under the Clean Water Act set water quality standards and effluent limitations. The two primary programs at the Laboratory 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 liquid effluent discharges from 99 industrial outfalls and 9 sanitary sewage treatment outfalls; the permit expires in March 1991. The Laboratory was within limits set by the NPDES permit in about 95 and 98% of the analyses done on samples collected for compliance monitoring at sanitary and industrial waste discharges, respectively. Chronically noncompliant discharges are being upgraded under an EPA/DOE Federal Facility Compliance Agreement.

Another NPDES permit authorizes liquid effluent discharge from the Fenton Hill Geothermal Project. The permit for a single outfall was issued to regulate the discharge of mineral-laden water from the recycle loop of the geothermal wells.

The SPCC program provides guidance for spill prevention, response, and cleanup of spills and requires preparation of an SPCC Plan. The Laboratory has many elements that are required in an SPCC plan and has adopted a Laboratory-wide formal SPCC plan. During 1988, engineering designs were prepared for the provision of secondary containment structures at seven existing sites with major spill potential. All new construction is designed and constructed to anticipate potential spill problems.

3. National Environmental Policy Act (NEPA). The Laboratory Environmental Review Committee reviews environmental documentation required by NEPA regulations as well as identifies other environmental items of concern to the Laboratory. An Environmental Evaluations Coordinator helps prepare required DOE documentation and identify other items requiring committee attention. Documentation is initiated with an Action Description Memorandum, a brief environmental evaluation to determine the need for NEPA documentation. If required, an Environmental Assessment, or more-detailed evaluation, is prepared. During 1988, the committee reviewed six Action Description Memorandums and one Environmental Assessment and forwarded this documentation to DOE.

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. During 1988, the Laboratory's operations remained in compliance with all federal and state air quality regulations. In response to these regulations, the Laboratory performed a wide variety of activities in 1988. Permit applications were prepared for new beryllium-processing operations at TA-3-35, the Low-Level Waste/Mixed

Waste Incinerator, and the Dual-Access Radiographic Hydrotest Facility. In June, the NMEID issued a permit for construction and operation of a proposed solid-waste-fired boiler at TA-16. Information was provided to the state on asbestos removal and disposal activities. A Laboratory-wide survey of toxic air pollutants was conducted and a data base was developed to calculate air emissions and to store information on usage, products, and wastes. To ensure compliance with state and federal air quality requirements, ambient air and source emissions monitoring were performed.

5. **Safe Drinking Water Act.** 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). The chemical quality of the water met EPA's National Interim Primary Drinking Water Standards (40 CFR 141) in 1988.

6. **Federal Insecticide, Fungicide, and Rodenticide Act.** The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 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.** The Laboratory's Environmental Evaluation Coordination and Quality Assurance programs provide protection as mandated by law for the hundreds of archaeological and historical resources located on DOE land. Pursuant to federal regulations implementing Sec. 106 of the National Historic Preservation Act of 1966, as amended, clearance for construction where no resource will be affected and mitigation of unavoidable adverse effects from Laboratory activity is determined in consultation with New Mexico's State Historical Preservation Office. During 1988, archaeologists performed 28 cultural resource surveys, monitored 7 projects, fenced 1 site, and undertook adverse impact mitigation at 2 sites.

8. **Threatened/Endangered 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 Environmental Review Requirements. Three Floodplains/Wetlands notifications were prepared for publication in the *Federal Register*. Laboratory biologists surveyed 17 proposed construction sites for potential impact. They identified no endangered or rare species at these sites.

9. **Comprehensive Environmental Response, Compensation, and Liability Act.** The Comprehensive Environmental Response, Compensation, and Liability Act (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 (ER) Program. The program is evaluating all areas at the Laboratory for possible contamination.

10. **Toxic Substances Control Act.** The Toxic Substances Control Act (TSCA) regulates the manufacture, processing, distribution, use, storage, and labeling of chemical substances, including polychlorinated biphenyls (PCBs). The Laboratory has EPA authorization to dispose of PCB wastes at its radioactive waste landfill (Area G) and burn PCB contaminated wastes at its Controlled Air Incinerator (99.9999% combustion efficiency). The Laboratory is in compliance with EPA's permit conditions for authorizing on-site disposal of PCB contaminated wastes.

11. **Emergency Planning and Community Right-to-Know Act.** Toxic-chemical-release reporting requirements under Sec. 313 of Title III of SARA of 1986 became effective in March 1988. The basic purpose of this provision is to make available to the public information about releases of certain toxic chemicals that result from operations at covered facilities in their community. Reports must be submitted annually to the EPA and to the state in which the facility is located. This new rule is in addition to other reporting requirements under SARA Title III, which went into effect in May 1987. 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 the calendar year 1987, the Laboratory reported environmental releases for nitric acid. This was the only compound exceeding applicable threshold amounts. Approximately 1500 kg (3300 lb) were reported released as nonpoint air emissions; 1100 kg (2500 lb), 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. Hence, no other environmental releases of nitric acid were reported.

12. Underground Storage Tanks. In 1988, 25 underground storage tanks were removed from the Laboratory. The majority of these tanks were installed in the 1940s. Surveys after removal of the tanks revealed that none of the tanks had ever leaked any reportable quantities. Soils contaminated with hydrocarbons were generally associated with overfilling of the tanks. Contaminated soils were removed for disposal at Area G in accordance with NMEID's recommended procedures. It is the Laboratory's policy to remove underground storage tanks when user groups determine that the tanks are no longer needed. Such 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) NNE of Albuquerque and 40 km (25 mi) NW of Santa Fe (Fig. 1). The 111-km^2 (43-mi^2) Laboratory site and adjacent communities are situated on Pajarito Plateau. The plateau consists of a series of fingerlike mesas separated by deep east-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 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 the 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

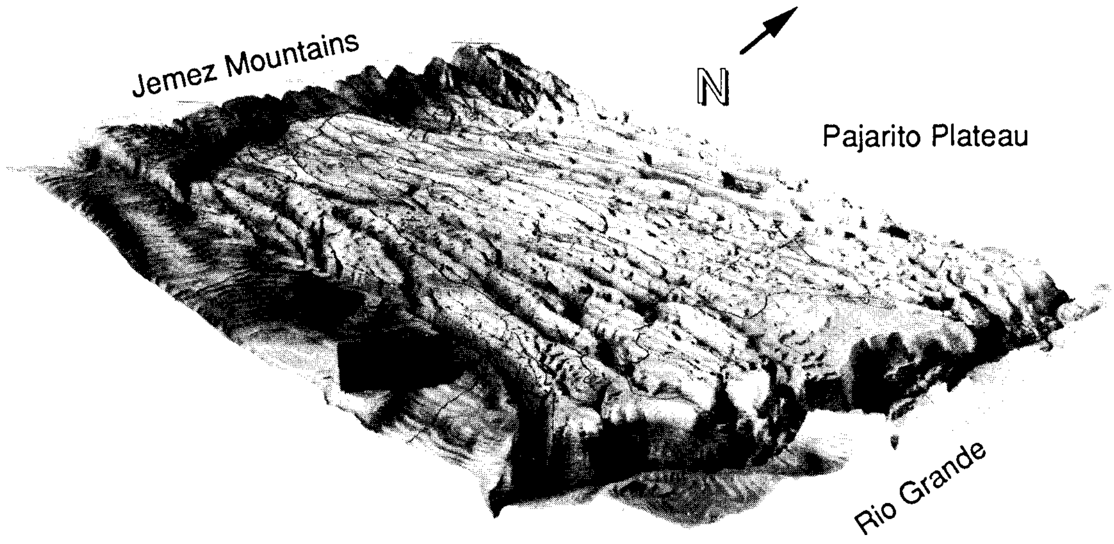

Fig. 3. Topography of the Los Alamos area.

rights-of-way (Fig. 4 and Appendix F). However, these account for only a small fraction of the total land area. Most land provides isolation for security and safety and is a reserve for future structure locations. The Long-Range Site-Development Plan (Engineering 1982) 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

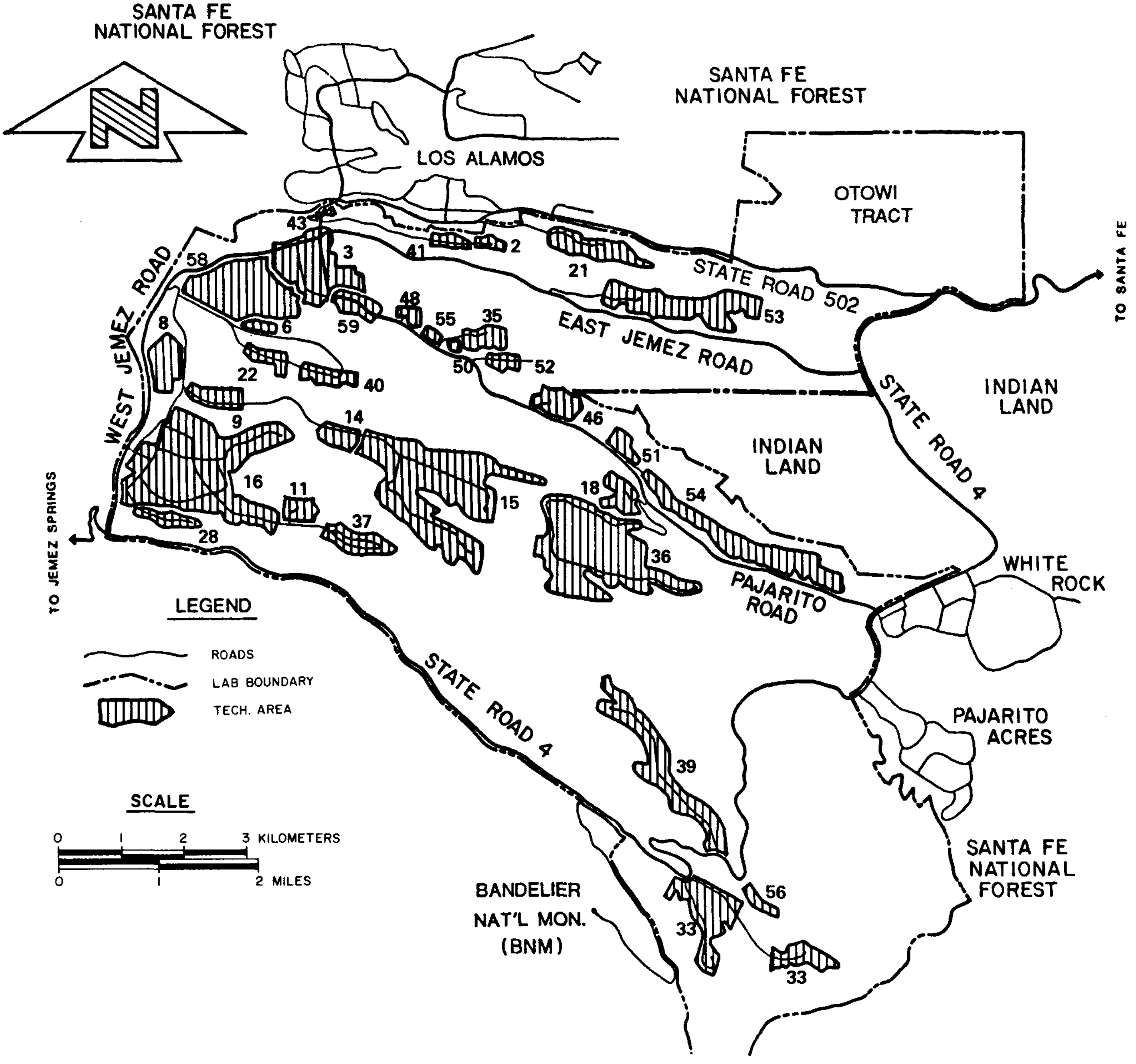

Fig. 4. Technical areas (TAs) of Los Alamos National Laboratory in relation to surrounding landholdings.

of State Road 502 near the White Rock Y, is open to the public subject to the 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). Ashfall, ashfall 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 older volcanics of the Tschicoma Formation, which form the Jemez Mountains. They are 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 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 to some canyons at rates sufficient to maintain surface flows for about 1.5 km (1 mi).

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 is separated from the underlying main body of ground water by an unsaturated zone),

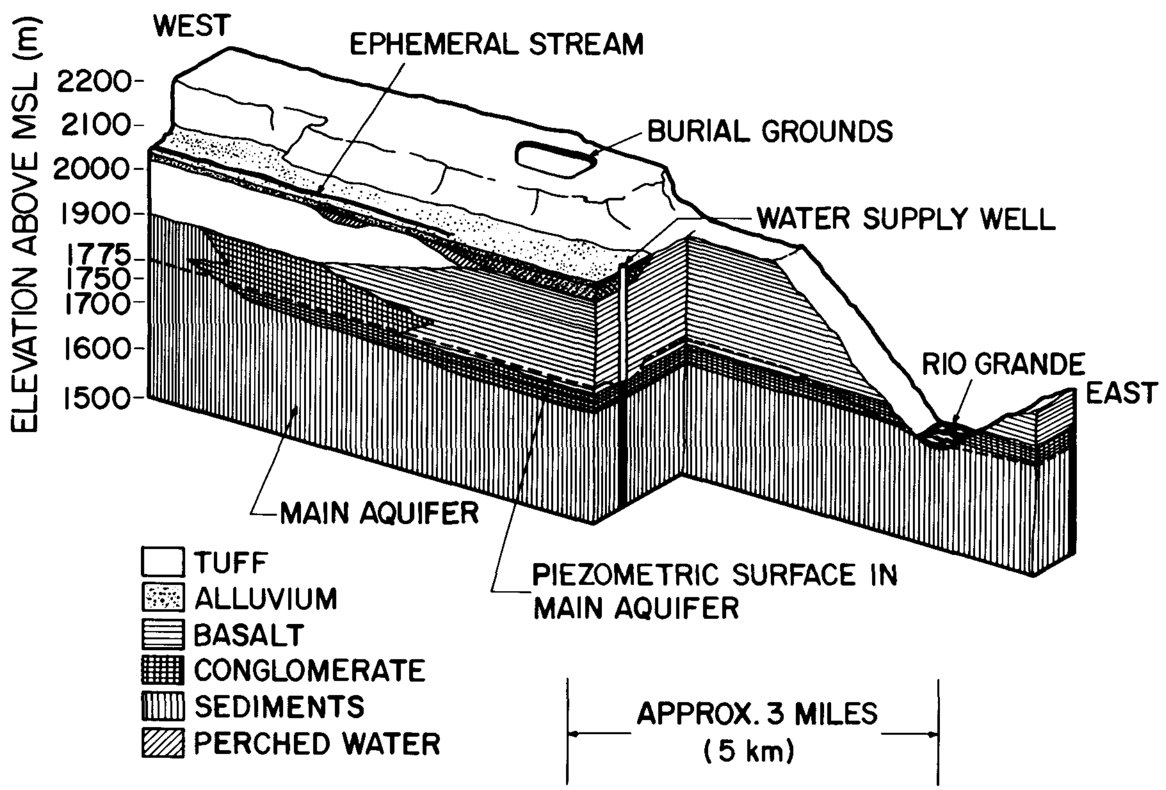

Fig. 5. Conceptual illustration of geologic-hydrologic relationships in Los Alamos area.

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 quite 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 downgradient within the alluvium. As water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into underlying volcanics (Purtymun 1977).

Perched water occurs in comglomerate and basalts beneath the alluvium in a limited area about 37 m (120 ft) 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 recharge the aquifer through 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 6.8×10^3 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 heavy during 1988, totaling 62 cm (24.3 in.). It was the fourth consecutive year with precipitation at least 130% of normal. Forty percent of the annual precipitation normally occurs during July and August from thundershowers. Rainfall was heavy during the spring and summer of 1988. Winter precipitation falls primarily as snow, with accumulations of about 130 cm (51 in.) annually. Snowfall was near normal during 1988.

Summers are generally sunny with moderate warm days and cool nights. Maximum temperatures are usually below 32°C (90°F). 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 to −4°C (15 to 25°F) during the night and from −1 to 10°C (30 to 50°F) during the day. Occasionally, temperatures drop to near −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.

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. No severe snowstorms occurred during the year. The largest daily snowfall was 20 cm (8 in.).

Surface winds in Los Alamos often vary dramatically with time-of-day and location because of complex terrain. 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 1988 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 35 m/s (75 mph) at isolated spots in the county, especially at lower elevations. Strong winds with gusts exceeding 27 m/s (60 mph) are common and widespread during the spring. A peak wind gust of 35 m/s (77 mph) was reported at the East Gate station on November 20.

Lightning is very common over Pajarito Plateau. There are 58 thunderstorm days during an average year, with most occurring during the summer. 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, whereas 1.3-cm (0.5-in.)-diam hailstones are rare. A strong thunderstorm caused 5 cm (2 in.) of hail accumulation at TA-59 on June 10.

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 the greatest during the spring when winds are strongest. However, deep vertical mixing is the 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 the least-dispersive conditions during the night and early morning.

The frequencies of atmospheric dispersive capability are 52% unstable (*A–C*), 21% neutral (*D*), and 27% unstable (*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 vertical wind variations. Stability generally increases (becomes less dispersive) toward the valley.

E. Population Distribution

Los Alamos County has an estimated 1988 population of approximately 19 500 (based on the 1980 census adjusted for 1988). Two residential and related commercial areas exist in the county (Fig. 4). The Los Alamos townsite (the original area of development, now including residential areas known as the Eastern Area, Western Area, North Community, Barranca Mesa, and North Mesa) has an estimated population of 12 200. 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 1988 place about 203 000 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 Department of Energy. The Laboratory's environmental program, conducted by the Environmental Surveillance Group, is part of a continuing investigation and documentation program.

Table 4. 1988 Population Within 80 km of Los Alamos[a,b]

	Kilometers from TA-53								
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	1 100	0	355
NNE	0	0	0	546	0	523	1 670	1 730	213
NE	1	0	0	0	306	14 800	974	1 090	3 690
ENE	0	0	0	1 840	1 510	2 570	2 610	1 150	2 190
E	0	0	79	24	526	1 080	658	0	1 440
ESE	0	0	0	0	0	277	21 900	1 060	1 470
SE	0	0	7 240	0	0	0	50 600	2 310	7
SSE	0	0	0	0	0	0	403	4 110	90
S	0	0	0	50	0	293	565	6 240	0
SSW	0	0	0	20	0	751	185	7 570	30 800
SW	0	0	0	0	0	0	289	3 820	0
WSW	0	0	0	0	0	289	288	2 340	190
W	0	0	0	0	0	0	0	151	122
WNW	0	1 540	7 000	0	0	0	0	0	2 830
NW	0	561	1 840	0	0	0	0	1 390	0
NNW	0	619	620	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 at TA-53. A slightly different distribution for Los Alamos County townsites was used to model releases from the TA-2 stack, which is located closer to Los Alamos.

[b] Total population within 80 km of Los Alamos is 203 000.

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 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 6 mrem from all pathways, which is 6% 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 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 2.2 person-rem during 1988. This is <0.01% of the 65 000 person-rem collective effective dose equivalent received by the same population from natural radiation sources and 0.02% of the 11 000 person-rem collective effective dose equivalent received from diagnostic medical procedures. Nearly 90% of this dose, 1.9 person-rem, was received by persons living in Los Alamos County. This dose is 0.03% of the 6500 person-rem received by the population of Los Alamos County from background radiation and 0.2% of the 1000 person-rem from diagnostic medical and dental procedures.

In 1988, the average added risk of cancer mortality to Los Alamos townsite residents was 1 chance in 83 000 000 from radiation from this year's Laboratory operations; this is much less than the 1 chance in 30 000 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 1988 Laboratory operations were calculated by AIRDOS-EPA/RADRISK. The maximum whole-body and organ doses were 9 mrem (whole body) and 11 mrem (testes). These doses were 37 and 15%, 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 it was modeled rather than measured. AIRDOS-EPA tends to overestimate radiation doses in the complex terrain around Los Alamos.

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 to 100 mrem/yr for all pathways of exposure (DOE 1985). 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), whole-body doses received through the air pathway 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 for measurement.

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 require that an individual actually receive 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 collective effective dose equivalent for 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 yr 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).

The effective dose equivalent is taken to be the same as the whole-body dose equivalent for whole-body external radiation. The effective dose equivalent for internal radiation is the weighted sum of the doses to individual organs (see Glossary).

All internal radiation doses (through inhalation or ingestion) are 50-yr dose commitments (Appendix D). This is the total dose received from intake of a radionuclide for 50 yr 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. Maximum Individual Dose to a Member of the Public from 1988 Laboratory Operations. The maximum individual effective dose equivalent to a member of the public from 1988 Laboratory operations is estimated to be 6.2 mrem/yr. This is the total effective dose equivalent from all pathways. This dose is 6% of the DOE's RPS of 100 mrem/yr effective dose equivalent from all pathways.

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

Table 5. Summary of Annual Effective Dose Equivalents Due to 1988 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	13 ± 3 mrem	6.2 mrem	0.12 mrem	0.07 mrem	2.2 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	—	6%	0.1%	0.1%	—
Background	336 mrem	336 mrem	336 mrem	329 mrem	65 000 person-rem
Percentage of Background	4%	2%	0.04%	0.02%	0.003%

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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 hypothetical individual is at the Laboratory boundary continuously (24 h/day, 365 day/yr).

[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.

based on 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 to provide a comparison with doses resulting from Laboratory operations. Doses from global fallout are only a small fraction of these doses (<1%) 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 report for 1987 (ESG 1988), estimates of background radiation are based on a recent comprehensive report by the National Council on Radiation Protection and Measurements (NCRP 1987). 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 the most current estimates of background radiation. This resulted in some small differences from the procedure used in surveillance reports prior to 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 (Sec. IV). Estimates of background from nonradon sources are based on measured external radiation background levels of 115 mrem (Los Alamos) and 109 mrem (White Rock) due to 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, 52 mrem at White Rock) by 20% to allow for shielding by structures and by reducing the terrestrial component (55 mrem at Los Alamos and 57 mrem at White Rock) by 30% to allow for self-shielding by the body (NCRP 1987). To these estimates, based on measurements, were added

Table 6. Maximum Individual Dose (mrem/yr) at East Gate from Laboratory Operations During 1988

	Laboratory Operation (mrem/yr)	Radiation Protection Standard (mrem/yr)	Percentage of Radiation Protection Standard (%)
Effective Dose Equivalent	6.2	100	6.2
Organ:			
Breast	6.7	5000	0.1
Lung	5.4	5000	0.1
Red marrow	5.5	5000	0.1
Bone surface	6.5	5000	0.1
Thyroid	6.7	5000	0.1
Testes	7.2	5000	0.1
Ovaries	4.8	5000	0.1

10 mrem at Los Alamos and 8 mrem at White Rock from neutron cosmic radiation (20% shielding assumed) and 40 mrem from internal radiation (NCRP 1987). The estimated whole-body dose from background, nonradon radiation is 136 mrem at Los Alamos and 129 mrem at 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 the construction materials in a building and in its underlying soil. The effective dose equivalent from exposure to background ^{222}Rn and its decay products is taken to be 200 mrem/yr (NCRP 1987). 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 (1984A, 1987).

The total effective dose equivalent to residents is 336 mrem/yr at Los Alamos and 329 mrem/yr at White Rock (Table 5), or 136 mrem/yr (Los Alamos) and 129 mrem/yr (White Rock) from nonradon sources and 200 mrem/yr from radon (in both areas).

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

3. Dose to Individuals from External Penetrating Radiation from Airborne Emissions. The thermoluminescent dosimeter (TLD) network at the Laboratory boundary north of LAMPF indicated a 12.7-mrem increment above cosmic and terrestrial background radiation during 1988 (Sec. IV). This increment is attributed to emission of air activation products from LAMPF. Based on 30% shielding from being inside buildings (NRC 1977), 30% self-shielding (NCRP 1987), and 100% occupancy, this 12.7-mrem increment translates to an estimated 6.2-mrem whole-body dose to an individual living along State Road 502 north of LAMPF (Table G-1). This location north of LAMPF has been the area where the highest boundary and individual doses have been measured since the dosimeter monitoring began. The 6.2 mrem is 25% 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).

A maximum on-site dose to a member of the public from external penetrating radiation from all Laboratory airborne emissions was estimated using a Gaussian dispersion meteorological model (Slade 1968). The estimated maximum on-site dose was 0.001 mrem (whole body) for 1988. This is <0.005% of the EPA's 25-mrem air pathway standard for protection of a member of the public (Appendix A). This dose was calculated (using credible worst-case conditions) for a person spending 4 h at the Laboratory's science museum, an area readily accessible to the public.

Average dose to residents in Los Alamos townsite attributable to Laboratory operations was 0.12 mrem to the whole body. The corresponding dose to White Rock residents was 0.07 mrem. The doses are 0.5% and 0.03%, respectively, of EPA's 25 mrem air pathway standard. They were estimated using an air dispersion model, measured stack releases (Table G-2), and 1988 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 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, or 0.03% 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 0.22 mrem to the bone surface; this is 0.3% 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.

All other atmospheric releases of radioactivity (Table G-2) were evaluated by theoretical calculations. 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 Part 61, Subpart H, the EPA requires that radiation doses be determined with the computer codes AIRDOS-EPA and RADRISK (40 CFR 61). The AIRDOS-EPA code was run with 1988 meteorology data and radioactive emissions data given in Table G-2 and RADRISK dose conversion factors (70-yr commitment). As expected, more than 98% of the maximum individual dose resulted from external exposure to the air activation products from LAMPF. The maximum individual whole-body dose, as determined by AIRDOS-EPA, was 9.1 mrem, corrected to include shielding by buildings (30% reduction). This dose, which would occur in the area just north of LAMPF, is 37% of the EPA's air pathway standard of 25 mrem/yr (whole body).

The maximum organ dose was calculated by AIRDOS-EPA to be 11 mrem to the testes, or 15% of EPA's air pathway standard of 75 mrem/yr to any organ. This dose would also occur in the area just north of LAMPF. Of the 11 mrem, approximately 99% is due to external penetrating radiation from LAMPF air emissions and 1% from other Laboratory emissions.

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 and are 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 2 mrem/yr of direct gamma and neutron radiation, which is 2% of the DOE's 100 mrem/yr standard for protection from exposure by all pathways (Appendix A). This value was based on 1988 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 70 mrem. This reflects direct radiation from a localized accumulation of ^{137}Cs on sediments transported from treated effluent released from TA-21 prior to 1964. No one resides near this location.

7. Doses to Individuals from Treated Liquid Effluents. Treated liquid effluents do not flow beyond the Laboratory boundary but are retained in 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 (Hakonson 1976A, 1976B, and Purtymun 1971, 1974A).

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 (eating liver from a steer that drinks water from and grazes in lower Los Alamos Canyon) to man from these canyon sediments. 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 1988 (Sec. VII) were used to estimate doses received from eating these foodstuffs. All calculated effective dose equivalents are 0.1% or less of the DOE's 100 mrem/yr standard (Appendix A).

Fruit and vegetable samples were analyzed for six radionuclides (^{3}H, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu). Maximum committed effective dose equivalent that would result from ingesting one quarter of an annual consumption of fruits and vegetables (160 kg)

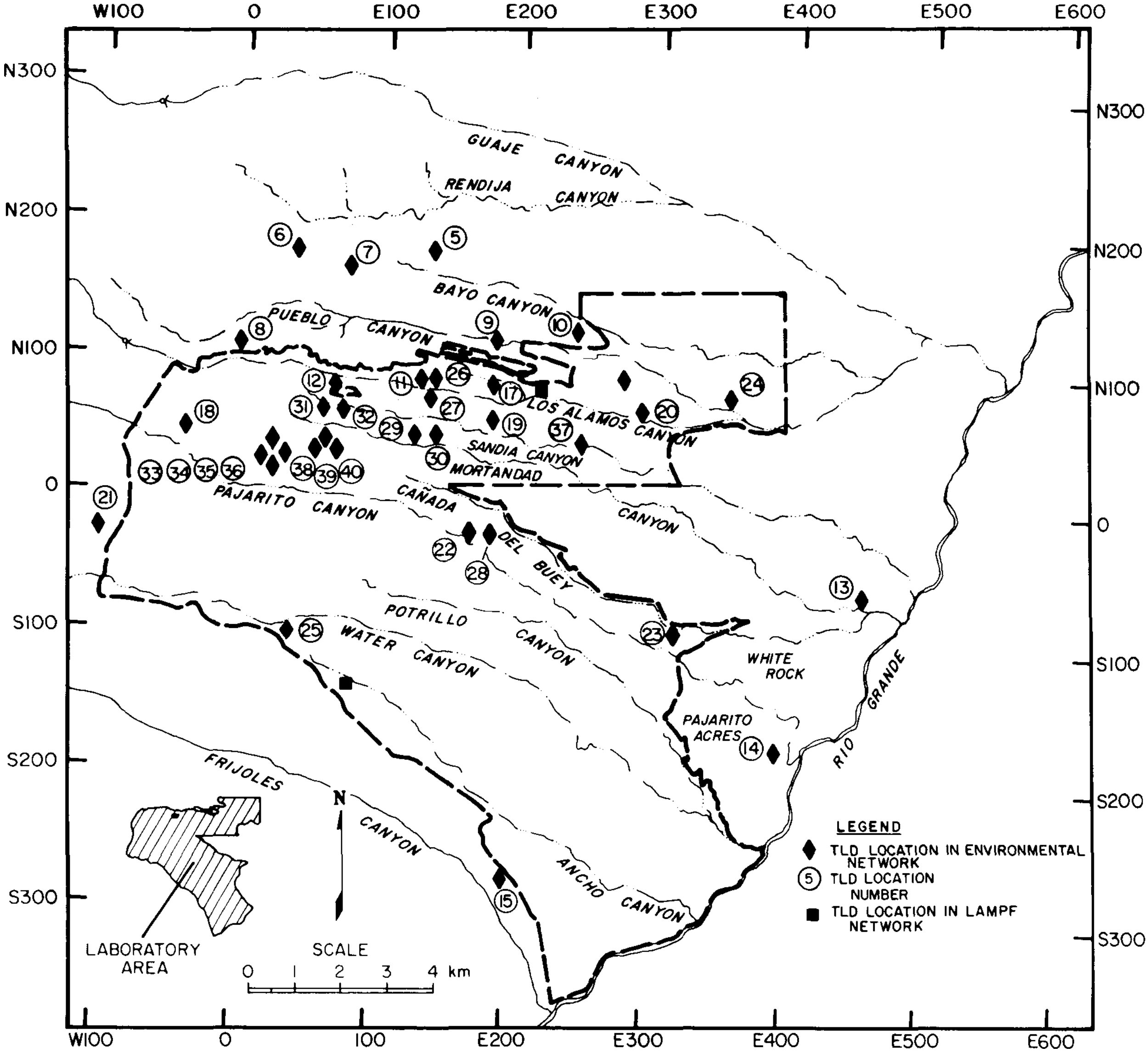

Fig. 6. Thermoluminescent dosimeter (TLD) locations on or near the Laboratory site.

from the off-site locations was 0.05 mrem. This dose is 0.05% 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 ^{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 0.03 mrem, which is 0.03% of DOE's 100-mrem standard (DOE 1985). Maximum organ dose is 0.3 mrem to bone surface.

Trace amounts of radionuclides were found 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 0.01 mrem, which is 0.01% of DOE's 100-mrem standard.

9. Collective Effective Dose Equivalents. The 1988 population collective effective dose equivalent attributable to Laboratory operations to persons living within 80 km (50 mi) of the Laboratory was calculated to be 2.2 person-rem. This dose is <0.01% of the 65 000 person-rem exposure from natural background radiation and 0.02% of the 11 000 person-rem exposure from medical radiation (Table 7). The 1988 collective whole-body dose equivalent is also 2.2 person-rem. This is because the dose is dominated by external whole-body radiation from LAMPF emissions. Whole-body doses received from external radiation equal total effective doses.

The collective dose from Laboratory operations was calculated from measured radionuclide emission rates (Table G-2), atmospheric modeling using measured meteorological data for 1988, and population data based on the 1980 Bureau of Census count adjusted to 1988 (Table 4 and Appendix D).

The collective dose from natural background radiation was calculated using the background radiation levels given above. The dose to the 80-km population 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 0.03% of the collective effective dose equivalent from background and 0.2% 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 0.001% of the dose from natural background radiation and 0.003% of the dose from medical and dental radiation.

Table 7. Estimated Collective Effective Dose Equivalents (person-rem) During 1988

Exposure Mechanism	Los Alamos County (19 400 persons)	80-km Region (203 000 persons)[a]
Total due to Laboratory releases	1.9[b]	2.2
Natural background:		
Nonradon	2 600	25 000
Radon	3 900	41 000
Total due to natural sources of radiation	6 500	65 000
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 30% reduction in cosmic radiation from shielding by structures and a 30% reduction in terrestial radiation from self-shielding by the body.

[c] Reference NCRP (1987).

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 National Council on Radiation Protection and Measurements (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.

The ICRP (1977) estimated that the total risk of cancer mortality from uniform, whole-body radiation for individuals is 0.0001 per rem, that is, there is 1 chance in 10 000 that an individual exposed to 1000 mrem (1 rem) of whole-body radiation would develop a fatal cancer during his lifetime due to that exposure. This same risk factor applies to the risk of cancer mortality per rem of effective dose equivalent. In developing risk estimates, the ICRP (1977) has warned that "radiation risk estimates should be used only with great caution and with explicit recognition of the possibility that the actual risk at low doses may be lower than that implied by a deliberately cautious assumption of proportionality."

2. Risk from Natural Background Radiation and Medical and Dental Radiation. During 1988, persons living in Los Alamos and White Rock received an average effective dose equivalent of 136 and 129 mrem, respectively, of nonradon (principally to the whole body) radiation 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 1988 was 1 chance in 73 000 in Los Alamos and 1 chance in 77 000 in 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 due to natural radiation sources that was not included in the estimate for whole-body radiation. For the background effective dose equivalent of 200 mrem/yr, the added risk due to exposure to natural ^{222}Rn and its decay products is 1 chance in 50 000.

The total cancer mortality risk from natural background radiation is 1 chance in 30 000 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 190 000.

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 due to radiation from Laboratory operations. The average doses to individuals in Los Alamos and White Rock because of 1988 Laboratory activities were 0.12 mrem and 0.07 mrem, respectively. These doses are estimated to add lifetime risks of about 1 chance in 83 000 000 in Los Alamos and 1 chance in 140 000 000 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 a cancer and a 1 in 5 chance of dying of cancer (EPA 1979A). The Los Alamos incremental dose 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 33 min.

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, amount of snow cover and position in the solar sunspot cycle can account for a 10-mrem variation from year to year.

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. 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). They showed an above-background radiation measurement of about 13 ± 3 mrem in 1988. This is essentially the same as the dose measured in 1987. 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 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 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 soil and rock types in the 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, the 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. The cosmic component can vary about ±5% because of solar modulations (NCRP 1975B).

Fluctuations in natural 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 operation of the Los Alamos Meson Physics Facility (LAMPF), two arrays of 48 thermoluminescent dosimeters (TLDs) each 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 deployed in three independent networks. These networks are used to measure radiation levels at (1) the Laboratory and regional areas, (2) the Laboratory boundary north of LAMPF, and (3) 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 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. Within the Laboratory, 24 locations comprise the on-site group (Fig. 6). Details of methodology for this network are found in Appendix B.

Annual averages of groups tended to be slightly higher in 1988 than in 1987 (Fig. 7). Regional and perimeter stations showed no statistically discernible increase in radiation levels attributable to Laboratory

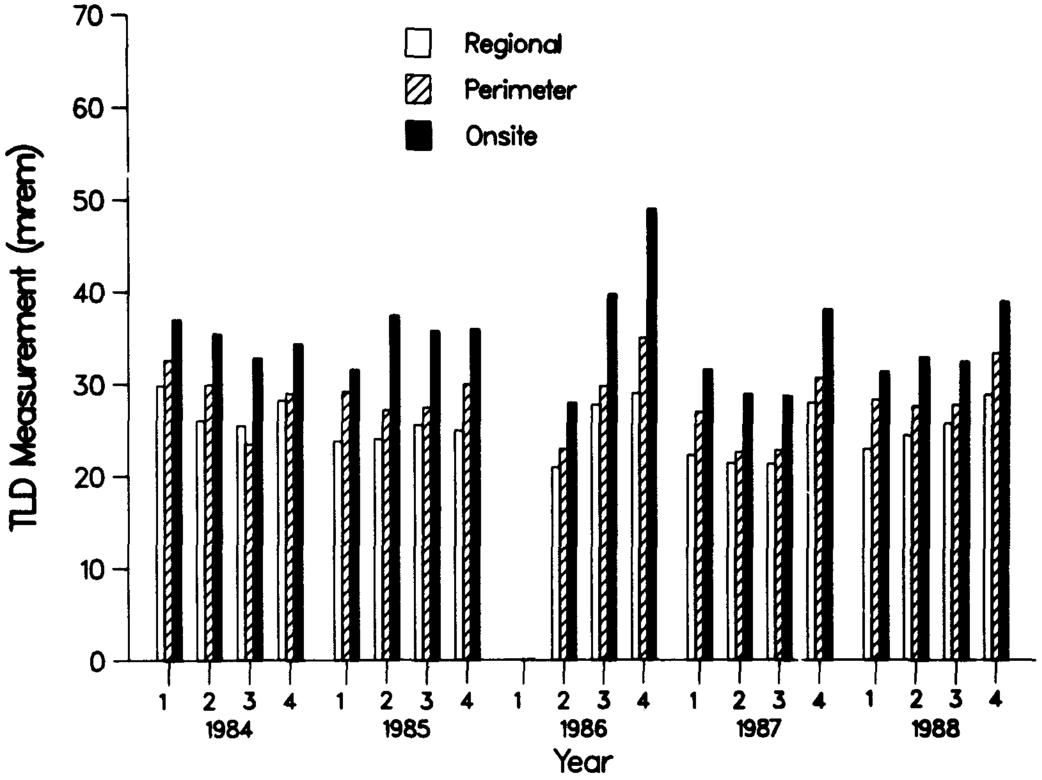

Fig. 7. Thermoluminescent dosimeter (TLD) measurements (includes contributions from cosmic, terrestrial, and Laboratory radiation sources).

operations (Table G-3). Annual measurements at off-site stations ranged from 79 to 143 mrem.

Some comparisons provide a useful perspective for evaluating these measurements. For instance, the average person in the United States receives about 53 mrem/yr from medical diagnostic procedures (NCRP 1987). The DOE's RPS is 100 mrem/yr, effective dose received from all pathways, and the dose received via air is restricted by EPA's standard of 25 mrem/yr (whole body) (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. Los Alamos Meson Physics Facility (LAMPF) TLD Network

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, or sooner if LAMPF's operating schedule indicates (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 13 ± 3 mrem for 1988. This value is obtained by subtracting the annual measurement at the background sites from the annual measurement at the Laboratory's boundary north of LAMPF (Appendix B). This year's measurement is essentially the same as the value measured in 1987 (Fig. 2).

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 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 waste management 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 (mrem) Measured by TLDs at On-Site Waste Areas During 1988

Area	Number of TLDs	Mean	Minimum	Maximum
A	5	118	110	127
B	14	124	118	132
C	10	124	119	130
E	4	129	119	135
F	4	131	122	155
G	27	161	129	305
T	7	140	115	250
U	4	123	119	127
V	4	125	115	134
W	2	140	142	137
X	1	118	—	—
AB	10	120	109	136

V. AIR MONITORING

Airborne radioactive emissions were monitored at 87 Laboratory release points. The largest airborne release was 121 000 Ci of short-lived (2- to 20-min half-lives) air-activation products from the Los Alamos Meson Physics Facility (LAMPF) during its operation from June 8 through October 5, 1988. 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 1988 annual average concentrations of these radioactive materials were much less than the 0.1% of concentrations that would result in DOE's Radiation Protection Standards being exceeded.

A. Airborne Radioactivity

1. Introduction. The sampling network for 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 results 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 with 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 the 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 stacks. 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 Los Alamos Meson Physics Facility (LAMPF). The emissions receive appropriate treatment before discharge, such as filtration for particulates 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 1988, the most significant releases were from LAMPF. The amount released for the entire year was 121 000 Ci of air-activation products (gases, particulates, and vapors) (Tables 3 and G-2). 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). Over 95% of the radioactivity was from the ^{11}C, ^{13}N, ^{14}O, and ^{15}O radioisotopes, and, therefore, this radioactivity declines very rapidly.

Airborne tritium emissions increased by a factor of 3.5, from 3180 Ci in 1987 to 11 000 Ci in 1988

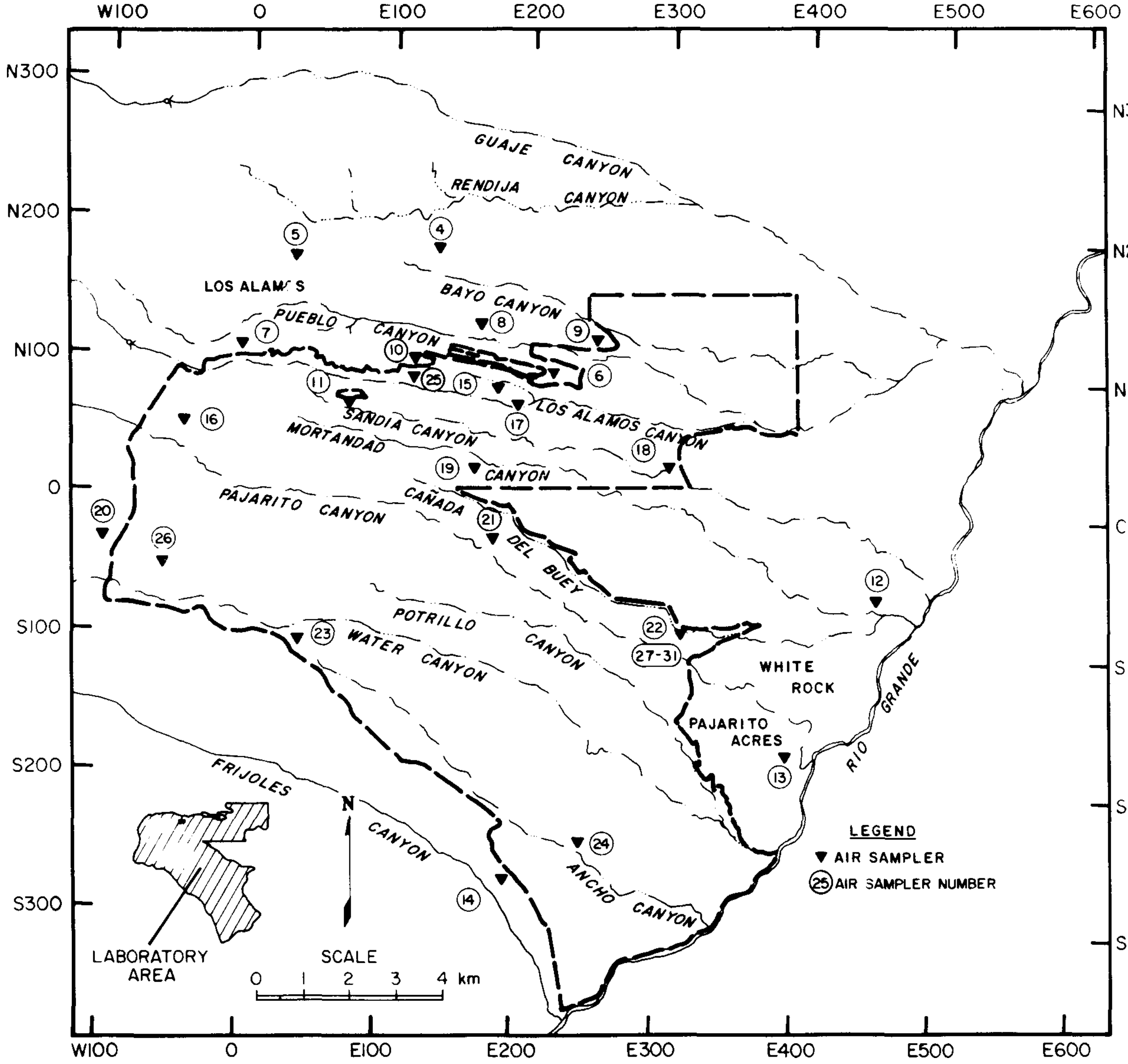

Fig. 8. Air sampler locations on or near the Laboratory site.

Table 3). This was principally due to increases in tritium releases at TA-33 and TA-41.

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 298 kg (657 lb) of depleted uranium were used in such experiments in 1988 (Table G-6). This mass contains about 0.14 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 indicate that no more than about 10% of the depleted uranium becomes airborne. Dispersion calculations indicate that resulting airborne concentrations are in the same range as that attributable to the natural abundance of uranium 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) under the auspices of the National Emission Standards for Hazardous Air

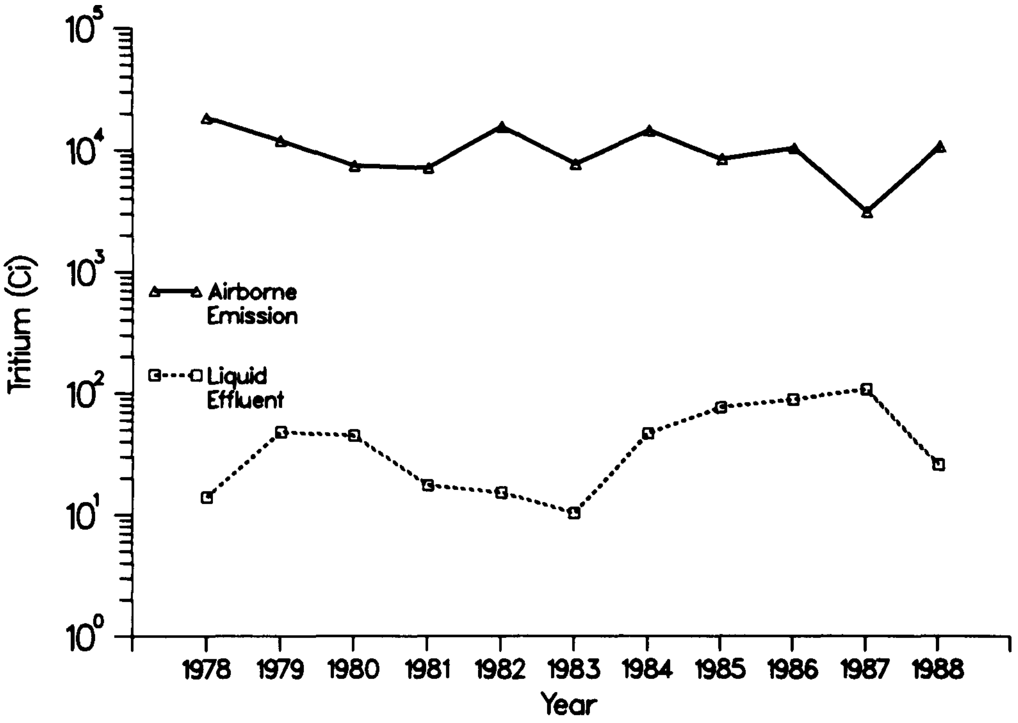

Fig. 9. Summary of tritium releases (airborne emissions and liquid effluents).

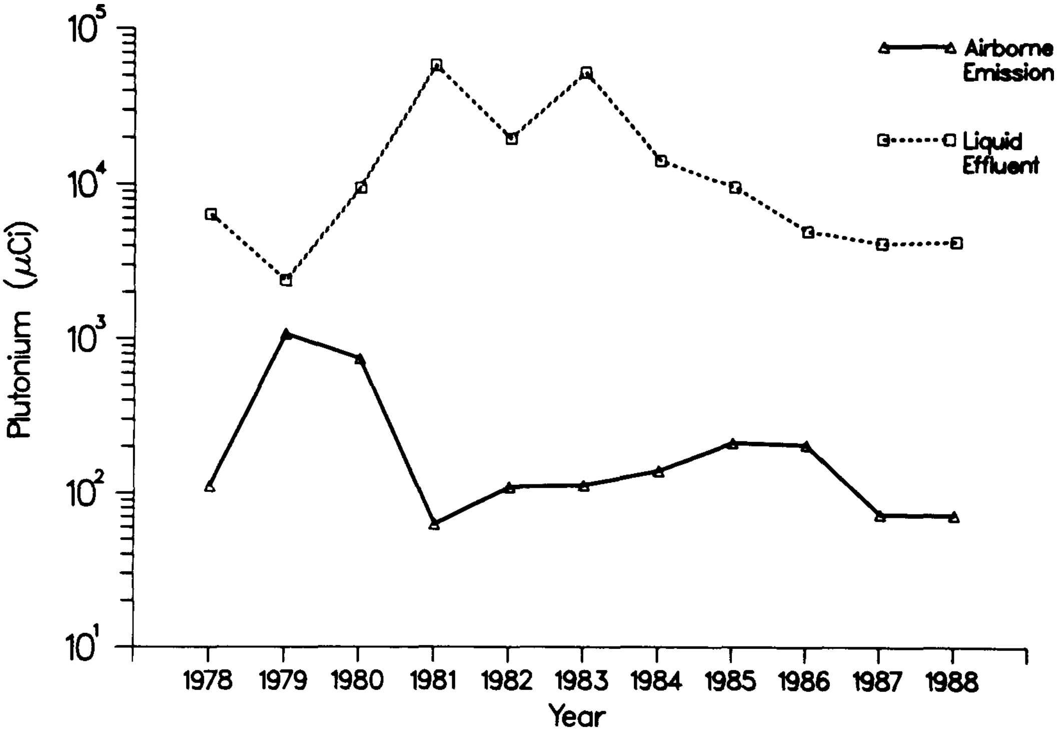

Fig. 10. Summary of plutonium releases (airborne emissions and liquid effluents).

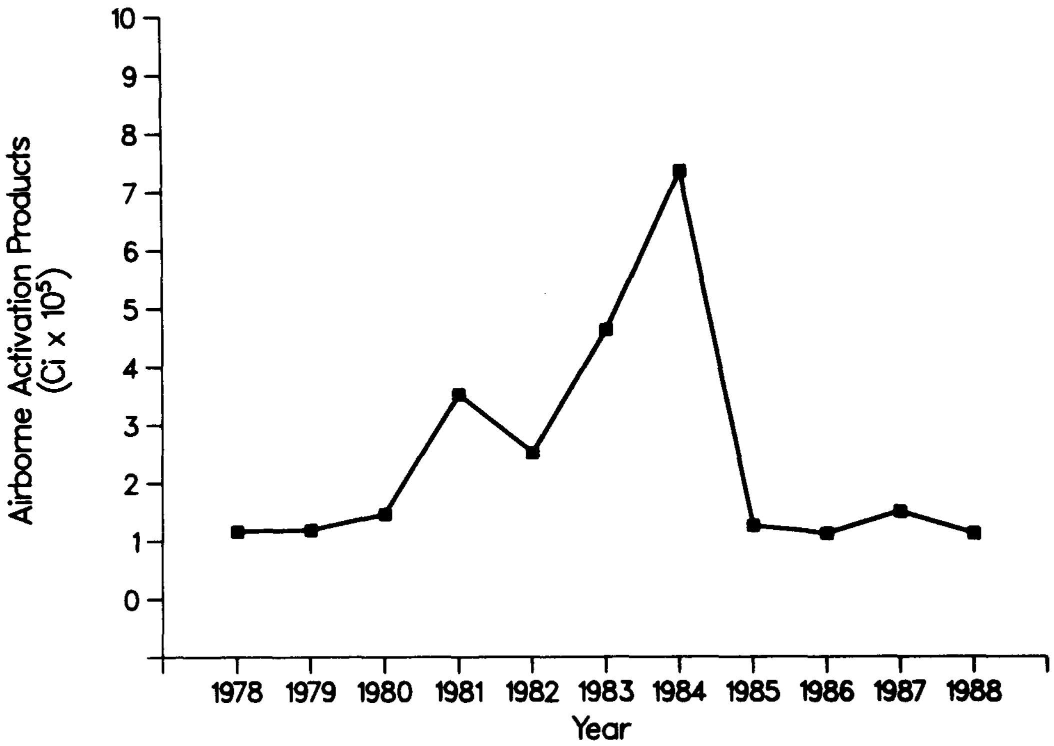

Fig. 11. Airborne activation product emissions (principally ^{10}C, ^{11}C, ^{13}N, ^{16}N, ^{14}O, ^{15}O, ^{41}Ar) from LAMPF, the Los Alamos Meson Physics Facility (TA-53).

Pollutants (EPA 1985). As discussed in Sec. III, the maximum individual doses caused by Laboratory operations during 1988, which resulted from releases of air-activation products at LAMPF, were 6.2 mrem to the whole body and 7.2 mrem to the testes. These doses were 25% of the EPA limit of 25 mrem/yr to the whole body and 10% 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 (19 mi) from the Laboratory and at an on-site sampling location (TA-59, OH-1).

4. Tritium. In 1988, the regional mean (2.5 × 10^{-12} μCi/mL) was statistically significantly lower than the perimeter annual mean (11.5 × 10^{-12} μCi/mL) and the on-site annual mean (23.9 × 10^{-12} μCi/mL) (Table G-7). This reflects the slight impact of Laboratory operations. The TA-2 (Station 25) and TA-33 (Station 24) annual means of 78.0 × 10^{-12} and 57.8 × 10^{-12} μCi/mL, respectively, were the two highest annual means measured in 1988. Both of these stations are located within the Laboratory boundary near areas where tritium is 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 98 air-sample analyses performed in 1988 for ^{238}Pu, only 7 were above the minimum detectable limit of 2.0 × 10^{-18} μCi/mL. The highest concentration occurred at TA-2 (17.4 ± 3.8 × 10^{-18} μCi/mL) and represents <0.1% of DOE's Derived Air Concentration guides for ^{238}Pu in controlled areas, 3 × 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 minimum detectable activity.

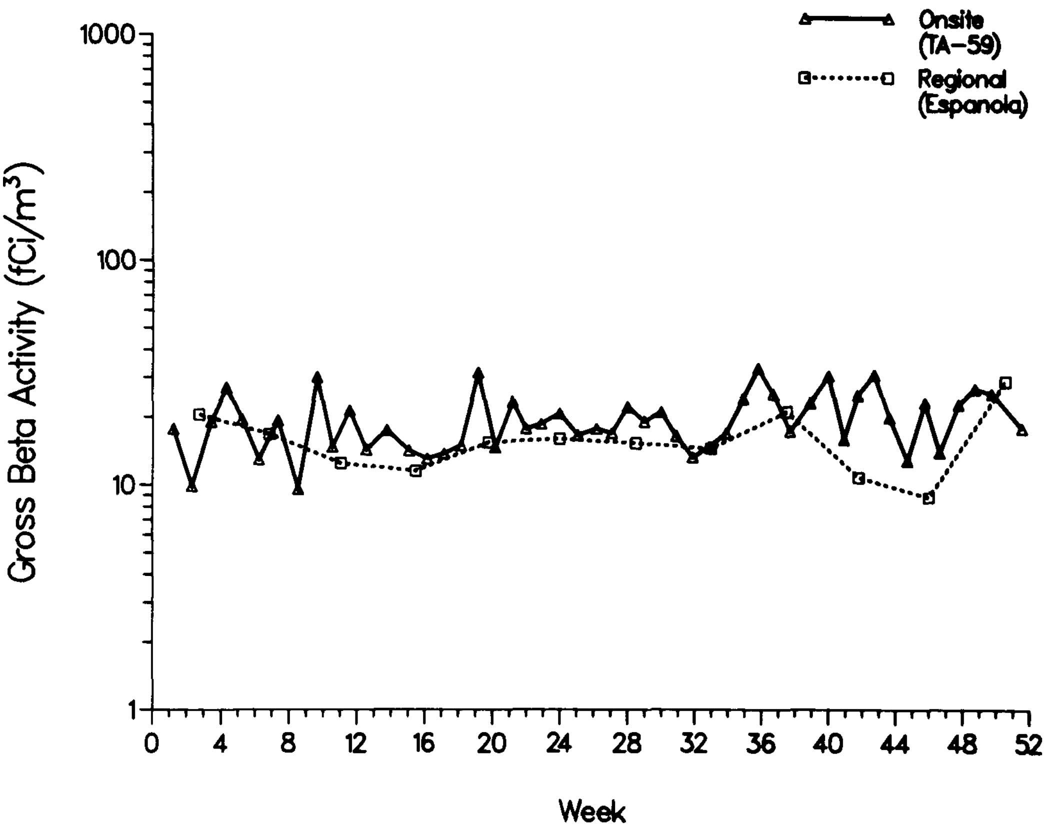

Fig. 12. Atmospheric gross beta activity at a regional (background) station and an on-site station during 1988.

The 1988 annual means for ^{239,240}Pu concentrations in air for the regional (0.8×10^{-18} µCi/mL), perimeter (0.8×10^{-18} µCi/mL), and on-site (4.1×10^{-18} µCi/mL) stations were all <0.1% of the derived guides for controlled or uncontrolled areas (Appendix A).

Measured concentrations of ^{241}Am were all <0.1% of the derived guides for controlled and uncontrolled areas (Appendix A).

The 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. Those stations with relatively higher annual averages or maximums are in dusty areas, where a higher filter dust loading accounts for collection of more natural uranium from resuspended soil particles.

The 1988 annual means were regional, 159 pg/m^3; perimeter, 56 pg/m^3; and on site, 62 pg/m^3 (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. The 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. At present, total suspended particulate (TSP) matter is measured at two sites in the vicinity of the Laboratory by the New Mexico Air Quality Bureau. Measurements are made once every 6 days at a site on West Road in Los Alamos and at the sewage treatment plant in White Rock. TSP levels measured at these sites, as well as the applicable standards, are reported in Table 9. The TSP ambient air quality standards were met in both Los Alamos and White Rock.

In 1988, the Laboratory restarted the ambient air monitoring station south of TA-49 adjacent to Bandelier National Monument. In 1989, fully quality-assured data will be collected for TSP matter, ozone, PM_{10} (particles with an aerodynamic diameter ≤ 10 μm), sulfur dioxide, and nitrogen dioxide.

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 bag-house filter is used to control 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 the New Mexico air quality permits. In 1988, the Laboratory submitted a permit application for additional beryllium-processing operations at TA-3-35.

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-11. These plants are a source of particulate matter, oxides of nitrogen (NO_x), carbon monoxide, and hydrocarbons. The NO_x emissions from the TA-3 power plant were estimated based on 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 1984). The decrease in emissions from 1987 to 1988 reflects the drop in fuel consumption, mainly at the TA-3 power plant. The Western Area steam plant, used as a standby plant, was operated only 1 month during 1988. The emissions from these plants are quite low, posing no threat of violating ambient air quality standards.

c. Asphalt Plant. Annual production figures and estimates of the particulate matter emissions from

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

Type	State Ambient Air Quality Standards Maximum Allowed	Measurements	
		Los Alamos	White Rock
24-h average	150	58 (43)[a]	83 (67)[a]
Annual geometric mean	60	21.8	23.6

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[a] Highest (second highest).

Table 10. Asphalt Plant Particulate Matter Emissions

Year	Production (ton/yr)	Emissions (lb/yr)
1987	8083	269
1988	7389	246

the asphalt concrete plant are found in Table 10. A multicyclone cleaner and a wet scrubber are used to clean the exhaust gas stream before it is released into the atmosphere. The particulate matter emissions from the plant decreased from 1987 to 1988 because of a decrease in production. There has been a substantial decrease in asphalt production since 1985 because most of the asphalt used at Los Alamos since then has been purchased from outside vendors. The particulate matter emissions estimate was based on stack testing data (Kramer 1977) and production data.

d. Burning and Detonation of Explosives. During 1988, a total of 15 201 kg (33 513 lb) of high-explosive wastes were disposed of by open burning at the TA-16 burn ground. Burning the explosives resulting in emissions of oxides of nitrogen, particulate matter, carbon monoxide, and hydrocarbons. Estimates of emissions resulting from this burning are reported in Table 11. The emissions were 17% lower than those for 1987. These estimates were made by using data from experimental work carried out by Mason and Hanger–Silas Mason Co., Inc. (MHSM 1976).

Dynamic experiments using conventional explosives are routinely conducted in certain test areas at the Laboratory. In some experiments these explosives contain toxic metals including uranium, beryllium, and lead. Estimates of emissions from this activity are shown in Table G-6. Uranium and lead emissions more than doubled; beryllium emissions remained constant from 1987 to 1988.

Estimates of average concentrations of these toxic metals downwind from the detonations have shown that ambient air quality impacts are likely to be <0.1% of the applicable standards. These estimates are based on information concerning the proportion of material aerosolized, limited field experiments involving aircraft sampling, and the amounts of toxic metals used in the experiments.

e. Lead-Pouring Facility. A lead-pouring facility for producing lead castings is located at TA-3-38. Approximately 7055 kg (15 554 lb) of lead were poured during 1988. This facility emits particulate matter containing lead. The maximum amount of lead poured per quarter was about 3300 kg (7300 lb), which took place during the second quarter. The estimated 1988 annual TSP emissions from this facility were 3.1 kg (6.8 lb); the maximum quarterly TSP emissions were 1.5 kg (3.2 lb). The estimated annual and maximum quarterly emissions of lead were 0.68 and 0.33 kg (1.5 and 0.73 lb), respectively. The emission estimates were based on the amounts of lead poured and an EPA emission factor for lead-casting operations (EPA 1984).

Table 11. Estimated Air Pollutant Emissions from the Open Burning of Waste Explosives (kg)

Pollutant	1987	1988
Oxides of nitrogen	556	459
Particulates	331	274
Carbon monoxide	143	119
Hydrocarbons	2	2

Both the national and New Mexico ambient air quality standards for lead are 1.5 $\mu g/m^3$ averaged over a calendar quarter. Air dispersion procedures recommended by the EPA (EPA 1986) were used to estimate the maximum quarterly average lead concentrations caused by emissions from the lead-pouring facility. These procedures provide conservative concentration estimates. The maximum quarterly concentration for 1988 was estimated to be 0.021 $\mu g/m^3$, approximately 1% of the standard.

3. **Visibility.** In cooperation with the Laboratory, the National Park Service established a visibility monitoring site on Laboratory property. The site is located near Bandelier National Monument, an area where visibility is considered an integral part of the Monument's attraction. The overall purpose of this national program is to characterize long-range visibility in and around the National Parks and Monuments. Although the Park Service has not yet published the data for 1988, the preliminary data indicate that typical visibility in this area is quite high, approaching the theoretical limit based on atmospheric scattering. The extensive forest fires in the western United States greatly reduced visibility on several days during the summer of 1988.

VI. WATER, SOILS, AND SEDIMENTS 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 due to Laboratory operations. The chemical quality of surface waters from areas with no effluent release varied with seasonal fluctuations. Water in on-site areas where treated effluent has been released contained radionuclides below DOE's concentration guides. The quality of water in these release areas reflected some impact of Laboratory operations, but these waters are confined within the Laboratory boundary and are not a source of municipal, industrial, or agricultural water supply.

Most regional and perimeter soil and sediment stations contained radioactivity at or near background levels. Concentrations that did exceed background were low and were not considered significant. Sediments from areas where treated discharges have been released contained radionuclides in excess of background. Concentrations of plutonium in sediments from regional reservoirs on the Rio Chama and Rio Grande reflected worldwide fallout.

A. Effluent Quality

In the past, treated liquid 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 (TA-53) (Tables 3, G-12, G-13, and Figs. 9, 10, and 13). In 1988, there were no releases from TA-21.

The total activity released in 1988 (ca. 32 Ci) was 29% of that released in 1987 (ca. 110 Ci) (Table 3). Release of ^{137}Cs from TA-50 increased fourfold because of cleanup activities at the TA-3-29 hot cells (Table G-12). 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 before the plant began operation in 1963.

Concentrations found in the TA-53 lagoon effluent in 1988 were lower than those found in 1987 for all radionuclides (Table G-13). The source of the radioactivity was activated nuclides in water from the beam-stop cooling systems. The volume discharged from the lagoons decreased substantially in 1988. Discharge from the lagoons sinks into the alluvium of Los Alamos Canyon within the Laboratory's boundary.

As discussed in subsequent sections, concentrations of radionuclides in water decrease from the point of discharge. Effluent radionuclides have not been detected beyond the Laboratory boundary in Mortandad Canyon. Although effluent radionuclides do occur off site in Los Alamos Canyon, the concentrations remain <0.1% of DOE's guides for off-site waters. 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-14). 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

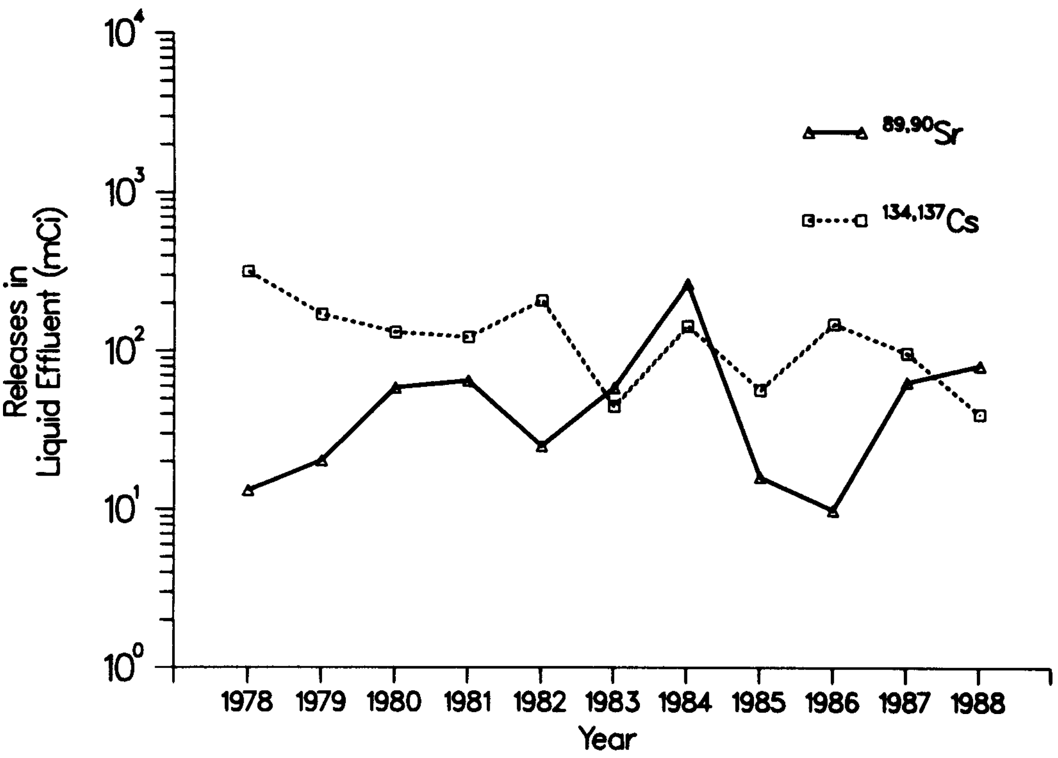

Fig. 13. Summary of strontium and cesium liquid effluent releases.

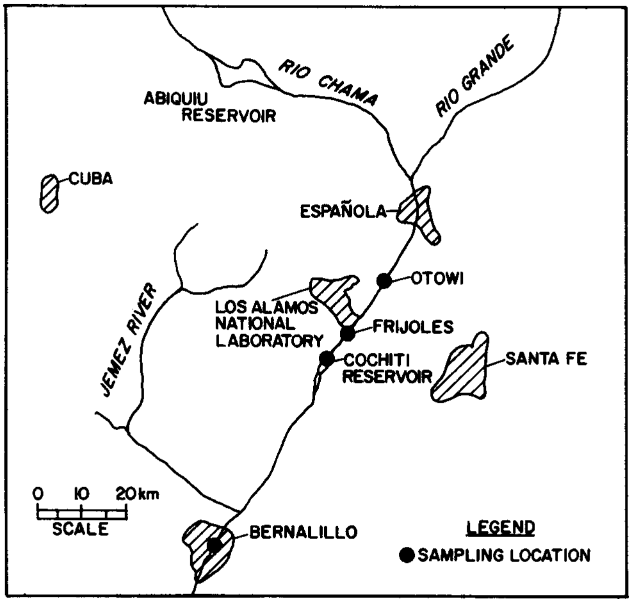

Fig. 14. Regional surface water, sediment, and soil sampling locations.

(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).

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 sampling stations were located at U.S. Geological Survey gaging stations. These waters provided baseline 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

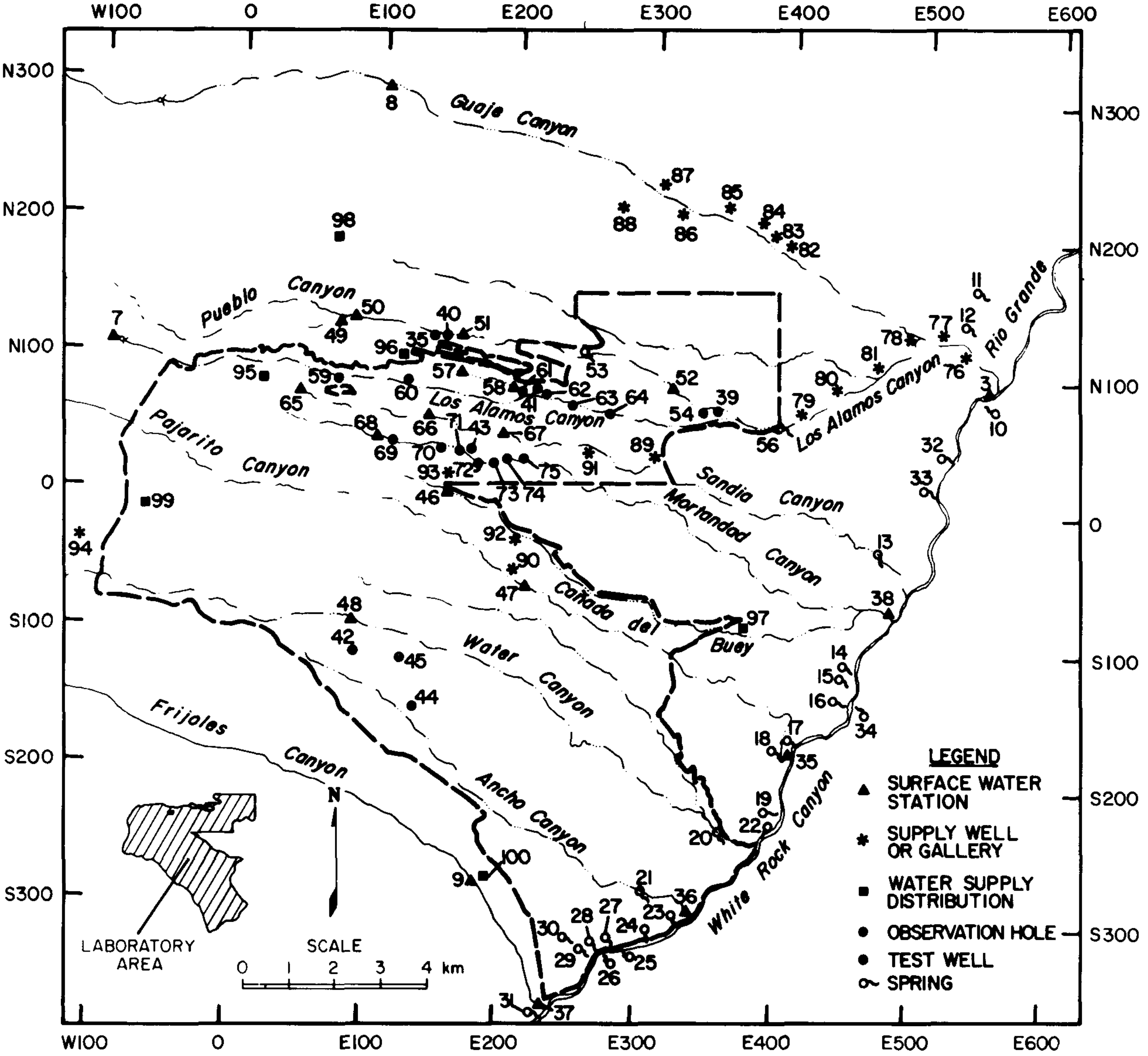

Fig. 15. Surface and ground-water sampling locations on and near the Laboratory site.

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 period of record (1895–1905 and 1909–1986) has ranged from a minimum of 1.7 m^3/s (60 ft^3/s) in 1902 to 691 m^3/s (24 400 ft^3/s) in 1920. The discharge for water year 1987 (October 1986 to September 1987) ranged from 22 m^3/s (780 ft^3/s) in July to 279 m^3/s (9850 ft^3/s) in May (USGS 1988).

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 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 1987 ranged from

1.3 m^3/s (46 ft^3/s) in January to 88 m^3/s (3100 ft^3/s) in April.

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 1987, discharge ranged from 0.62 m^3/s (22 ft^3/s) in September to 56 m^3/s (1960 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. Water from these rivers is part of recreational areas on state and federal lands.

a. Radiochemical Analyses. Surface water samples from regional stations were collected in February and September 1988. Cesium, plutonium, tritium, and total uranium activity levels in these waters were low (Tables 12 and G-15). Samples collected downgradient from the Laboratory showed no effect from the Laboratory's operation. Sampling results from 1988 exhibited no major differences from 1987's. Maximum concentrations of radioactivity in regional surface water samples were well below DOE's concentration guides for off-site areas.

b. Stable Chemical Analyses. Surface water samples from regional stations were collected in March 1988. Maximum concentrations in regional water samples were well below drinking water standards (Tables 13 and G-16). There were some variations from previous years' results. These fluctuations result from 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 23 springs, 3 streams, and a sanitary effluent release area (Fig. 15 and Table G-14).

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 16.6 km^2 (6.4 mi^2) above the intake. The reservoir is used for storage and recreation. Water flows by gravity through about 10.2 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. Guaje Reservoir in upper Guaje Canyon has a capacity of 0.9×10^3 m^3 (0.7 acre-ft) and a drainage area above the intake of about 14.5 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.

The 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 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 seep 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 (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

Table 12. Maximum Concentrations of Radioactivity in Surface and Ground Waters from Off-Site and On-Site Stations

	Number of Stations	^{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	0.5 (0.3)	145 (69)[b]	4 (1)	0.017 (0.012)	0.013 (0.010)
Perimeter						
Adjacent	6	1.2 (0.3)	145 (63)	4 (1)	0.009 (0.013)	0.019 (0.010)
White Rock	25	0.8 (0.3)	101 (79)	13 (1)	0.026 (0.014)	0.032 (0.015)
Off-Site Station Group Summary						
Maximum concentration		0.8	145	13	0.026	0.019
Maximum concentration as percentage of DCG		<1	5	2	<1	<1
On-Site Stations (Controlled Areas):						
Noneffluent Release Areas						
Ground water (main aquifer)	6	−0.1 (0.3)	32 (60)	2 (1)	0.019 (0.013)	0.027 (0.013)
Surface water	3	−0.5 (0.3)	−62 (54)	2 (1)	0.024 (0.014)	0.006 (0.006)
Observation wells (Pajarito Canyon)	3	−0.5 (0.3)	−30 (55)	1 (1)	0.020 (0.014)	0.016 (0.008)
Effluent Release Areas						
Acid-Pueblo Canyons	7	0.2 (0.3)	14 (53)	1 (1)	0.015 (0.012)	0.339 (0.038)
DP-Los Alamos Canyons	6	1.1 (0.4)	92 (62)	2 (1)	0.002 (0.004)	0.010 (0.007)
Sandia Canyon	3	−0.5 (0.3)	68 (61)	1 (1)	0.008 (0.011)	0.012 (0.010)
Mortandad Canyon	7	490 (50)	100 (63)	6 (1)	1.38 (0.135)	5.70 (0.238)
On-Site Station Group Summary						
Maximum concentration		490 (50)	100 (63)	6.1	1.38 (0.135)	5.70 (0.238)

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[a] See Appendix A.

[b] Counting uncertainty is in parentheses.

Table 13. Maximum Chemical Concentrations in Surface and Ground Waters from Regional and Perimeter Stations (mg/L)

	Number of Stations	Ca	Na	Cl	F	N	TDS
Regional Stations							
Rio Chama	1	45	24	6	0.3	<0.2	268
Rio Grande	4	37	24	9	0.5	0.3	228
Jemez River	1	17	9	9	0.3	0.2	98
Perimeter Stations							
Surface Water	3	6	6	3	0.2	0.8	99
Springs	3	20	20	12	0.6	0.7	172
White Rock Canyon							
Group I	9	33	17	7	0.7	1.4	198
Group II	9	24	21	8	0.6	5.7	173
Group III	2	24	60	4	1.2	0.9	230
Group IV	1	32	139	4	1.1	<0.2	496
Streams	3	20	13	5	0.5	0.6	173
Sanitary Effluent	1	26	76	4	14	7.8	389
Drinking Water Standard							
(for comparison [EPA 1976])		—	—	250	4.0	10	500

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 also sampled in Mortandad Canyon at its confluence with the Rio Grande.

Detailed results of radiochemical and stable chemical analyses of samples collected from the perimeter stations are shown in Tables G-17 through G-21.

a. Radiochemical Analyses. Cesium, plutonium, tritium, and total uranium activity for samples collected at perimeter stations were low and well below DOE's concentration guides for off-site areas (Tables 12, G-17, and G-18).

b. Stable Chemical Analyses. Maximum chemical concentrations in samples from the perimeter stations were within drinking water standards including waters (sanitary effluent) from Mortandad Canyon at the Rio Grande (Tables 13, G-19, and G-20). Table G-21 presents results for 68 elements in water from springs and streams in White Rock Canyon. The resulting values were either low or undetectable. These results provide a baseline for future sampling. Concentrations in water samples from the 16 springs and 3 streams in White Rock Canyon were also within drinking water standards.

4. On-Site Stations. On-site sampling stations are grouped by location: (1) those that are not in effluent release areas (noneffluent release areas) and (2) those that are in areas receiving or that have received treated industrial effluents (effluent release areas) (Fig. 15, Table G-14).

a. Noneffluent Release Areas. On-site, noneffluent sampling stations consist of seven deep test wells, three surface water sources, and three new, 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 pump in Test Well 2 was removed for repairs in 1988 and the well was not sampled. Test Well 3 is in the midreach of Los Alamos Canyon with 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 at about 295 m (968 ft) below the surface.

These test wells are constructed to seal out all water above the main aquifer. The wells 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 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-14). 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 12 and G-22). Concentrations of tritium, cesium, and plutonium were at or below limits of detection.

Stable chemical quality of ground water from the test wells into the main aquifer reflected local conditions of the aquifer around the well (Tables 14, G-23, and G-24). Quality of surface water and of observation wells in Pajarito Canyon varied slightly. The effect, if any, was small, and probably was the result of natural seasonal fluctuations. Maximum concentrations of chemical constituents in the on-site surfaces and ground-water samples were within drinking water standards, except for lead from Test Well 8 (0.060 mg/L); ground water in Pajarito Canyon contained manganese in excess of 0.05 mg/L. Surface water and shallow ground water in Pajarito Canyon contained iron in excess of 0.3 mg/L. The total dissolved solids in surface water from Pajarito Canyon exceeded standards (Table G-23).

b. Effluent Release Areas. On-site effluent release areas are 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 the Los Alamos County treatment plants in the upper and middle reaches of Pueblo Canyon. Sanitary effluents form some perennial flow in the canyon, but do not reach the confluence with Los Alamos Canyon except during storm or snowmelt run-off.

Water occurs seasonally in the alluvium dependent on the volume of surface flow from sanitary effluents and storm run-off. Hamilton Bend Spring discharges from alluvium in the lower reach of Pueblo Canyon and 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-14). Two other sampling stations are located in the middle reach (Test Well T-2A) and lower reach (Test Well T-1A) of Pueblo Canyon. Test Well T-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 indicated that the perched aquifer is of limited extent. Water-level measurements 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 from the recharge area near Hamilton Bend Spring to Test Well 1A is estimated to be 1 to 2 months, with another 2 to 3 months to reach Basalt Spring.

DP-Los Alamos Canyon has received treated industrial effluents, which contain some radionuclides and

Table 14. Maximum Chemical Concentrations in On-Site Surface and Ground Waters

		Maximum Concentration			**Group Summary**	
	Standards[a]	**Test Wells (Main Aquifer)**	**Surface Water**	**Observation Wells (Pajarito Canyon)**	**Maximum Concentration**	**Maximum Concentration as a Percentage of Standard**
Number of Stations		6	3	3		
Chemical Constituents (mg/L)						
Ag	0.05	<0.001	<0.001	<0.001	<0.001	<2
As	0.05	0.003	0.011	0.024	0.024	48
Ba	1.0	0.078	0.360	0.513	0.513	51
Cd	0.01	<0.001	<0.001	<0.001	<0.001	<1
Cr	0.05	0.004	0.002	0.012	0.012	24
F	4.0	0.6	1.1	0.7	1.1	28
N	10	6.0	<0.2	<0.2	6.0	60
Pb	0.05	0.060	0.001	0.010	0.060	120
Se	0.01	0.001	0.003	0.004	0.004	40
Cl	250	31	174	58	174	70
Cu	1.0	0.024	0.010	0.108	0.108	11
Fe	0.3	0.20	4.7	32	32	10 700
Mn	0.05	0.007	<0.053	10.1	10.1	20 200
SO_4	250	23	9	3	9	2
Zn	5.0	0.989	0.054	0.147	0.989	20
TDS	500	278	743	464	743	148

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[a] USEPA primary and secondary drinking water standards are used for comparison only. These stations are not used for the industrial or municipal water supply.

some sanitary effluents from treatment plants at TA-21. Treated industrial effluents have been released into the canyon since 1952. During 1988, there were no liquid discharges from TA-21. In the upper reaches of Los Alamos Canyon (above Station LAO-1), there are 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, as storm run-off is at a minimum. Sampling stations consist of two surface water stations in DP Canyon and six observation wells completed into alluvium (about 66 m [20 ft] thick) in Los Alamos Canyon (Table G-14).

Sandia Canyon has a small drainage area that heads on Pajarito Plateau in 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 indicated no perched water in the alluvium in this area. There are three surface-water sampling stations in the reach of the canyon that contains perennial flow (Table G-14).

Mortandad Canyon has a small drainage area that also heads in 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 flow beyond the Laboratory's boundary because the small drainage area in the upper part of the canyon results in limited run-off and a thick section of unsaturated alluvium in the lower canyon allows rapid infiltration and storage of run-off when it does occur. Monitoring stations in the canyon are 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, Mortandad, and Sandia canyons all contained surface and shallow ground waters with measurable amounts of radioactivity (Table G-25). Radionuclide concentrations from treated effluents decreased downgradient 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 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).

Stable chemical quality of effluents varied from canyon to canyon (Table G-26). Concentrations of nitrates, lead, chlorides, iron, manganese, zinc, and total dissolved solids have exceeded the standards as a result of effluents released into some of the canyons (Tables 15 and G-27). Relatively high nitrate concentrations were found in waters from Mortandad Canyon, which receives the largest volume of industrial effluents (Purtymun 1977). Though the concentrations of some chemical constituents in the waters of these canyons were high when compared with drinking water standards (Table 15), these on-site surface and shallow ground waters are not a source of municipal, industrial, or agricultural supply.

Maximum chemical concentrations occurred in water samples taken near treated effluent outfalls (Tables G-26 and G-27). Chemical quality of the water improved downgradient from the outfalls. Surface flows in Acid-Pueblo and DP-Los Alamos canyons reach the Rio Grande only during spring snowmelt or heavy

Table 15. Maximum Chemical Concentrations in Water from On-Site Effluent-Release Areas

		Maximum Concentration				Group Summary	
	Standards[a]	**Acid-Pueblo Canyons**	**DP-Los Alamos Canyons**	**Sandia Canyon**	**Mortandad Canyon**	**Maximum Concentration**	**Maximum Concentration as a Percent of Standard**
Number of Stations		7	6	3	8		
Chemical Constituents (mg/L)							
Ag	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<2
As	0.05	0.016	0.017	0.014	0.004	0.017	34
Ba	1.0	0.167	0.169	0.111	0.288	0.288	29
Cd	0.01	<0.001	<0.001	0.002	<0.001	0.002	20
Cr	0.05	0.014	0.003	0.015	0.016	0.016	32
F	4.0	1.3	2.7	1.2	2.9	2.9	72
N	10	5.7	1.5	5.2	123	123	1230
Pb	0.05	0.109	0.006	0.046	0.007	0.109	218
Se	0.01	0.001	0.002	0.001	0.002	0.002	20
Cl	250	262	175	125	38	262	104
Cu	1.0	0.037	0.016	0.058	0.014	0.058	6
Fe	0.3	5.4	0.87	1.17	1.1	5.4	1800
Mn	0.05	1.52	0.165	0.213	0.308	1.52	3040
SO_4	250	29	23	101	50	50	20
Zn	5.0	12.8	0.009	0.295	0.026	12.8	256
TDS	500	517	481	456	1086	1086	217

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[a] USEPA primary and secondary drinking water standards are used for comparison only. These waters are not a source of industrial or municipal water supply.

summer thunderstorms. There has been no surface runoff to Laboratory boundaries recorded in Mortandad Canyon since 1960, when observations began.

5. Monitoring Quality of 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 Well LA-6 contains excessive amounts of natural arsenic (up to 0.200 mg/L) that cannot be reduced to acceptable limits by mixing it in the distribution

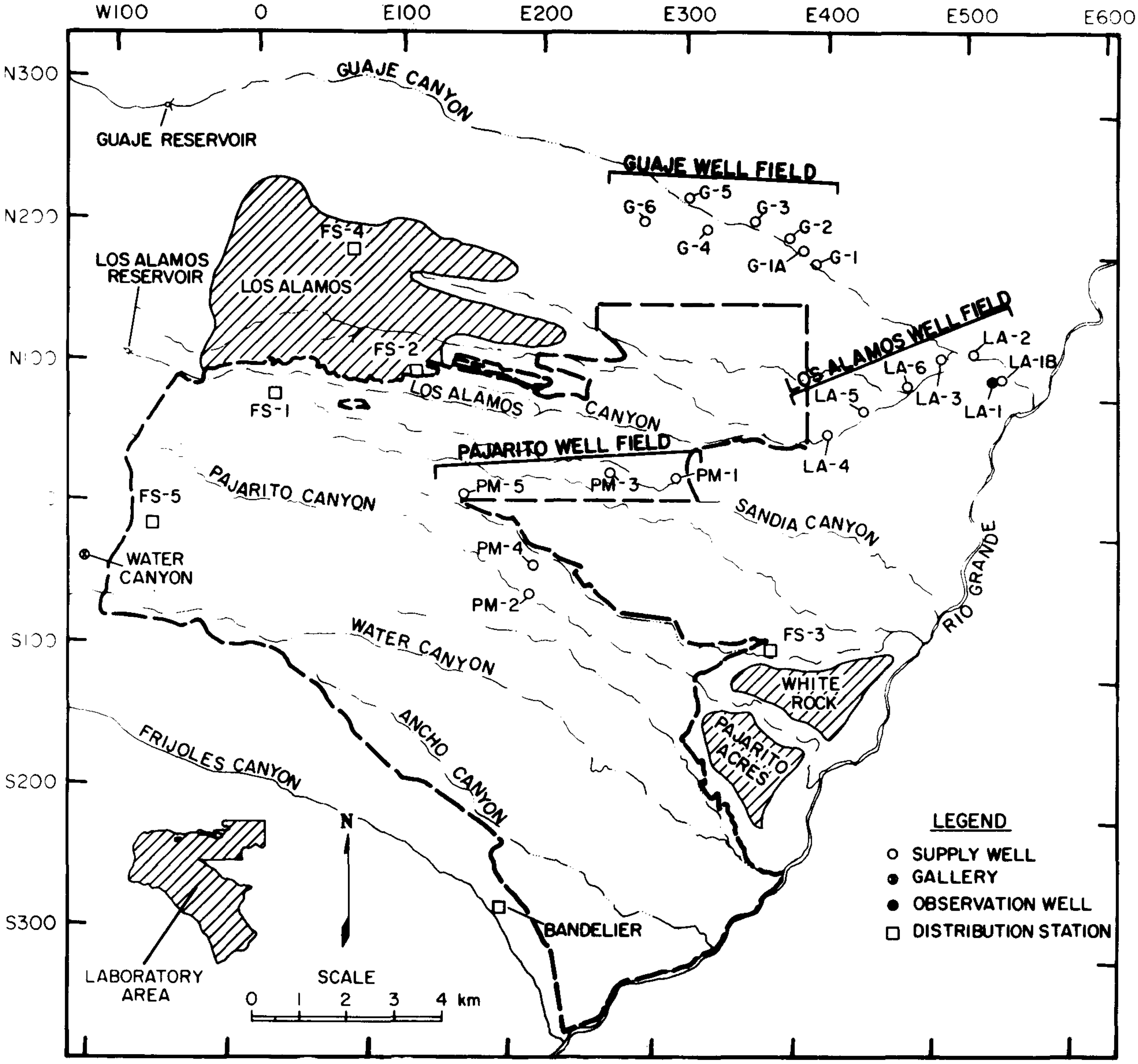

Fig. 16. Locations of reservoirs, well fields, supply wells, and gallery water supply.

system (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). Wells in the field were inoperative for part of 1988, and no samples were collected.

The Guaje well field is composed of seven producing wells. Wells in the field range in depth from 463 to 610 m (1520 to 2000 ft). Movement in 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 that range 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 (85 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 prior to entering the distribution system.

Water in the distribution systems was sampled at five community and Laboratory locations (fire stations), Bandelier National Monument, and Fenton Hill (Fig. 16, Table G-14). For results from routine surveillance monitoring, federal and state standards (Appendix A) are used only for comparison. Sampling confirming compliance with federal and state drinking water standards is discussed in Sec. VIII.E.

a. Radioactivity in Municipal and Industrial Water Supply. The maximum radioactivity concentrations found in the supply (wells and gallery) and distribution (including Fenton Hill) systems are below the EPA's drinking water standards (Tables 16 and G-28).

b. Stable Chemical Quality of Municipal and Industrial Water Supply. The chemical quality of water from wells and the distribution systems is within EPA's primary and secondary standards for all but one parameter (Tables 17, G-29, and G-30). Iron at one station in the distribution system was 117% of the standard (Table G-29).

The quality of water from the wells varied with local conditions within the same aquifer (Tables G-29 and G-30). 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 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 is highest near the treated effluent outfall and decreases in concentration downgradient 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.

A spring snowmelt and three summer samples of run-off were analyzed for plutonium in solution and suspended sediments. Radioactivity in solution is defined at that in filtrate that passes through a 0.45-m pore-size filter; radioactivity in suspended sediments is defined as that in residue retained by the filter.

The summer run-off samples were collected at three stations around Area 2 at TA-49. These contained only background levels in solution and suspension (Table 18). The single sample of snowmelt run-off was collected in Los Alamos Canyon at State Route 4. This sample also contained no measurable plutonium in solution. However, above-background levels were found in suspended sediments. This canyon has received low-level radioactive effluents in the past. The plutonium on the sediments represents either adsorption by soil particulates of soluble plutonium in the effluents or ion exchange with effluent particulates.

Table 16. Maximum Concentrations of Radioactivity in Water from Supply Wells and Distribution System

	Number of Stations	^{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 concentration level (MCL)[a]		20	200	1800[b]	15	15	15	—
Supply wells (Los Alamos)	10	−0.6 (<1)[c]	56 (28)	2 (<1)	0.009 (<1)	0.024 (<1)	11 (73)	7.8
Distribution (Los Alamos)	6	−0.8 (<1)	135 (68)	1 (<1)	0.032 <1	0.016 (<1)	7 (64)	6.8
Distribution (Fenton Hill)	1	—	5 (3)	2 (<1)	0.007 <1	0.014 (<1)	1 (9)	6.2

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[a] EPA (1976).
[b] ICRP (1977).
[c] Percentage of EPA's MCL is in parentheses; this usage is for comparison only.

Table 17. Maximum Chemical Concentration in Water from Supply Wells and Distribution System

	Standard[a]	Supply Wells	Percentage of Standard	Distribution System	Percentage of Standard
Number of Stations		10		7	
Chemical Constituents (mg/L)					
Primary					
Ag	0.05	<0.001	<2	0.002	4
As	0.05	0.034	68	0.011	22
Ba	1.0	0.086	9	0.105	11
Cd	0.01	<0.001	<10	<0.001	<10
Cr	0.05	0.006	12	0.006	12
F	4.0	0.8	20	0.6	15
Hg	0.002	<0.0002	<10	<0.0002	<10
NO_3 (N)	10	0.6	6	0.5	5
Pb	0.05	0.007	14	0.002	4
Se	0.01	0.001	10	0.001	10
Secondary					
Cl	250	7	3	30	12
Cu	1.0	0.104	10	0.033	3
Fe	0.3	0.042	14	0.350	117
Mn	0.05	0.002	4	0.001	2
SO_4	250	6	2	9	4
Zn	5.0	0.081	2	0.230	5
TDS	500	230	46	279	56

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[a] USEPA primary and secondary drinking water standards are used for comparison only.

7. Organic Analyses of Surface and Ground Water. Surface and ground-water samples were collected from 10 stations representing water from 4 test wells in the main aquifer, a perched aquifer, an observation well, a spring, and 4 surface-water sampling stations (Fig. 15, Table G-14). All the samples were analyzed for 65 volatile compounds, 68 semivolatile compounds, 13 pesticide compounds, 4 herbicide compounds, and polychlorinated biphenyls (PCBs). The limits of quantification (LOQ) for the volatile and semivolatile compounds, herbicides, pesticides, and PCBs are given in Appendix C. Only compounds that exceeded the LOQ are discussed; these compounds are also listed in Table 19.

a. Volatile Compounds. Water from the 10 stations was analyzed for 65 volatile compounds; however, only 3 stations had water samples containing compounds that exceeded the LOQ.

The water from test well DT-10 completed in the main aquifer contained acetone at a concentration of 777 ± 233 µg/L (LOQ 2 µg/L) and styrene at 202 ± 61 µg/L (LOQ 2 µg/L). The water from the well was resampled. Three additional samples collected from the well contained no organic compounds; thus the initial sample must have been contaminated when collected.

The volatile compound naphthalene was reported in samples from two surface-water stations. Water from Cañada del Buey contained naphthalene at

Table 18. Plutonium in Solution and Suspended Sediments in Storm Run-Off[a]

Summer Run-Off[b]	Technical Area TA-49 Station 2	 Station 3	 Station 5
Solution (10^{-9} μCi/mL)			
^{238}Pu	0.008 (0.011)	−0.008 (0.011)	0.020 (0.012)
^{239,240}Pu	0.024 (0.011)	0.015 (0.011)	−0.004 (0.009)
Suspended Sediments (pCi/g)			
^{238}Pu	−0.003 (0.011)	0.017 (0.003)	0.001 (0.001)
^{239,240}Pu	0.071 (0.019)	0.704 (0.031)	0.008 (0.002)

Snowmelt Run-Off[c]	Los Alamos Canyon Station at SR-4
Solution (10^{-9} μCi/mL)	
^{238}Pu	0.000 (0.010)
^{239,240}Pu	0.004 (0.015)
Suspended Sediments (pCi/g)	
^{238}Pu	0.894 (0.179)
^{239,240}Pu	2.43 (0.296)

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[a] Counting uncertainty is in parentheses.
[b] Summer run-off, August 10, 1988, TA-49.
[c] Snowmelt run-off, April 21, 1988, Los Alamos Canyon.

a concentration of 5.3 ± 1.5 μg/L, and water from Pajarito Canyon had a concentration of 8.4 ± 2.5 μg/L. The naphthalene found in the two surface-water stations was in trace amounts and near the LOQ of 2.0 μg/L.

b. Semivolatile Compounds. Water from the 10 stations was analyzed for 68 semivolatile compounds. Only the water from test well DT-10 contained a compound above the LOQ. The test well contained benzyl alcohol at a concentration of 14 ± 2.8 μg/L (LOQ 10 μg/L). Three additional samples collected at a later date from the well contained no semivolatile compounds.

c. Pesticides. Water from the 10 stations was analyzed for 13 pesticide compounds. Trace amounts of pesticide compounds were detected in water from a perched zone in a test well and from a surface-water station (Table 19). Water from the test well TW-1A had a concentration of endrin of 0.10 ± 0.02 μg/L (LOQ 0.05 μg/L). Water from SCS-1 contained lindane at 0.26 ± 0.05 μg/L LOQ 0.01 μg/L), heptachlor at 0.09 ± 0.02 μg/L (LOQ 0.01 μg/L), and

Table 19. Summary of Organic Compound Analyses from Surface and Ground-Water Stations

	Location No.[a]	Depth (ft)	Depth to Water (ft)	Organic Compounds				
				Volatile	Semivolatile	Pesticides	Herbicides	PCBs
Number of Compounds Analyzed				65	68	13	4	1
Test Wells								
Main Aquifer								
TW-1	39	593	642	(0)[b]	(0)	(0)	(0)	(0)
TW-3	41	815	750	(0)	(0)	(0)	(0)	(0)
DT-9	44	1501	1006	(0)	(0)	(0)	(0)	(0)
DT-10	45	1409	1085	(2)	(1)	(0)	(0)	(0)
TW-1A[c]	54	225	183	(0)	(0)	(0)	(1)	(0)
Observation Well (Alluvium)								
PCO-1 (Pajarito Canyon)	102	12	4.5	(0)	(0)	(0)	(0)	(0)
Basalt Springs	56	—	—	(0)	(0)	(0)	(1)	(0)
Surface Water								
SCS-1 (Sandia Canyon)	65	—	—	(0)	(0)	(3)	(1)	(0)
Cañada del Buey	46	—	—	(1)	(0)	(0)	(1)	(0)
Pajarito	47	—	—	(1)	(0)	(0)	(0)	(0)

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[a] See Fig. 15 and Table G-14 for location.

[b] Numbers in parentheses indicate number of organic compounds detected.

[c] Water perched in basalt above main aquifer.

dieldrin at 0.07 ± 0.01 μg/L (LOQ 0.04 μg/L). The concentrations of the four pesticides reported in the surface water were low, near the LOQ; if present in the water these concentrations are not a health or environmental hazard.

d. Herbicides. Water from the 10 stations was analyzed for 4 herbicide compounds. Trace amounts of herbicides were found in the perched water in a test well, spring, and two surface-water stations.

Water from test well TW-1A contained the herbicide 2,4,5-T with a concentration of 0.3 ± 0.06 μg/L (LOQ 0.2 μg/L), and Basalt Spring contained 2,4,5-T with a concentration of 0.4 ± 0.1 μg/L. Surface water at SCS-1 also contained 2,4,5-T, with a concentration of 3.4 ± 0.2 μg/L.

Water from Cañada del Buey contained the herbicide 2,4-D with a concentration of 0.8 ± 0.06 μg/L (LOQ 0.2 μg/L).

The herbicide concentrations detected at the four stations were low, near the LOQ, and may or may not be actually present in the water. If they are present, they do not represent a health or environmental problem.

e. Polychlorinated Biphenyls. Water from the 10 stations was analyzed for polychlorinated biphenyls (PCBs). The results of all the analyses showed that concentrations were below the limits of quantification of 0.1 μg/L.

C. Radioactivity in Soils and Sediments

1. Background Levels of Radioactivity in Soils and Sediments. Samples were routinely collected and analyzed for radionuclides from regional stations from 1974 through 1986 (Purtymun 1987). They were used to establish background levels of ^{3}H, ^{137}Cs, total uranium, ^{238}Pu, and ^{239,240}Pu in soils and sediments (Table 20). Average concentrations plus twice the standard deviation were used to establish the upper limits of the background concentrations. Samples were collected from 5 regional soil stations and 10 regional sediment stations (Table G-31). Concentrations of radionuclides in soils and sediments from seven regional stations were measured in 1988. Results of the analyses are presented in Tables 20 and G-32. Background concentrations have varied slightly due to changes in analytical backgrounds or procedures over the years.

See Appendix B for description of methods for collection of soil and sediment samples.

2. Perimeter Soils and Sediments. Six perimeter soil stations were sampled within 4 km (2.5 mi) of the Laboratory. Ten sediment stations near the Laboratory boundary and in intermittent streams that cross the Pajarito Plateau were also sampled (Figs. 17 and 18). The perimeter soil and sediment sampling stations are listed in Table G-31 and detailed analytical results are found in Table G-33.

Analyses of the perimeter soil samples indicated that background concentrations were slightly exceeded for ^{137}Cs, total uranium, and ^{239,240}Pu.

Analyses of sediments from the 10 perimeter stations indicated that concentrations of most radionuclides were at or below background (Table 20).

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

Concentrations of tritium, ^{137}Cs, ^{238}Pu, and ^{239,240}Pu in soil samples exceeded regional background levels in several of the on-site soil stations. The concentrations are low and reflect no health or environmental problem (Tables 20 and G-34).

Three canyons received or are receiving treated, low-level radioactive effluents: Acid-Pueblo, DP-Los Alamos, and Mortandad canyons. The concentrations of radionuclides in these canyons exceeded regional background levels (Table 20). The concentrations in sediments of Pueblo and DP-Los Alamos canyons decrease downgradient as the radionuclides are dispersed and mixed with uncontaminated sediments (Table G-34). The concentrations in Mortandad also decrease downgradient in the canyon; however, the concentrations at the Laboratory boundary do not indicate any transport to this point or beyond. The radionuclides in these canyons are derived from low-level radioactive effluents released from the treatment plants. The concentrations are low and pose no health or environmental problems.

Table 20. Maximum Concentrations of Radionuclides in Soil and Sediments

	Number of Stations	^{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
Soil:						
Background (1974–1986)[a]	5	7.2	1.09	3.4	0.005	0.025
Regional stations	7	0.0 (0)[b]	1.4 (1)	3.5 (1)	0.014 (1)	0.019 (0)
Perimeter stations	6	0.9 (0)	1.4 (2)	5.9 (3)	0.003 (0)	0.026 (1)
On-site stations	10	7.8 (1)	1.4 (1)	6.2 (0)	0.164 (1)	0.103 (3)
Sediments:						
Background (1974–1986)[a]	10	—	0.44	4.4	0.006	0.023
Regional stations	7	—	0.17 (0)	4.4 (0)	0.008 (1)	0.004 (0)
Perimeter stations	17	—	0.45 (1)	5.0 (2)	0.003 (0)	0.010 (0)
On-Site Effluent Release Areas:						
Acid–Pueblo Canyons	6	—	0.35 (0)	3.8 (0)	0.052 (1)	12.4 (4)
DP–Los Alamos Canyons	11	—	5.9 (7)	12.0 (3)	0.112 (8)	0.669 (10)
Mortandad Canyon	7	—	43.0 (4)	4.8 (1)	8.78 (4)	33.5 (4)

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

[b] Number in parentheses indicates number of stations exceeding the 97.5 percentile background value.

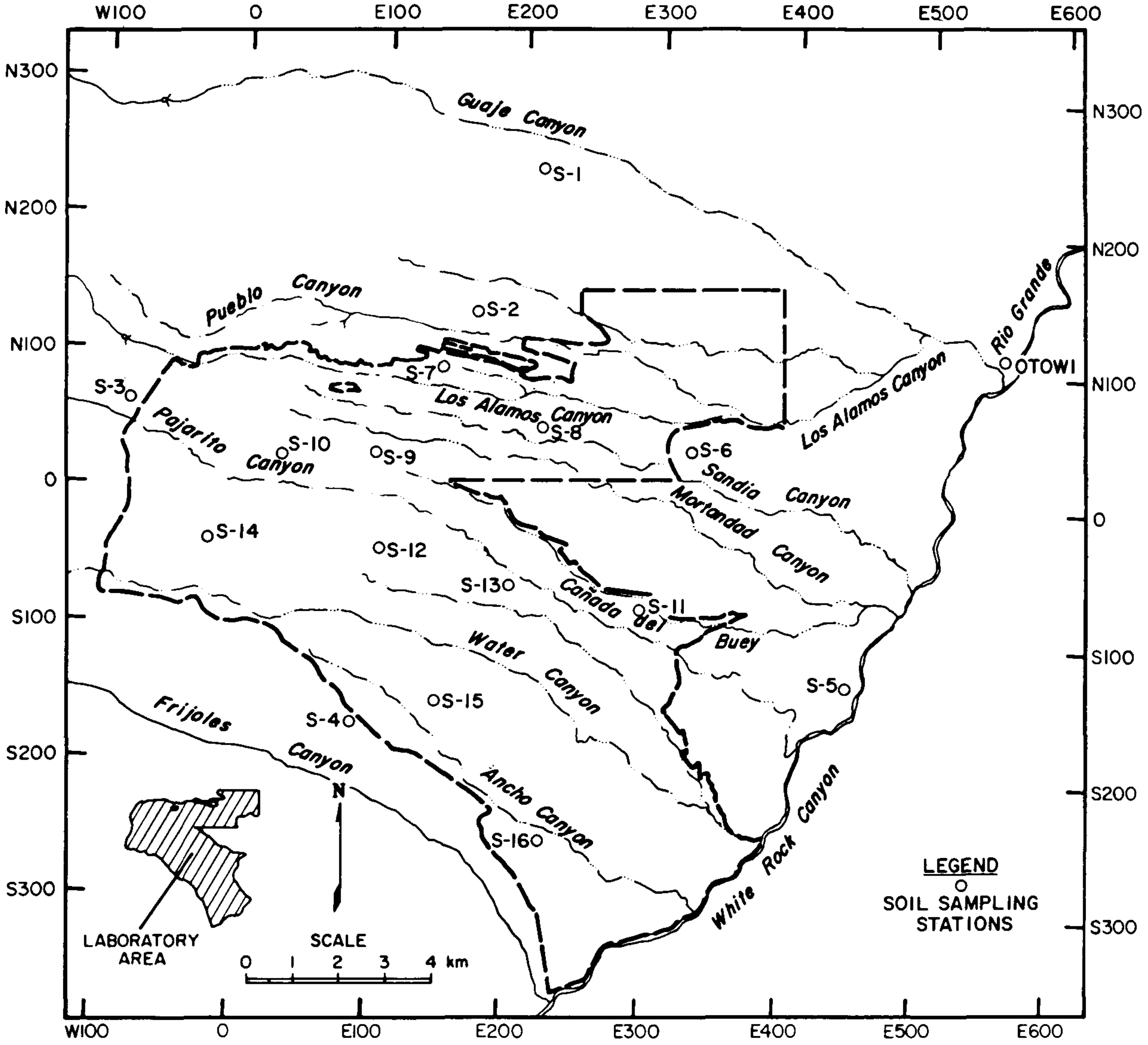

Fig. 17. Soil sampling locations on and near the Laboratory site.

4. Sediments in Regional Reservoirs. Reservoir sediments were collected from three stations in Abiquiu Reservoir on the Rio Chama and three stations in Cochiti Reservoir on the Rio Grande south of Los Alamos (Fig. 19). Except for the sample taken from lower Cochiti, the 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) of sediments. Analysis of the sample from lower Cochiti used only 0.1 kg because part of the sample was lost. The large samples increase the sensitivity of the plutonium analyses, which is necessary to effectively evaluate background plutonium concentrations in fallout from atmospheric tests. Normal sample sizes were used for analyzing for ^{90}Sr and total uranium.

Concentrations of radionuclides were within the range of regional background levels (Table 21). The distribution of plutonium was similar to that from samples collected in previous years (1979, 1982, 1984, 1985, 1986, and 1987) when plutonium in Cochiti was consistently higher than that in Abiquiu reservoir. Sediments in Cochiti Reservoir contain a higher

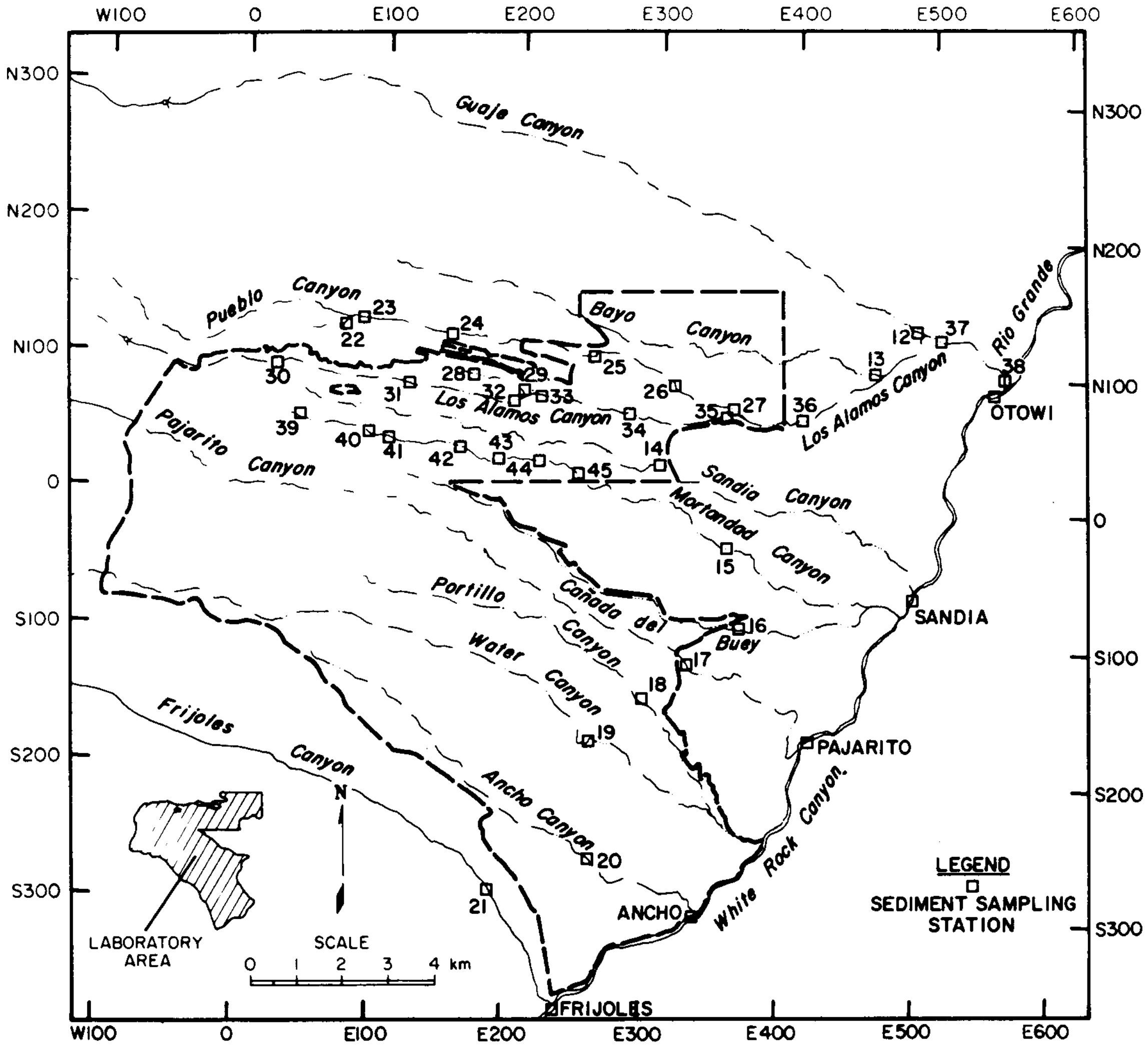

Fig. 18. Sediment sampling locations on and near the Laboratory site.

fraction of finer particles and organic materials than do sediments from Abiquiu. These features enhance the capacity of the sediment to adsorb plutonium and other metal ions. The difference does not appear to be attributable to Laboratory operations. With one exception, the ratios of $^{239,240}Pu$ to ^{238}Pu in the Cochiti sediments do not differ significantly from the ratio characteristic of worldwide fallout, and is about the same as that found in sediment at Abiquiu Reservoir. The sample from middle Cochiti had a ratio far lower than expected. This is probably an analytical artifact because past results have conformed with the expectation of a ratio consistent with natural fallout. Future routine monitoring will seek to confirm this interpretation. The plutonium concentrations in sediments from the two reservoirs are low, within the range of worldwide fallout and are not a health or environmental concern.

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

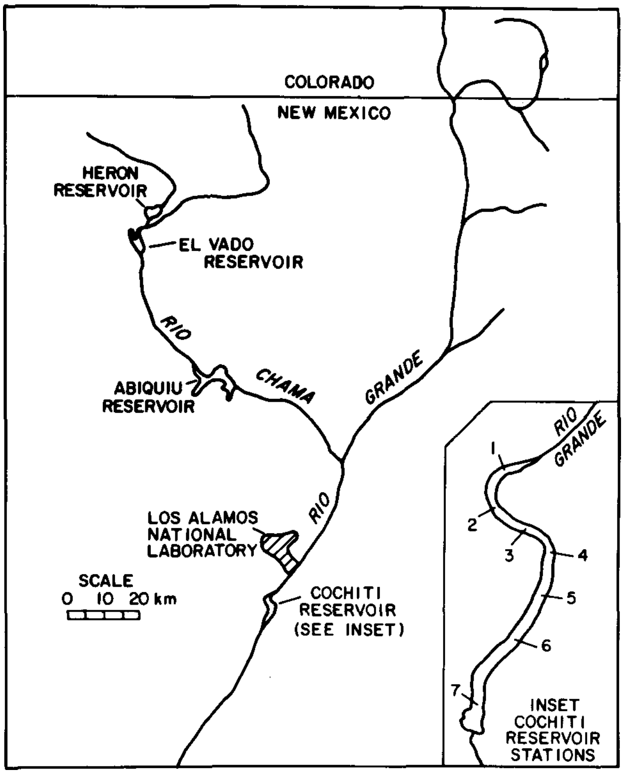

Fig. 19. Special regional sediment sampling locations.

Table 21. Radiochemical Analyses of Sediment from Reservoirs on the Rio Chama and Rio Grande[a]

	Total Uranium (µg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	^{90}Sr (pCi/g)
Abiquiu Reservoir				
Upper	2.9 (0.3)	0.0001 (0.0002)	0.0047 (0.0002)	−0.21 (0.08)
Middle	2.9 (0.3)	0.0004 (0.0001)	0.0100 (0.0004)	−0.04 (0.09)
Lower	3.4 (0.4)	0.0004 (0.0000)	0.0076 (0.0003)	−0.18 (0.09)
Summary [$\bar{X}(s)$]				
1988	3.1 (0.3)	0.0003 (0.0002)	0.0074 (0.0026)	−0.14 (0.09)
1987	3.6 (0.3)	0.0002 (0.0001)	0.0038 (0.0031)	−0.04 (0.50)
Cochiti Reservoir				
Upper	2.8 (0.3)	0.0007 (0.0001)	0.0124 (0.0005)	0.05 (0.06)
Middle	3.7 (0.4)	0.0041 (0.0005)	0.0148 (0.0013)	−0.04 (0.06)
Lower[b]	3.9 (0.4)	0.0003 (0.0001)	0.0090 (0.0006)	−0.07 (0.06)
Summary [$\bar{X}(s)$]				
1988	3.5 (0.6)	0.0017 (0.0021)	0.0121 (0.0029)	−0.02 (0.06)
1987	3.8 (0.0)	0.0008 (0.0007)	0.0175 (0.0138)	0.06 (0.03)

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[a] Samples were collected in June 1988; counting uncertainty is in parentheses.
[b] Sample mass = 0.1 kg; other samples had a mass of 1 kg.

1982 outside the perimeter 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 February 1988 (Table G-35).

Some radionuclides are transported from Area G as suspended or bed sediments. Cesium-137 in sediment at Stations 2 and 7 was slightly above the 1974–1986 background for sediments (0.44 pCi/g) (Table 22). Plutonium-238 in excess of background (0.006 pCi/g) occurred in sediments from Stations 4, 5, 7, 8, and 9, and concentrations of ^{239,240}Pu from Stations 4, 5, and 7 exceeded background (0.023 pCi/g). The ^{3}H, total uranium, and gross gamma of the sediments were below or near background.

The ^{137}Cs, ^{238}Pu, and ^{239,240}Pu concentrations are low. When combined with storm run-off in Cañada del Buey 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.

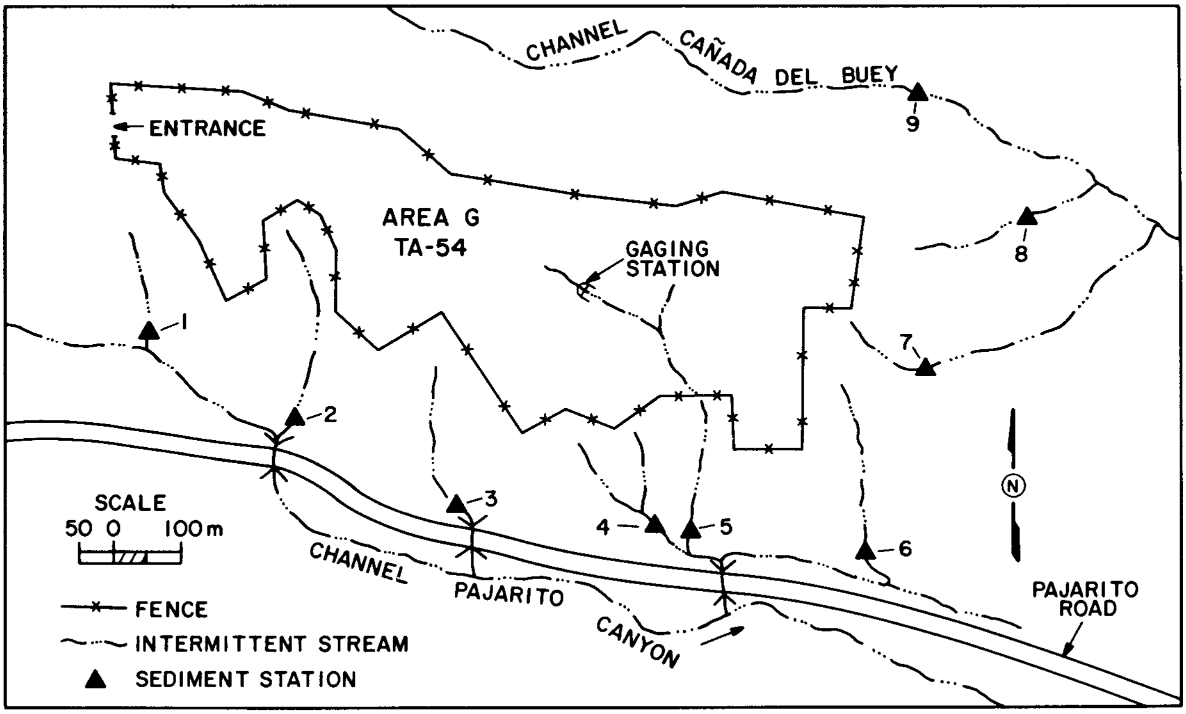

Fig. 20. Locations of surface run-off sampling stations at TA-54.

Table 22. Radiochemical Analyses of Sediments at Area TA-54 that Exceed Background Concentrations

	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)
Background	0.44	0.006	0.023
Station Number: [a]			
2	0.47	—	—
4	—	0.015	0.163
5	—	0.013	0.120
7	0.74	0.343	0.493
8	—	0.017	—
9	—	0.416	—

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[a] As shown in Fig. 20.

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 tritium and uranium. 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, garden soil, 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 (Fig. 21). These regional sampling locations are upstream from the confluence of the Rio Grande and intermittent streams that cross the 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.

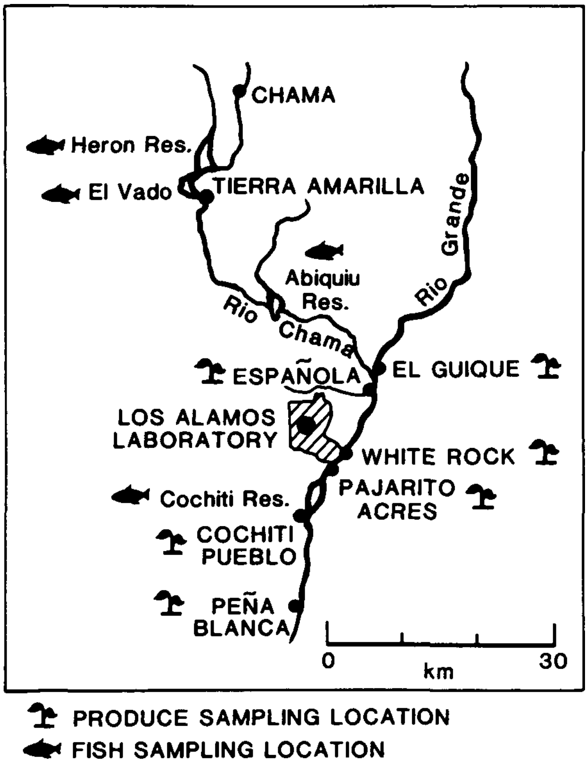

Fig. 21. Fish and produce sampling locations.

B. Produce

Data in Table G-44 summarize produce sample results for ^{3}H (in tissue water), ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and total uranium. Sampling and preparation methods are described in Appendix B.

Concentrations of ^{137}Cs, ^{238}Pu, and total uranium in produce from regional, perimeter, and on-site sampling locations were statistically indistinguishable (one-way analysis of variance at the 95% confidence level). Significantly higher levels of ^{3}H and ^{239,240}Pu were found in on-site produce than in produce from some other sites. One sample of chile from White Rock contained quite high concentrations of ^{238}Pu (0.9 ± 0.04 pCi/g) and ^{239,240}Pu (0.08 ± 0.008 pCi/g). Since other samples from the same garden did not show these extremes, these results were probably processing or analytical anomalies and were not included in Table G-36.

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 public. The Laboratory contributions to doses received in 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 could potentially 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 ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and total uranium.

Results for fish are presented in Table G-37. For ^{137}Cs, ^{238}Pu, 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. Thus, significantly higher concentrations of plutonium in Cochiti sediments (Table 21) were not reflected in the food chain. In some previous years, higher levels of ^{137}Cs had been observed in fish upstream. As in previous 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 fish, although the difference remained low (6 µg/g).

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

D. Honey

The honeybee hive locations are listed in Table G-38 and shown on the map in Fig. 22. None of the

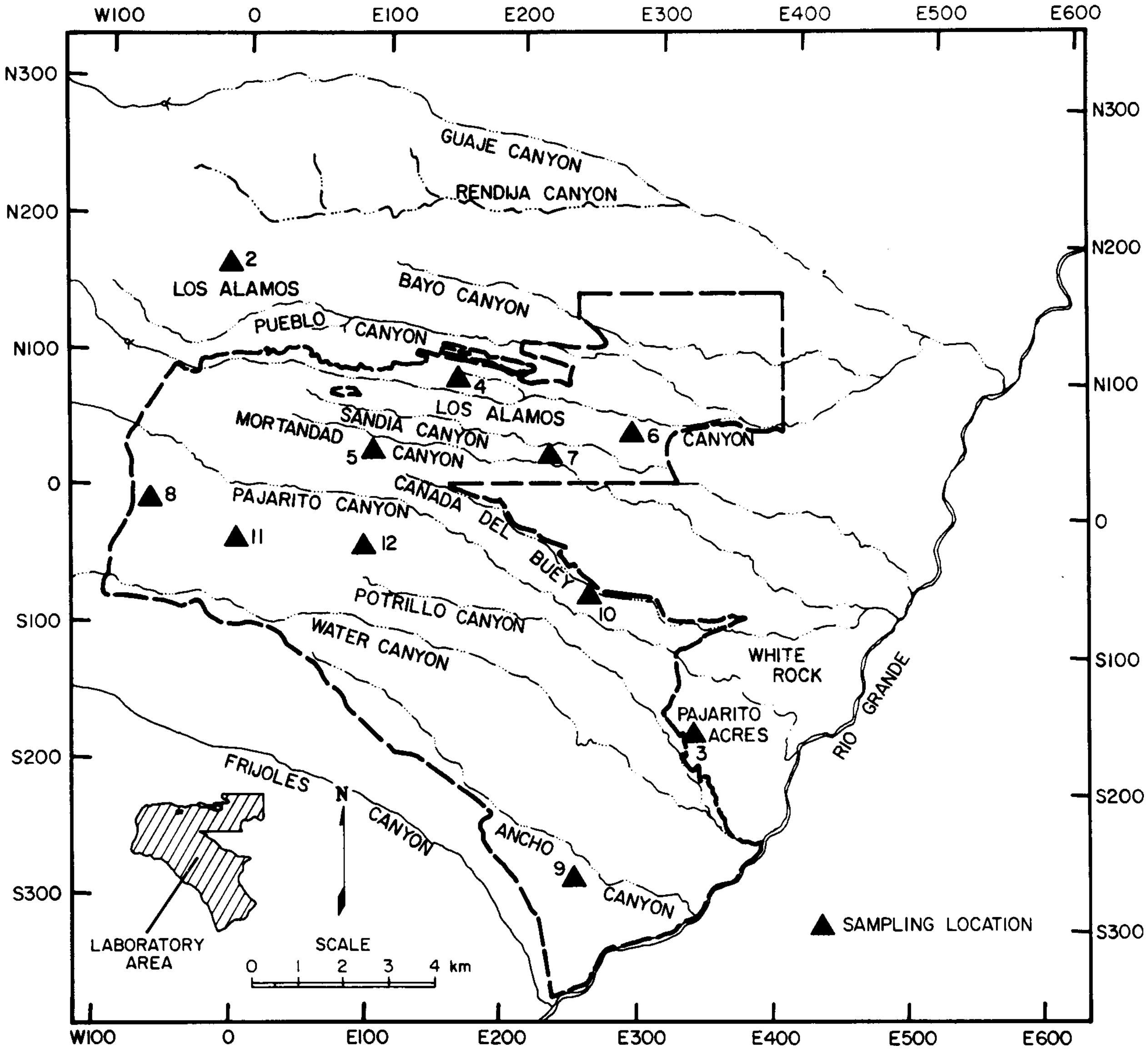

Fig. 22. Locations of beehives.

honey produced by the hives in Los Alamos County is available for consumption. The most recent data (1987) for bees and honey are shown in Tables G-39 and G-40. Radionuclide data were within the variation exhibited in previous years. Some activation products were elevated at TA-53 (LAMPF). Tritium concentrations are elevated at several on-site hives. These results reflect activities that are ongoing at the Laboratory. There are several high results from the hives at regional stations that do not reflect Laboratory operations. These results may be artifacts of counting statistics. Most results on- and off-site were within the counting uncertainty of the analytical systems.

VIII. ENVIRONMENTAL COMPLIANCE

In accordance with the policy of the Department of Energy, the Laboratory complies with federal and state environmental requirements. These requirements address handling, transport, release, and disposal of hazardous materials as well as protection of ecological, archaeological, historical, atmospheric, and aquatic resources. The Laboratory is currently applying for federal and state permits for operating hazardous waste treatment and storage areas as well as renewing a permit for discharge of liquid effluents. Numerous meetings have been held with the New Mexico Environmental Improvement Division and the United States Environmental Protection Agency negotiating the terms of the draft hazardous waste permit that is scheduled for public hearing this summer. The permit will be either issued or denied by November. The Laboratory was in compliance with treated liquid discharge permit limits in 95 and 98% of monitoring analyses from sanitary and industrial effluent outfalls, respectively. Sanitary waste treatment facilities are currently being upgraded to improve compliance. All airborne releases were well within regulatory limits during 1988. A total of 130 asbestos-removal jobs were 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 119 activities for compliance with cultural resource requirements. During 1988, 7 documents were prepared to ensure environmental compliance of new Laboratory activities.

A. Resource Conservation and Recovery Act (RCRA)

1. Background. The Resource Conservation and Recovery Act (RCRA) (as amended by the Hazardous and Solid Waste Amendments of 1984 [HSWA]) mandates a comprehensive program to regulate hazardous wastes from generation to ultimate disposal. Major 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 23.

The EPA has granted New Mexico RCRA authorization 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 (HWMR). 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 the federal regulations and easier to interpret, there will still be some confusion 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 are generated from ongoing manufacturing operations that support research, such as liquid wastes from circuit board preparation and lithium hydride scrap from metal machining. Although they occur in larger volumes than discarded laboratory chemicals, process wastes are few in number, well defined, and not acutely toxic. High-explosive (HE) wastes include small pieces of explosives and contaminated sludges and liquids that are thermally treated on site.

Table 23. Major Regulatory Requirements of the Hazardous and Solid Waste Amendments of 1984 Impacting Waste Management at Los Alamos National Laboratory

The Hazardous and Solid Waste Amendments 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 waste 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 that generators of manifested wastes certify that they have minimized the volume and toxicity of wastes to the degree economically feasible.
- require that the operators of landfills or surface impoundments certify that a ground-water monitoring program is in place or a waiver demonstrated by November 8, 1985, with failure to do so resulting in loss of interim status on November 23, 1985.
- require that federal installations submit an inventory of hazardous waste facilities by January 31, 1986.
- require the preparation by August 8, 1985, of a health assessment for landfills and surface impoundments seeking a Part B permit.

2. Permit Application. The Los Alamos Area Office of DOE has submitted both Part A and Part B applications under RCRA and the Hazardous Waste Act for the Laboratory (Table 24). In response to changes in waste handling, comments from NMEID, and changes in regulations, DOE submitted revised applications in November 1988.

Landfilling of hazardous wastes was discontinued in 1985, and existing landfills will be closed once NMEID approves closure plans. All facilities listed in Table G-41 as having interim status, but not included in the Part B application, must be closed before the application is approved.

3. Area P Landfill and Surface Impoundment. The Area P landfill and surface impoundment are located in a remote area of the northeastern section of TA-16, adjacent to burning pads. The landfill was used from the early 1950s until about 1982 to dispose of HE-contaminated materials. The surface impoundment received filtered liquid extract from HE-contaminated waste water associated with activities at structures 401 and 406. Both sites received soluble barium nitrate, which is considered hazardous because it is under the criteria of EPA's Extraction Procedure for toxicity characteristics. Neither site was included in the Laboratory's original or updated RCRA Part B permit applications, but both are listed in the Part A application. The Laboratory chose to separately close each of these sites under interim status standards (40 CFR 265). Appropriate closure and post-closure plans were submitted to NMEID in 1985, and both plans are awaiting final approval. Area P is expected to be closed in FY 90; the surface impoundment, in FY 89.

Table 24. Environmental Permits Under Which the Laboratory Operated in 1988

Type	Permitted Activity	Issue Date	Expiration Date	Administering Agency
RCRA hazardous waste facility	Hazardous waste storage, treatment, and disposal	Revised application submitted November 1988	—	NMEID[a]
	Post-closure care	Application submitted September 1988		EPA[b]
PCB	Disposal of PCBs	June 5, 1980	—	EPA
PCB oil	Incineration of PCB oils	May 21, 1984	—	EPA
NPDES, 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[c]	—	EPA
Ground-water discharge plan, Fenton Hill	Discharge to ground water	June 5, 1985	June 1990	NMOCD[d]
NESHAP	Construction and operation of four beryllium facilities	December 26, 1985; March 19, 1986; September 8, 1987	—	NMEID

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[a] New Mexico Enviromental Improvement Division.
[b] U.S. Environmental Protection Agency.
[c] Renewal pending.
[d] New Mexico Oil Conservation Division.

A modified landfill closure and post-closure 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 the Laboratory its RCRA permit. Furthermore, HSE-8 desired to establish a 30-yr post-closure ground-water monitoring plan that would be consistent with regard to monitoring parameters and 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 amounts of ground water have been observed; average unsaturated gravimetric borehole moisture contents range from 2 to 24%. Based on 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 further data from the Laboratory. In response to this action, the Laboratory supplied further data and 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 it will occur prior to the issuance of a RCRA permit. Furthermore, this clean closure does not require the typical 30-yr, post-closure care requirements for in-place closure. The same process could not be used for the landfill because explosion hazards may preclude landfill excavations.

4. 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 Area L and Area G has been submitted to the NMEID. Vadose zone (partially saturated zone above the water table) monitoring beneath the landfills and perched-water monitoring in the adjacent canyons are being conducted. Quarterly reports of the pore gas sampling and perched-water analysis have been submitted to the NMEID.

Table G-41 lists several storage areas and seven miscellaneous units currently under interim status but for which a Part B permit is not being sought. TA-3-102, used to store drummed lithium hydride scrap, was closed under interim status in 1988 and reopened as a <90-day storage area. TA-22-24 and TA-40-2 were magazines used for storage of HE wastes. These were closed to waste storage in 1988 and were replaced by other satellite storage units. The TA-40 scrap detonation pit used for destroying scrap high explosives has been closed to waste detonation. Closure will be accomplished in FY 89. All scrap generated will be handled at other detonation sites included in the Part B application. Closure plans for this facility have been submitted to NMEID.

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

In June 1988, the NMEID conducted a Notice of Violation (NOV) compliance inspection (Table 25); no findings were issued. In August 1988, EPA/NMEID conducted a joint hazardous waste compliance inspection (Tables 25 and G-42). Violations were noted and an NOV was issued in November 1988. A response to the NOV was sent to the NMEID in January 1989 and 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 all point source effluent discharges to the nation's waters. The permit establishes specific chemical, physical, and biological criteria that an effluent must meet prior to discharge. The DOE has two NPDES permits, one for Laboratory facilities in Los Alamos and one for

Table 25. Environmental Inspections Conducted at the Laboratory in 1988

Day	Purpose	Performing Agency
August 8–12	Hazardous waste management inspection	New Mexico's Environmental Improvement Division (NMEID) and the U.S. Environmental Protection Agency (EPA)
May 2–June 24	Environmental survey field sampling	DOE Headquarters
April 7	NPDES compliance evaluation inspection, main technical area	EPA
June 21	Notice of violation (NOV) compliance inspection	NMEID
August 8	Hazardous waste compliance Inspection	EPA/NMEID
October 27	Inspection of underground injection wells	NMEID
November 21	Inspection of spill-control facilities at TA-35	NMEID

the hot dry rock geothermal facility, located 50 km (30 mi) west of Los Alamos in the Jemez Mountains (Table 24). Both permits are issued and enforced by EPA Region VI, Dallas, Texas. However, through a federal/state agreement and grant, NMEID performs compliance monitoring and reporting as agents for EPA.

The NPDES permit in effect for the Laboratory in 1988 (NM0028355) was reissued May 29, 1987 and will expire March 1, 1991. As of December 31, 1988, the permit regulates 99 industrial outfalls and 9 sanitary outfalls (Table G-43). Each outfall represents a sampling station for permit compliance monitoring.

The Laboratory forwarded two NPDES permit modification requests to DOE for transmittal to EPA during 1988. The first request (March 30, 1988) provided EPA with information regarding outfall 051 (TA-50-1), specifically emphasizing the potential for influent to the treatment plant to contain waste water from the controlled-air incinerator and the chemical batch-treatment plant. The modification request also attempted to correct an error in the permit limitations associated with outfall 09S (TA-53 sanitary wastewater plant). The second modification request (July 25, 1988) addressed the addition of four new outfalls, the reactivation of one outfall, corrections regarding two existing outfalls, and the elimination of two outfalls.

Weekly sampling results are tabulated in a discharge monitoring report (DMR) 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-44 through G-46). During 1988, 95.2 and 98.5% of monitoring analyses complied with NPDES limits at sanitary and industrial outfalls, respectively (Fig. 23).

2. Federal Facility Compliance Agreement. The Federal Facility Compliance Agreement (FFCA) between EPA and DOE/Los Alamos Area Office (LAAO) contains interim effluent limitations and a schedule of compliance for several outfalls and outfall categories that had experienced frequent noncompliance with the NPDES permit limitations (Tables G-47 and G-48).

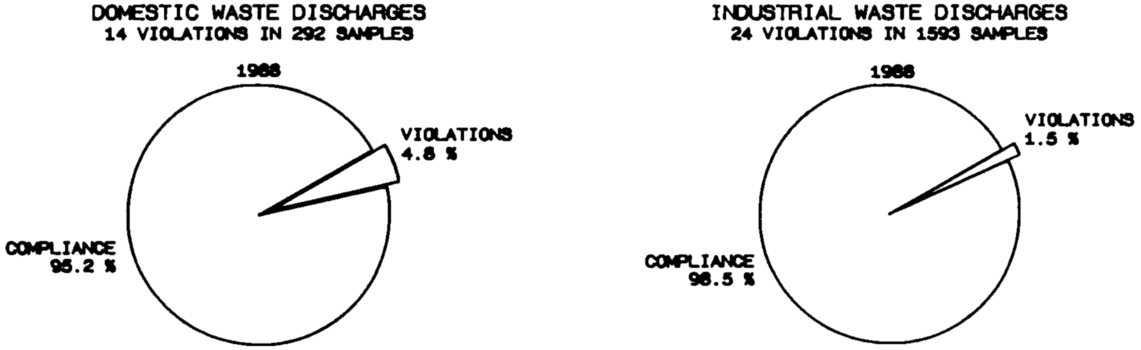

Fig. 23. 1988 Summary of Clean Water Act Compliance, NPDES Permit NM0028353.

Throughout 1988, required FFCA quarterly progress reports reflected that the Laboratory was well ahead of schedule in meeting final compliance milestones. On October 8, 1988, DOE/LAAO reported that all compliance milestones had been completed and requested that the FFCA be amended to allow for treatment system modifications on outfalls: 09S (TA-53); 04S (TA-18), Category 02A (Boiler Blowdown); and Category 05A (High Explosives). The FFCA amendments were pending EPA approval at the end of 1988.

3. Clean Water Act Inspections. The EPA conducted one inspection under the Clean Water Act in 1988 (Table 25). An EPA Compliance Evaluation Inspection (CEI) was conducted on April 7, 1988. The EPA inspector complimented the Laboratory's recordkeeping and self-monitoring program for its completeness, accuracy, and level of detail, although several minor compliance discrepancies were noted. Regarding these discrepancies, a Notice of Deficiency was received from EPA regarding three minor permit compliance problems. These were corrected immediately and a letter to that effect was sent to EPA on April 29, 1988.

4. Administrative Order. On August 30, 1988, EPA Region VI issued an Administrative Order (AO) to DOE regarding NPDES Permit NM0028355. The AO was based on self-monitoring reports submitted by the Laboratory that identified a number of individual parameter violations occurring at outfalls during 1987 and 1988. DOE/LAAO responded to the AO in a submittal to EPA dated October 6, 1988.

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 24). 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 prior to the expiration date, through 1986 EPA Region VI had not acted upon the application. Therefore, the existing permit was administratively continued until supplanted by a new permit.

On April 15, 1987, EPA requested an updated application for the permit in order to reflect present conditions at the site, and 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.*). The proposed permit included effluent monitoring and reporting requirements for flow, pH, and phenols.

Because proposed NPDES permits are subject to state review and certification, a meeting was held with the NMEID and New Mexico Oil Conservation Division (NMOCD) to discuss the proposed permit and the environmental concerns of the state agencies. Subsequent to the meeting, a site inspection was held at Fenton Hill on November 9, 1987, to review the discharge location(s), inspect treatment systems, sample the waste water, and survey the drainage system affected by the discharge. On December 29, 1987, an information package containing a description of all water and waste water piping and storage at the site was mailed by

DOE/LAAO to the state agencies. State certification was granted by NMEID on January 8, 1988, with no additional state-imposed permit conditions. Issuance of the final NPDES permit was anticipated during the first quarter of 1988. However, the final permit was not issued by EPA during 1988 and, therefore, the discharge continues to be regulated by the original permit. EPA has not stated any reason(s) for the delay in final permit issuance.

The original Fenton Hill NPDES permit regulates a single outfall. The daily monitoring requirements for the outfall during discharge include 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. The proposed Fenton Hill NPDES permit also will regulate the same single outfall. The daily monitoring requirements for the outfall during discharge will include 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 system.

During 1988, Title I engineering designs were initiated on seven individual spill-control projects, consisting primarily of providing secondary containment around existing storage tanks. Title II design and construction are anticipated to take place during 1989. Meanwhile, spill prevention and control training lectures were given to more than a dozen operating groups Laboratory-wide. In addition, spill-response equipment was purchased and distributed to numerous operating groups.

7. Sanitary Waste-Water System Consolidation. The TA-3 waste-water treatment plant and many of the other existing sanitary waste-water treatment facilities at the Laboratory are over 30 yr old and do not consistently meet NPDES permit requirements. The cost of operation of these facilities has increased over the years due to maintenance and replacement of old equipment and other factors. In 1985, the Laboratory initiated the Sanitary Waste-Water Systems Consolidation (SWSC) project to replace most of these facilities and to provide an area-wide waste-water treatment system. The proposed SWSC project will be designed to meet current discharge requirements and reduce operation and maintenance costs. The waste-water collection system additions for the project will include approximately 15 630 m (51 280 ft) of gravity sewer line, four canyon crossings using suspension bridges, three lift stations, and approximately 4 070 m (13 350 ft) of force main.

The new waste-water treatment plant will be located near TA-46 and will use the extended aeration process. The proposed plant will include preliminary treatment works, flow equalization facilities, an aeration basin, two secondary clarifiers, and facilities for disinfection of effluent. Effluent from the treatment plant will be reused for cooling water at the TA-3 power plant and for other nonpotable uses. Excess effluent will be discharged to Cañada del Buey under a new NPDES permit.

Upon completion, the proposed SWSC project will replace 8 waste-water treatment plants and approximately 35 septic tank systems currently maintained by the Laboratory. The proposed SWSC project will provide a modern treatment facility for meeting NPDES permit requirements and will eliminate noncomplying discharges. The project will also reduce operation and maintenance costs associated with operating the existing treatment plants and maintaining the existing septic tank systems. Also, the number of discharge points requiring sampling, testing, and reporting will be reduced. In addition, a study is now being conducted to determine the feasibility of replacing the TA-53 lagoons by expanding the SWSC project.

The final design criteria for the SWSC project have been approved, and the consulting engineer selected for the project is now under contract. The engineer will be completing Title I planning for the project during 1989. Construction is scheduled to be completed in 1992.

8. TA-53 Waste-Water Treatment System Modifications. Effluent from the TA-53 sanitary waste-water treatment system on occasion had exceeded NPDES permit limitations for the parameters of total suspended solids and pH. Additionally, because the effluent also contains low-level radioactivity (primarily tritium), compliance with the DOE concentration guidelines for radioactivity is paramount. Therefore, during 1988 an engineering study was initiated to conceptualize treatment system modifications in order to enhance waste-water treatment and environmental protection.

Segregation and separate handling of the radioactive and sanitary waste waters were determined to provide the most timely and cost-effective alternative. Radioactive waste water was recommended to be confined to an existing Hypalon-lined 1-acre pond, sufficiently sized to ensure total evaporation. The remaining two 1-acre ponds could perform facultative treatment of the sanitary waste water. Selective wintertime discharge for algae control and effluent acidification for pH control were recommended as an acceptable low-cost method of achieving NPDES compliance. During 1988 the conceptual designs were completed to accomplish the segregation. Detailed engineering design was also completed, with construction of the modifications targeted to begin early in 1989.

9. Septic Tank System Survey and Registration. During 1988, a survey of all septic tank systems at the Laboratory was updated and 75 systems were found to be in operation or under design. Eight of these systems were new facilities and were registered with the NMEID District II Office, which serves as the reviewing authority for septic tank systems at the Laboratory under the New Mexico Liquid Waste Disposal Regulations.

In addition, new leach fields were installed at three existing systems in order to prevent effluent from surfacing. Five septic tank systems that receive limited flow were plugged and converted into holding tanks to eliminate any potential overflows. Approximately 35 of the existing septic tank systems at the Laboratory are scheduled to be replaced in 1992 by collection lines discharging to the proposed SWSC project.

10. Boiler Blowdown Improvements (NPDES Category O2A). The steam plant located at TA-16-540 was studied during 1988 to determine the cause and solution for a chronic pH control problem on the boiler blowdown discharge. The installation of a carbon dioxide eductor on the steam plant blowdown pipeline to neutralize the pH was recommended. The design was performed for a passive system, using waste carbon dioxide from the plant's gas stacks and waste energy in the blowdown to drive a mixing eductor to accomplish the pH shift. The passive system was installed and it demonstrated the technology could perform the pH shift. However, because the boiler plant is operated in an oxygen-rich combustion mode, insufficient percentage-by-volume concentrations of carbon dioxide were present to meet the pH neutralization range of 6 to 9 standard units. Therefore, a gas-cylinder carbon dioxide injection system was added to boost the delivery of carbon dioxide. The combined systems assure pH levels in compliance with the NPDES permit.

11. Española Valley and Pojoaque Valley Waste-Water Master Plan. During 1988, a group of local and tribal governments and other organizations joined together to form a steering committee to help control pollution of the ground water in the Española and Pojoaque Valley areas originating from septic tank systems and other sources. The Laboratory was invited to join the steering committee and has provided technical assistance to the committee during the preparation of a waste-water master plan.

The purpose of the master plan is to identify areas affected by ground-water pollution in the study area and to recommend alternative waste-water treatment methods and management options that could be used to control ground-water pollution. The master plan is designed to provide specific recommendations for pollution control for local areas in the study area and to lay out a long-term strategy for waste-water treatment on a regional basis.

The waste-water master plan is scheduled to be completed by mid-1989. The steering committee is presently working to initiate a water supply master plan for the Española and Pojoaque Valley areas to develop a regional plan for improving domestic water quality and water supply systems in the study area.

12. TA-9 Sanitary and Industrial Mapping. During 1988 existing sanitary and industrial sewer piping at TA-9 was investigated and mapped. This project was undertaken to complement the Laboratory-wide Sanitary Waste-Water System Consolidation (SWSC) Project, as inadequate as-built mapping existed for TA-9. In addition, cross-connections between high-explosive outfalls, treated cooling-water outfalls, and sanitary waste water were investigated. A dye study procedure was implemented to investigate cross-connections and a plane survey of manhole and outfall locations was performed. A scale map of the technical area was produced showing the existing layouts of the sanitary and industrial sewer systems and showing precise manhole locations and elevations based on the plane survey. Three sanitary waste-water septic tanks were discovered in need of rehabilitation; such construction will take place during 1989.

C. National Environmental Policy Act (NEPA)

The National Environmental Policy Act of 1969 requires that federal agencies evaluate proposed actions for their potential environmental impacts. Unless categorically excluded under provisions of DOE's implementing guidelines (DOE 1987), initial compliance takes the form of an Action Description Memorandum (ADM). The ADM provides a brief description of the proposed action and indicates potential environmental issues, permits, and approvals. It serves as a basis for determining the level of NEPA documentation, if any, required for further evaluation of environmental issues. This documentation may, as requested by the DOE, consist of either an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). A Laboratory Environmental Evaluation Coordinator (EEC) assists project and health/safety personnel to prepare the appropriate documentation for transmittal to DOE. The Laboratory Environmental Review Committee (LERC) reviews NEPA-associated documentation for relevant Laboratory issues.

The EEC reviews Laboratory projects relative to DOE's NEPA requirements and initiates Health, Safety, and Environmental (HSE) Division review of those projects not clearly excluded from NEPA. The HSE review process identifies general environmental, health, and safety requirements by means of an HSE Project Review Committee. The committee evaluated over 80 projects during 1988. Of these, 15 were determined to require ADMs. The LERC reviewed six ADMs and one EA during 1988 (Table G-49).

D. Federal Clean Air Act and 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 Emissions Standards for Hazardous Air Pollutants (NESHAP). This regulation sets reporting, permitting, emissions control, disposal, stack testing, and other requirements for specified operations involving hazardous air pollutants. New Mexico's EID has responsibility for administering these regulations except those governing radionuclides. Laboratory operations that are regulated by NESHAP include radionuclide handling, 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 1988, DOE and the Laboratory submitted an application to the EPA for construction of the Dual Axis Radiographic Hydrotest Facility and the Low-Level-Waste/Mixed-Waste Incinerator, as required under 40 CFR Part 61, Subpart H. Both these applications were approved in 1988 by the EPA.

Notification, emission control, and disposal requirements for operations involving the removal of friable asbestos are specified under the NESHAP regulations (Subpart M). The NMEID requires that asbestos-disposal certification forms be filled out and submitted before every large asbestos-removal job and that an annual one be submitted for all small renovation jobs.

During 1988, a total of 130 asbestos jobs, involving the removal of 1416 m (4645 ft) of asbestos materials on pipe and 196 m^2 (2114 ft^2) on other facility components, were performed by Pan Am World Services. These jobs involved the disposal of 257 m^3 (9075 ft^3) of asbestos-contaminated wastes. Asbestos wastes are disposed of at TA-54 in accordance with required disposal practices. Five disposal certification forms, including the annual notification for the small disposal jobs, were submitted to the NMEID during 1988. Also submitted were seven notifications of asbestos removal, including the annual notification for small renovation jobs. In 1988, 52% of the asbestos removed, including 46.9% of the asbestos removed from pipe, involved small renovation jobs that required no job-specific notification to the state.

The beryllium NESHAP includes notification, emission limit, and stack performance testing requirements for beryllium sources. The four beryllium facilities at the Laboratory operate under state air quality permits containing these requirements. The Laboratory applied for a permit for a fifth beryllium-processing operation to be located in TA-3-35. The four permitted beryllium operations were inspected by NMEID during the first quarter of 1988. No notices of violations were issued.

b. National and New Mexico Ambient Air Quality Standards. Federal and state ambient air quality standards are shown in Table 26. The New Mexico standards are generally more stringent than the national standards. Based on available monitoring data and modeling, Laboratory emissions have not exceeded federal or state standards. The ozone monitor operated by the Laboratory has shown instances when the state ozone standard has been exceeded. However, exceeded standards are probably caused by ozone that is transported from heavily populated and/or industrialized areas.

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).

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 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 apply to 72 source categories. Its provisions include emission standards, notification, and 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 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. The AQCR 501 sets emission standards according to process rate and requires 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 particulates 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

Table 26. National and New Mexico Ambient Air Quality Standards

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

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

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

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 not required to meet NSPS stack-emission limits for asphalt plants, it meets these standards (Kramer 1977).

c. AQCR 604. The AQCR 604 requires gas-burning equipment 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 have not been operated beyond this limit.

Thus, these boilers have not been subject to this regulation. The TA-3 power plant meets the emission standard, although it is not required to do so. 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. The AQCR 702 requires the permitting of any new or modified source if it exceeds a given emissions rate and is not addressed by other regulations. When new Laboratory emission sources or modifications to existing sources are planned, an air-pollution regulatory compliance review is carried out. This review evaluates the steps to be followed to comply with state and federal air pollution regulations. As part of the permitting process, NMEID reviews new or modified sources for compliance with all state and federal air-pollution regulations.

In September 1988, the New Mexico Environmental Improvement Board (NMEIB) adopted revisions to Air Quality Control Regulation 702 Permits that require new sources of toxic air pollutants to obtain an air quality permit. More than 500 toxic air pollutants are now regulated by these changes. A permit is required if the construction of a toxic air pollutant source is started after December 31, 1988, and if the potential emission rate (at maximum capacity and without air pollution control equipment) is greater than the minimum specified by the regulation.

In 1988, the Laboratory obtained an air quality construction permit for a steam production facility consisting of two solid-waste-fired boilers and two gas-fired auxiliary boilers. This facility will replace the TA-16 steam plant. It will burn county and Laboratory refuse as well as natural gas and will generate steam for TA-16. Meteorological dispersion modeling of emitted substances demonstrated that impacts on the local air quality, including impacts at Bandelier National Monument, are negligible.

The need to obtain an air quality permit before starting construction of the planned special nuclear materials (SNM) R&D building was evaluated. A stack test was conducted at the plutonium facility in August to measure emissions from processes that will be moved to the SNM R&D building. To estimate total uncontrolled emissions from the planned building, the stack test results were combined with processing information and the emission inventory estimates for processes to be moved from the CMR building. The results clearly indicate that a permit is not necessary for the planned SNM R&D building.

e. AQCR 752. 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-50, where the annual air emissions are ranked in pounds per year. In general, air emissions are quite 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 (Municipal and Industrial Water Supplies)

1. Background. The federal Safe Drinking Water Act (SDWA) (42 U.S.C. 300f *et seq.*), as amended, requires the adoption of national drinking water regulations as part of the effort to protect the quality of drinking water in the United States. The EPA is responsible for the administration of the act and has promulgated National Interim Primary Drinking Water regulations. Although EPA is designated by law as the administrator of the Act, assignment of responsibilities to a state is permitted, and primacy for administration and enforcement of federal drinking water regulations has been approved for New Mexico. The state of New Mexico administers and enforces the drinking water requirements through regulations adopted by the NMEIB and implemented by the NMEID. Municipal and industrial water supplies for the Laboratory and community met the regulations during 1988.

2. Total Trihalomethane Monitoring of Water Supply System. During 1988, a total of 20 samples were collected at 5 sites throughout the Laboratory and community distribution systems and tested for total trihalomethane. After samples were collected by HSE-8, they were shipped to the Scientific Laboratory Division

Table 27. Total Trihalomethane Concentrations (mg/L) in Water Supply and Distribution Systems

	1st Quarter	2d Quarter	3d Quarter	4th Quarter
Los Alamos Airport	<0.004	<0.004	<0.004	<0.004
White Rock Fire Station	<0.004	<0.006	<0.004	<0.004
North Community Fire Station	<0.004	<0.004	<0.004	<0.004
S-Site Fire Station	0.021	<0.004	<0.005	<0.004
Barranca Mesa Fire Station	<0.004	<0.004	<0.004	<0.004

Note: EPA maximum contaminant level = 0.10 mg/L.

(SLD) for total trihalomethane analyses. All analytical results were found to be in compliance with New Mexico's Regulations Governing Water Supplies and the SDWA (Table 27). Analytical results were reported to the NMEID by SLD.

3. Inorganic Chemical Monitoring of Water Supply System. The Laboratory and community water supply was sampled at one location in the drinking water distribution system for inorganic chemical analyses required by New Mexico's Regulations Governing Water Supplies and the SDWA. Samples were collected by HSE-8 and shipped to SLD for inorganic analysis. Analytical results were found to be in compliance with state and federal regulations (Table 28). The SLD reported analytical results to NMEID.

4. Radiological Monitoring of Water Supply System. The Laboratory and community water supply was sampled at one location in the drinking water distribution system for radiological analyses as required by New Mexico's regulations. Samples were collected by HSE-8 and shipped to SLD for radiological analyses. Analytical results were found to be in compliance with state and federal regulations (Table 29).

5. Organic Contaminant Monitoring of Water Supply System. In 1988 the Laboratory and

Table 28. Inorganic Chemical Concentrations (mg/L) in Water Supply and Distribution Systems

	Distribution System (Los Alamos)	EPA Maximum Contaminant Level
Nitrate	0.44	10
Fluoride	0.29	4.0
Arsenic	<0.005	0.05
Barium	<0.1	1
Cadmium	<0.001	0.010
Chromium	0.006	0.05
Lead	<0.01	0.05
Mercury	<0.0005	0.002
Selenium	<0.005	0.01
Silver	<0.001	0.05

Table 29. Radioactivity (pCi/L) in Water Supply and Distribution Systems

Analyses	Value	Uncertainty	Detection Limit
Gross Alpha [a]			
With ^{241}Am reference	0.60	0.30	0.60
With natural uranium reference	0.80	0.30	0.60
Gross Beta			
With ^{137}Cs reference	3.20	0.60	1.10
With ^{90}Sr/^{90}Y reference	3.40	0.60	1.10

[a] EPA gross alpha maximum contaminant level = 15 mg/L.

community water supply was sampled at all operating water supply sources (14 wellheads and one infiltration gallery) for 8 regulated and 51 unregulated organic contaminants. This sampling is required by the 1986 amendments to the SDWA. Samples were collected by HSE-8 and NMEID and shipped to SLD where samples were composited and analyzed for organic contaminants. Analytical results show that no organic contamination was detected.

6. Microbiological Contaminant Monitoring of Water Supply. In 1988 over 500 samples were collected throughout the Laboratory and community water supply and distribution systems and were analyzed for microbiological contamination. Samples are examined for the presence of coliform and noncoliform bacteria. Samples are collected by and analyses are performed by Pan Am World Services under contract to the Laboratory. Analytical results are in compliance with state and federal regulations.

F. Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 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 control of 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 1988. No inspections of the Laboratory's pesticide operations or facilities were conducted in 1988.

G. National Historic Preservation Act

As required by Sec. 106 of the National Historic Preservation Act of 1966, as implemented by 36 CFR 800, "Protection of Historic Properties," Laboratory undertakings are evaluated in consultation with the State Historic Preservation Officer for possible effects to historic and prehistoric resources. During 1988, Laboratory archaeologists evaluated 119 undertakings, conducted 46 field surveys, and recorded 21 archaeological sites. As a result of Laboratory activities, 51 sites were monitored, 4 sites were fenced, and 1 site was test excavated. In compliance with 36 CFR 79, "Curation of Federally Owned and Administered Archaeological Collections," an inventory of artifacts collected from DOE land was initiated. Artifacts, including those from the Romero Cabin project, were curated at the Museum of New Mexico.

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 Environmental Review Requirements. The floodplain/wetland assessments were done for portions of Los Alamos, Mortandad, and Ancho canyons. Notifications of Involvement and Statements of Findings were submitted to the Department of Energy for publication in the *Federal Register* for the Materials Science Laboratory (TA-3) Utilities Restoration in Los Alamos Canyon and a revised siting of the Pulsed Power Assembly Building (TA-39). Laboratory biologists surveyed 27 proposed construction sites for potential impact. Biologists identified no endangered, threatened, or rare animal or plant species at those sites.

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

The Comprehensive Environmental Response, Compensation, and Liability Act (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 action at about 500 potential release sites at the Laboratory are being addressed under the DOE's Environmental Restoration (ER) Program.

The DOE Albuquerque Operations Office (AL) established their ER Program Technical Support Office at the Laboratory to assist in overall program management and to have principal responsibility for carrying out remedial investigation/feasibility study activities for the eight AL installations, including Los Alamos. The Laboratory will be responsible for carrying out any remedial design and remedial action determined necessary as the program progresses.

J. Toxic Substances Control Act (TSCA)

The 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 control of chemicals found to pose an unreasonable risk. No inspections of the Laboratory's TSCA activities took place in 1988.

The Code of Federal Regulations (40 CFR 761) contains the regulations applicable to polychlorinated biphenyls (PCBs). This part 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 at PCB concentrations of 50 parts per million (ppm) and above. At the Laboratory, materials with >500 ppm PCBs are transported off site for treatment and disposal.

During 1988, efforts have continued toward removal and disposal of PCB-containing equipment from the Laboratory. There have been 34 632 kg (76 349 lb) of PCB-containing oil, 2289 capacitors (170 531 kg [375 950 lb]), 33 transformers (15 605 kg [34 402 lb]), and 2432 kg (5361 lb) of PCB debris sent off site for disposal. Additionally, 406 915 kg (897 078 lb) of PCB-contaminated soil, debris, and equipment have been disposed of at Area G, and 11 transformers are undergoing a process that will render them PCB-free after completion of a 20-month retrofill cycle. Over the past 6 months, an intensive effort has been made to repair all of the leaking transformers requiring daily inspection. At the present time, only two transformers are "leakers" and these are scheduled to be removed.

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

Toxic-chemical-release reporting requirements under Sec. 313 of Title III of SARA became effective on March 17, 1988. The focus of this new rule is the toxic-chemical-release inventory provision. This provision 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 releases of toxic chemicals publicly available. Reports must be submitted annually to the EPA and to the state in which the covered facility is located. This new 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 primary Standard Industrial Classification (SIC) code between 20 and 39; and (3) that exceeds an applicable manufacture, process, or use threshold. For manufacturing or processing, these use thresholds vary by year. In 1987 it was 34 000 kg (75 000 lb), in 1988 it was 23 000 kg (50 000 lb), and in 1989 and thereafter it was 11 000 kg (25 000 lb). For toxic chemicals used for other purposes, the threshold for all years was 4500 kg (10 000 lb). For each listed toxic chemical that exceeds the threshold, the covered facility must report the amount of 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 off site to Publicly Owned Treatment Works (POTWs) 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 the calendar year 1987, the Laboratory reported environmental releases for nitric acid. This was the only compound exceeding applicable threshold amounts triggering the reporting requirement that was not otherwise exempted under 40 CFR, Sec. 372.38.

The first reporting date under Sec. 313 was for the year 1987. Approximately 91 000 kg (200 000 lb) of nitric acid was used at Los Alamos during 1987. Of this amount, approximately 1517 kg (3346 lb) were released as nonpoint air emissions, and 1150 kg (2535 lb) were released as stack air emissions. The remaining amounts of nitric acid were either used up in chemical reactions or were completely neutralized by sodium hydroxide in waste-water treatment operations. Hence, no other environmental releases of nitric acid were reported.

L. Underground Storage Tanks (USTs)

Subtitle I of the Hazardous and Solid Waste Amendments to RCRA has broadened the scope of underground tank regulations. Previously, only Subtitle C of RCRA regulated underground tanks that contained hazardous waste. Subtitle I now brings underground tanks that contain regulated substances under RCRA control. Final EPA regulations pertaining to these tanks were published in the *Federal Register* (53 F.R. 37082) on September 23, 1988, and became effective December 22, 1988.

The EPA has delegated full regulatory authority to individual states, requiring that the state's regulations must be no less stringent than EPA's. The state of New Mexico promulgated its regulations for USTs on September 12, 1988, and they became effective October 12, 1988. The state regulations cover tank registration and fees, release reporting, technical standards, financial responsibility (insurance), and installer certification.

The one part of the state's regulations that has not yet been finalized addresses corrective actions to clean up leaks or spills from USTs. Issues pertaining to these actions are expected to come before the NMEIB at a public hearing in late spring 1989. In response to these requirements, HSE-8 has been working closely with the Facilities Engineering Division to design a vault or secondary containment system for future USTs. This type of system would exempt these tanks from the regulations pertaining to USTs and would relieve any environmental concerns.

In 1988, 25 abandoned tanks or tanks in need of being upgraded were removed throughout the Laboratory. These tanks included the 15 tanks from the abandoned tank farm on DP road north of TA-21, 3 from the old western steam plant, 3 from TA-35, 1 from TA-21, 1 next to the old incinerator building (TA-0-1123), 1 at the Los Alamos airport, and 1 located near a Laboratory-operated building at Kirtland Air Force Base, Albuquerque. A summary of the tanks is shown in Table 30.

The majority of these tanks were installed in the mid-1940s. The tanks were ranked for removal according to age, tank size, and overall environmental concerns. Residual fuels in these tanks were pumped

Table 30. Summary of Underground Petroleum Storage Tanks Removed at Los Alamos

Laboratory Structure No.	Tank Size (gal.)	Substance Stored	Year Removed
A-3-318	5 000	Diesel	1987
TA-6-47	2 000	Diesel	1987
TA-8-60	2 000	Diesel	1987
TA-8-61	2 000	Diesel	1987
TA-15-52	6 000	Diesel	1987
TA-15-274	218	Leaded gasoline	1987
TA-16-16	1 000	Diesel	1987
TA-16-196	4 000	Leaded gasoline	1987
TA-52-12	400	Diesel	1987
TA-0-195-5	300	Leaded gasoline	1988
TA-0-1051-1	14 496	Fuel oil	1988
TA-0-1051-2	1 496	Fuel oil	1988
TA-0-1051-3	2 938	Fuel oil	1988
TA-0-1123-1	5 000	Diesel	1988
TA-21-3	150	Diesel	1988
TA-21-ATF-1	21 000	Diesel	1988
TA-21-ATF-2	21 500	Diesel	1988
TA-21-ATF-3	26 000	Diesel	1988
TA-21-ATF-4	22 000	Diesel	1988
TA-21-ATF-5	5 500	Diesel	1988
TA-21-ATF-6	3 000	Kerosene	1988
TA-21-ATF-7	2 500	Leaded gasoline	1988
TA-21-ATF-8	5 500	Diesel	1988
TA-21-ATF-9	25 000	Diesel	1988
TA-21-ATF-10	25 000	Diesel	1988
TA-21-ATF-11	38 000	Leaded gasoline	1988
TA-21-ATF-12	38 000	Kerosene	1988
TA-21-ATF-13	36 000	Diesel	1988
TA-21-ATF-14	26 500	Diesel	1988
TA-21-ATF-17	49 000	Leaded gasoline	1988
TA-35-18	4 000	Diesel	1988
TA-35-19	5 000	Diesel	1988
TA-35-20	5 000	Diesel	1988
KAFB-9014-1	2 000	Leaded gasoline	1988

out and sold to a recycling firm in Albuquerque after being tested to verify their chemical composition.

When the tank and all of its associated piping had been removed, investigations were conducted to determine whether the tank had ever leaked. It was found that none of the 25 tanks removed in 1988 had ever leaked any reportable quantity of product. Soils contaminated with hydrocarbons were usually associated with overfilling the tanks. These soils were removed and disposed of in a landfill at Area G in accordance with NMEID's recommended procedures. Once the tank was removed it was decontaminated and sold as scrap steel.

It is the Laboratory's policy to remove USTs when user groups determine they are no longer a necessary part of the group's mission. It is expected that a few tanks a year could fall into this category. To relieve the Laboratory of future liabilities, these tanks will be removed as the funding permits.

In October 1988, seven tanks were tested to see if they were tight. This brings the total to 32 tanks tested at the Laboratory. Two of the tanks tested this year failed previous tests. The problems were corrected and they tested tight the second time. The other five tanks tested this year were at the Pan Am tank farm. The results for these tanks are still outstanding. This type of testing is a useful tool to help set priorities for future tank upgrades or removal.

M. Health, Safety, and Environmental Appraisal of Laboratory Operations and Facilities

Laboratory policy requires line management to establish an effective health, safety, and environmental (HSE) protection program. These programs must be appraised periodically to evaluate their effectiveness. The HSE Division began an appraisal program in November 1987, and over the next 3 years it will perform operational and facility appraisals of the HSE programs of all Divisions. Appraisal teams are comprised of one representative each from the Safety (HSE-3), Industrial Hygiene (HSE-5), Waste Management (HSE-7), and Environmental Surveillance (HSE-8) groups. The responsibility of HSE-8 is to determine the effectiveness of divisional and facilities programs for ensuring compliance with applicable Laboratory policy, DOE orders and guidelines, federal and state regulations, and prudent management practices for protection of the environment and the general public.

Group HSE-8's appraisal includes evaluations of air emissions, liquid effluents, toxic substances use, waste management practices, and archaeological/cultural resources protection as applicable. The Group also evaluates whether the operation or facility is in accord with applicable environmental documentation such as an EIS, EA, ADM, or completed HSE Preliminary Project Questionnaire. The group takes the opportunity during the appraisal to inform operations and facilities of potential environmental problems and of the availability of support from the group for addressing these problems.

N. Engineering Quality Assurance

The Laboratory has a Quality Assurance program (Facilities 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 the DOE's program division, the DOE's Albuquerque Operations and Los Alamos Area Offices, the Laboratory's operating group(s), and the Laboratory's Facility Engineering Division, design contractor, inspection organization, and construction contractor. Each proposed project is reviewed by personnel from the Environmental Surveillance Group (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 below. Many of these are ongoing and provide information for surveillance and compliance activities at the Laboratory.

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

1. Weather Summary. Los Alamos received heavy precipitation for the fourth consecutive year, with 62 cm (24.3 in.) of water equivalent falling during 1988. Heavy rains during April through September were responsible for the heavy annual precipitation. Snowfall totaled 125 cm (49.3 in.), near normal, and less than 28% of 1987's record annual snowfall. Heavy rain fell in June, nearly 4 times the normal amount. Summer (June–August) was the third wettest on record. Haze was common during the first part of September, resulting from forest fires in the northern Rockies (including Yellowstone). The year as a whole had slightly cooler than normal temperatures. The annual summary is shown in Fig. 24; other data are shown in Tables G-51 through G-54.

The strong southern storm track that gave Los Alamos over 91 cm (36 in.) of snow during December 1987 continued through January 1988. Snowfall totaled 16.0 in., including 20 cm (8.0 in.) on the 18th. Several Arctic air masses and heavy snow cover during the month kept temperatures well below (2.3°C [4.2°F]) normal. The low temperature fell below −12°C (10°F) on eight dates. It was only the fourth January on record with heavy snow cover (≥10 cm [4 in.]) for the entire month. The weather pattern changed in early February as a large high-pressure ridge formed over western North America. This system kept storms well to the north and allowed mild temperatures. Precipitation totaled only 0.50 cm (0.20 in.); snowfall totaled 4.6 cm (1.8 in.). An extensive deck of cirrus clouds gave Los Alamos and much of northern New Mexico a rare optical display on the 25th. Ice crystals in the clouds refracted and reflected the sun's rays into rarely seen optical phenomena.

As is often the case, intense storms gave Los Alamos winds and snow during March. One storm dropped 19 cm (7.5 in.) of snow on the 17th and brought record cold temperatures. The temperature reached only −1°C (30°F) on the 17th, a record low for that date, and then fell to a record low of −13°C (9°F) the next morning. Record high temperatures occurred just 2 days later, 18°C (64°F) on the 20th and 18°C (65°F) on the 21st. A storm on the 24th produced strong winds, with peak gusts reaching 27 m/s (62 mph). The very warm weather continued through the 30th, with a balmy 21°C (70°F) on the 27th. Another storm dropped 20 cm (8.0 in.) of snow on the 31st.

Wet weather continued in April with precipitation totaling 4.4 cm (1.75 in.), over twice the normal amount. Much of the monthly precipitation came from a storm on the 16th that dropped 3.1 cm (1.22 in.) of rain. Weather was dry and abnormally warm during the first half of May. The temperature reached 27°C (80°F) on four dates (13th–16th), including 28°C (82°F) on the 15th. A high-pressure system over the central and southeastern United States kept those areas abnormally dry, but transported Gulf of Mexico moisture northwestward toward New Mexico, causing an unusually early monsoon season. Nearly 4.4 cm (1.75 in.) of rain fell during the 16th–20th alone. The drought over the United States intensified, but the monsoon circulation became unusually strong during June. The heavy rain of 11.1 cm (4.36 in.) during the month made it the fourth wettest June on record. A locally heavy thunderstorm on the 10th dropped 5.2 cm (2.05 in.) of

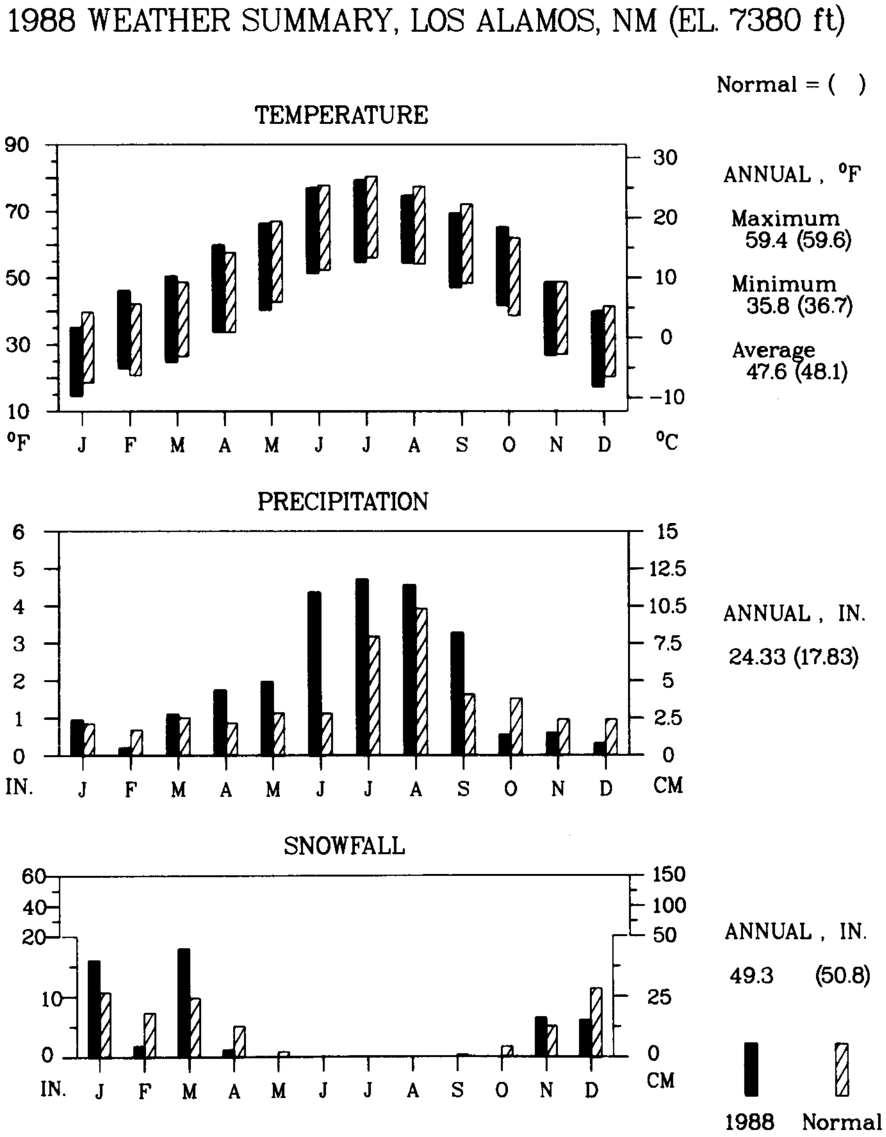

Fig. 24. Summary of 1988 weather in Los Alamos (TA-59).

rain and 5 cm (2 in.) of hail at TA-59. The 2-h rainfall of 4.6 cm (1.80 in.) equaled a 25-yr rainfall event. Rainfall remained heavy during July and August, totaling 12.0 cm (4.71 in.) during July, which is nearly 50% above normal. Another 11.6 cm (4.56 in.) (slightly above normal) fell during August. The heavy rains during summer (June–August) gave Los Alamos its third wettest summer on record.

The monsoon pattern broke up during September, but two unusually strong storm systems moved through the southern Rockies and dumped heavy rain. The first of the storms dropped 5.7 cm (2.25 in.) of rain during the 11th–13th. Another storm produced 2.5 cm (1.01 in.) of rain during the 21st–23d. September was the seventh consecutive month with above-normal precipitation. Earlier in the month, haze caused by the transport of smoke from the northern Rockies' extensive forest fires reduced visibility and created spectacular sunrises and sunsets during the 6th–10th.

A strong high-pressure system formed over the western United States during October, giving Los Alamos dry and warm weather. The only measurable precipitation fell as rain (1.4 cm [0.54 in.]) during the 5th–7th. Windy and quite dry conditions prevailed during November. Numerous intense storms traveled west to east across the central Rockies, causing heavy snows as close as the Colorado-New Mexico border. However, Los Alamos primarily received clouds and winds, with only light snows. Strong winds produced a peak gust of 27 m/s (60 mph) on the 15th at TA-59, and a peak gust of 34 m/s (77 mph) was reported at the East Gate station on November 20. The storm track remained slightly north of New Mexico during December, keeping the precipitation and snowfall well below normal.

2. Wind Roses. The 1988 surface wind speed and direction measured from three sites at Los Alamos are plotted in wind roses for day, night, and total hours (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 one of 16 primary compass points (N, NNE, etc.) and is centered on a 22.5°-wide sector of the circle. The frequency of the calm winds, defined as those having speeds less than 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.

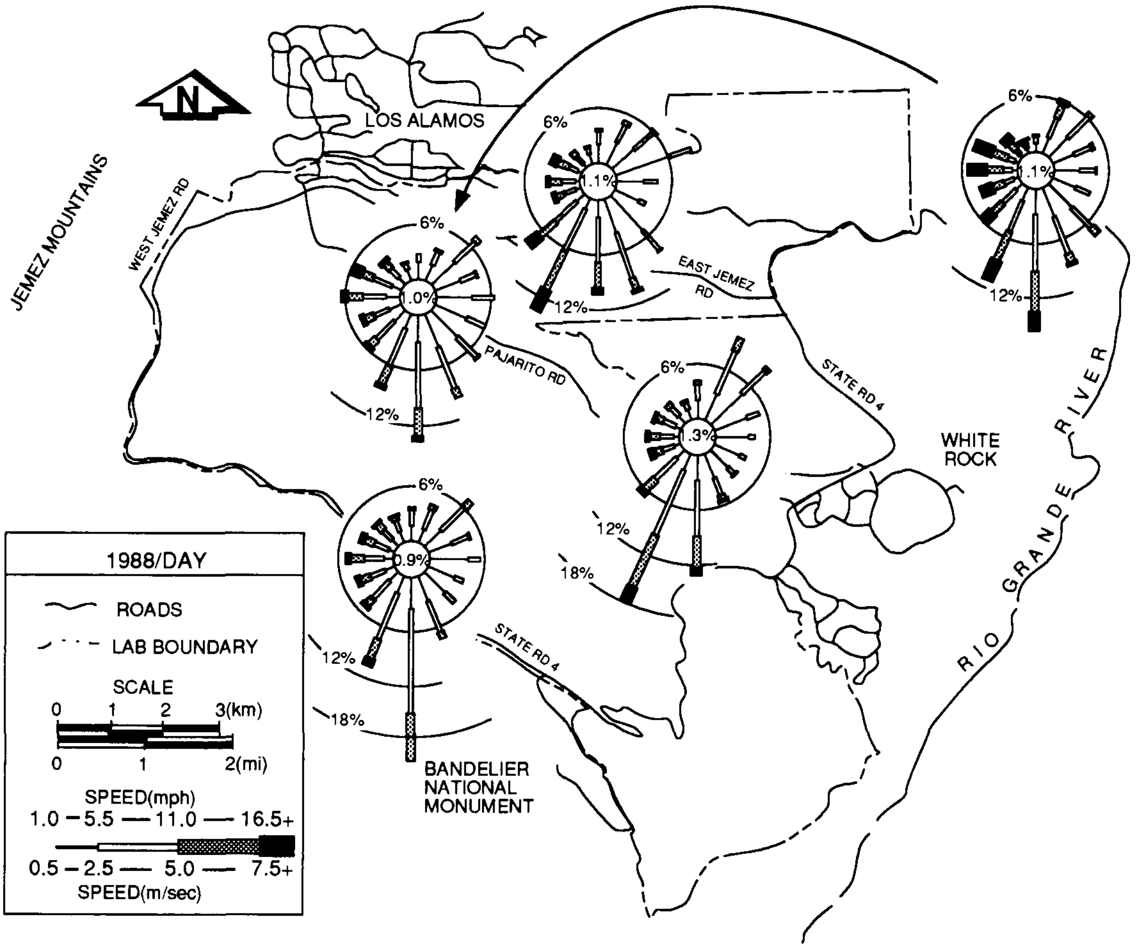

Fig. 25. Daytime wind roses at Laboratory stations during 1988. Surface winds (11 m AGL) are represented at TA-50 (upper left) clockwise to East Gate, Area G, and Bandelier. The TA-50, 92-m AGL wind rose is displaced to the upper right, with an arrow pointing toward TA-50.

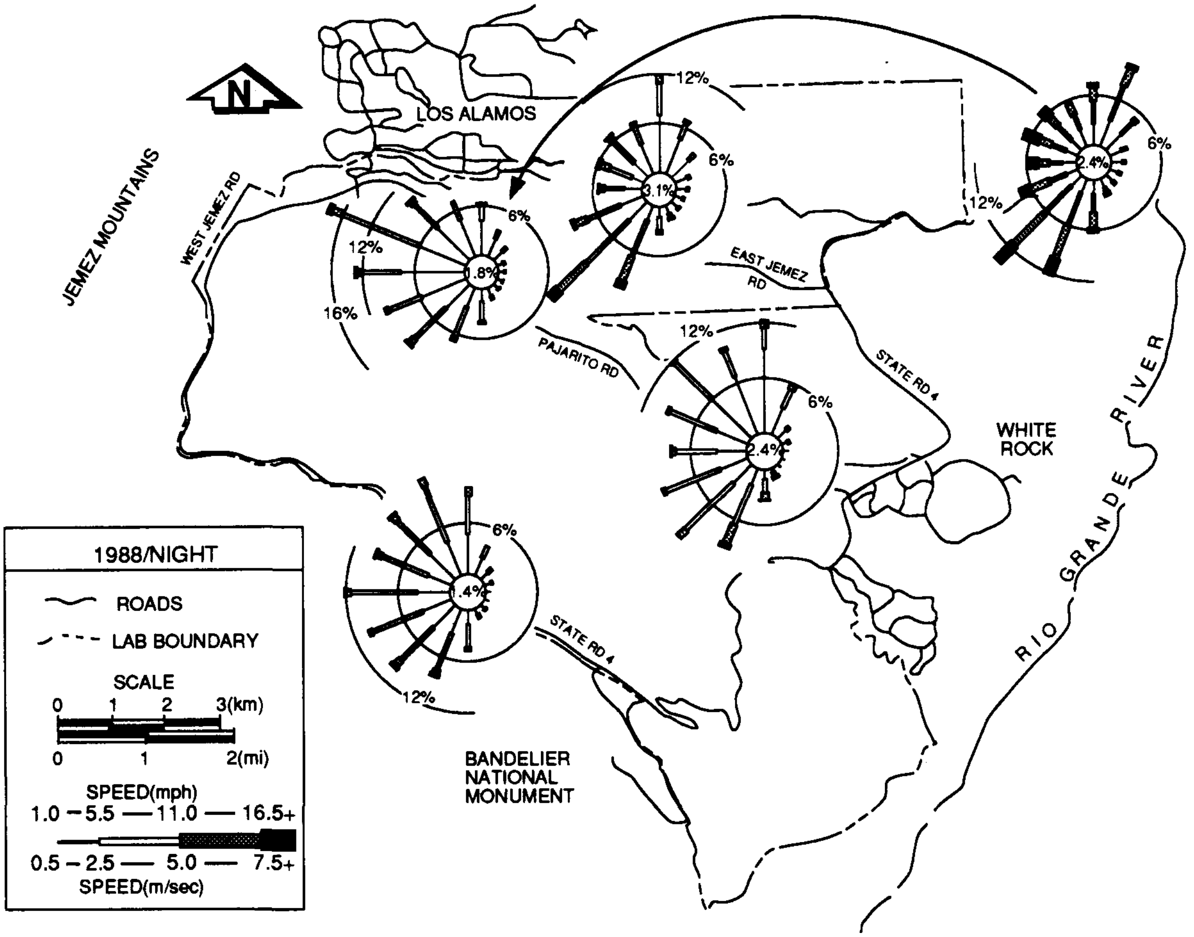

Fig. 26. Nighttime wind roses at Laboratory stations during 1988. Surface winds (11 m AGL) are represented at TA-50 (upper left) clockwise to East Gate, Area G, and Bandelier. The TA-50, 92-m AGL wind rose is displaced to the upper right, with an arrow pointing toward TA-50.

The wind roses represent winds at TA-50 (2216 m above sea level or ASL [7270 ft]), Bandelier (2146 m ASL [7040 ft]), East Gate (2140 m ASL [7019 ft]), and Area G (2039 m ASL [6688 ft]). Surface winds were measured at a height of about 11 m (36 ft) at the four sites and an upper level wind rose is shown for the 91-m (300-ft) level at TA-50. Data recovery exceeded 99% at all sites.

Surface winds at Los Alamos are generally light, with an average speed of 3 m/s (7 mph). Wind speeds greater than 5 m/s (11 mph) occurred with frequencies ranging from 12% at TA-50 to 21% at East Gate. Many of the strong winds occurred during the spring. Over 38% of surface winds at all sites were less than 2.5 m/s (5.5 mph). The average wind speed increases to over 4 m/s (9 mph) at 91 m (300 ft). Wind speeds greater than 5 m/s (11 mph) occurred 35% of the time, and speeds less than 2.5 m/s (5.5 mph) occurred 31% of the time at the higher level.

Distribution of winds varies with site, height above ground, and time of day, primarily because of the terrain features found 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 SE through S winds during the day at TA-50 (both levels) and East Gate (Fig. 25). Upslope winds are generally light, less than 3 m/s (7 mph). Winds become more SSW and S at Bandelier and Area G (that is, at lower elevations). The winds here are more affected by the Rio Grande Valley than

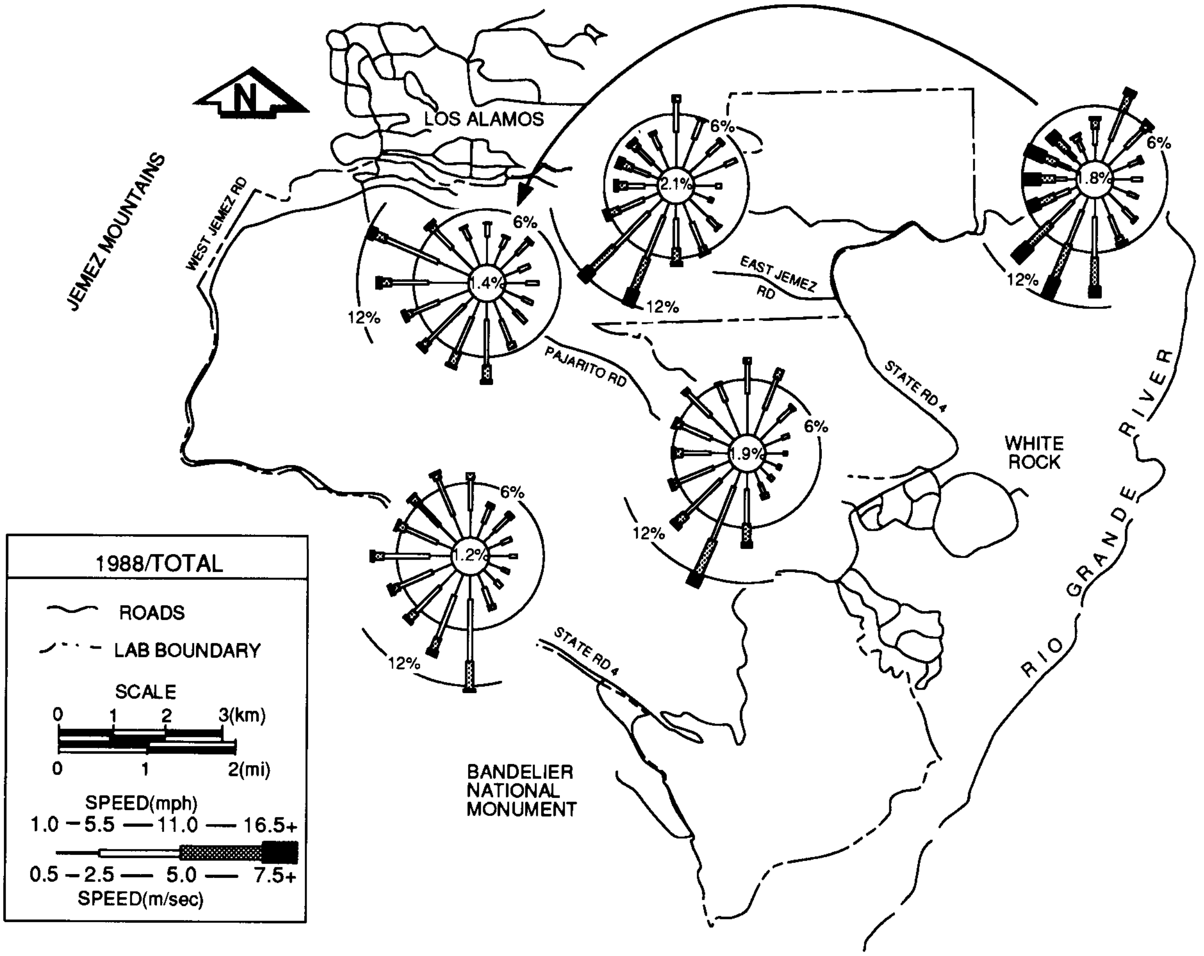

Fig. 27. Total wind roses at Laboratory stations during 1988. Surface winds (11 m AGL) are represented at TA-50 (upper left) clockwise to East Gate, Area G, and Bandelier. The TA-50, 92-m AGL wind rose is displaced to the upper right, with an arrow pointing toward TA-50.

by the plateau. Channeling of regional-scale winds by the valley contributes to the high frequency of SSW and NNE or NE winds. In addition, a thermally driven up-valley wind probably causes some of the SSW winds under 3 m/s (7 mph) at Area G.

Winds display a reversal during the night. A shallow drainage wind often forms and flows down the plateau on clear nights with light, large-scale winds. These winds are generally less than 4.5 m/s (9 mph). Surface wind peaks from the NW through W are evident at TA-50, whereas the drainage wind at Bandelier and Area G are evenly distributed from the WNW through the N. Downslope winds are much less frequent at East Gate. The TA-50 wind rose at 91 m (300 ft) shows dramatically different winds from those at the surface, with valley-channeled winds dominating. A high frequency of winds are up-valley (SW and SSW) and down-valley (N through NE). Note that less-frequent channeled winds also occur at the other sites during the night.

3. Precipitation Summary. Los Alamos precipitation was heavy during 1988, with as much as 62 cm (24.3 in.) falling at TA-59 and more than 56 cm (22 in.) falling at S-Site and North Community. Figure 28 shows precipitation analyses for the summer (June–August) and the entire year. Monthly precipitation totals are presented in Table G-52. Heavy spring

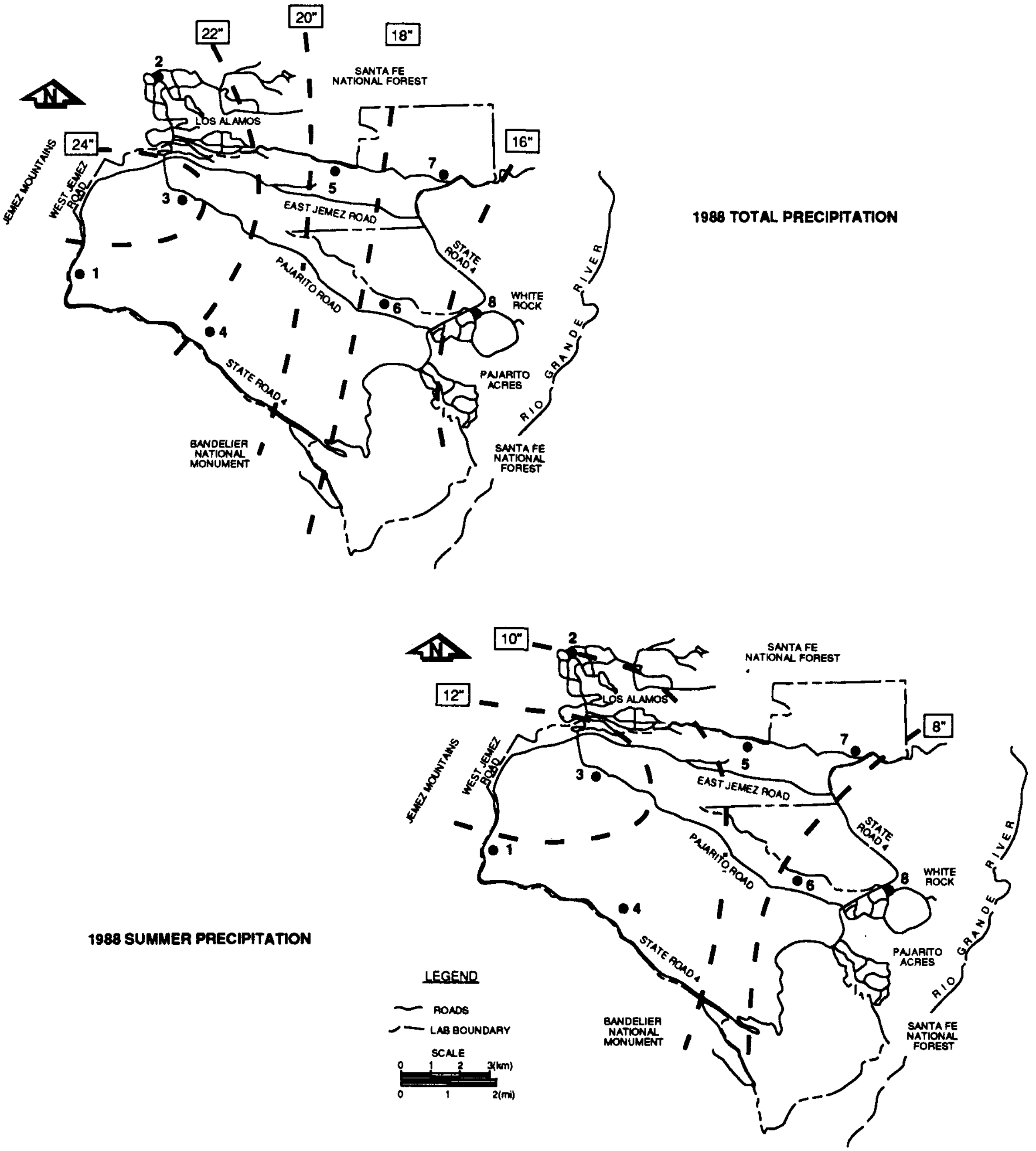

Fig. 28. Summer (June–August) and annual precipitation during 1988 (in inches).

and summer rainfalls were responsible for pushing 1988 precipitation totals to at least 20% above normal at all sites except S-Site and North Community. The final 3 months of 1988 were quite dry. Note that the TA-59 area had maximum summer rainfall and annual precipitation: several heavy thunderstorms during June and July dropped locally heavy rains at TA-59. Precipitation was generally the highest in the northwest part of Los Alamos County, near the mountains and at the highest part of the Pajarito Plateau. Precipitation generally decreased with decreasing elevation and increasing distance from the Jemez Mountains.

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

To investigate the potential impacts of Laboratory operations on lands belonging to San Ildefonso Pueblo (the Pueblo), the Department of Energy entered into a Memorandum of Understanding with the Pueblo and the Bureau of Indian Affairs (BIA) to conduct environmental sampling on Pueblo land. During 1987, water, soil, and sediment samples were collected (Purtymun 1988B). Splits of these samples were taken and analyzed by the BIA. The results of these and later data collected on the Pueblo will be compiled in a joint report by the BIA and the Laboratory.

In 1988, the informal agreement was for the Laboratory to collect and analyze water from 5 stations east and west of the Rio Grande (station 2, New Community well; station 3, Pajarito Well; station 8, Holladay Well; station 9, East-Side Artesian Well; and station 10, West-Side Artesian Well) and sediments from 4 stations in Mortandad Canyon (Fig. 29). Two extra sediment analyses from Mortandad taken as part of the routine monitoring effort are included in the sediment section to present a full profile of the distribution of radionuclides in Mortandad Canyon.

1. Ground Water. Radiochemical analyses in 1988 of ground water from stations 2, 8, and 9 indicated no significant change from the analyses that were performed on wells at those locations in 1987 (Table 31). The gross alpha activity from station 10 decreased from 22 × 10^{-9} μCi/L to 8 × 10^{-9} μCi/L, whereas the gross alpha activity in water from station 3 increased from 10 × 10^{-9} μCi/L to 22 × 10^{-9} μCi/mL.

The gross alpha activity in water from station 3 was 22 × 10^{-9} μCi/mL. As detailed in Purtymun (1988B), the gross alpha activity in this area is due to uranium

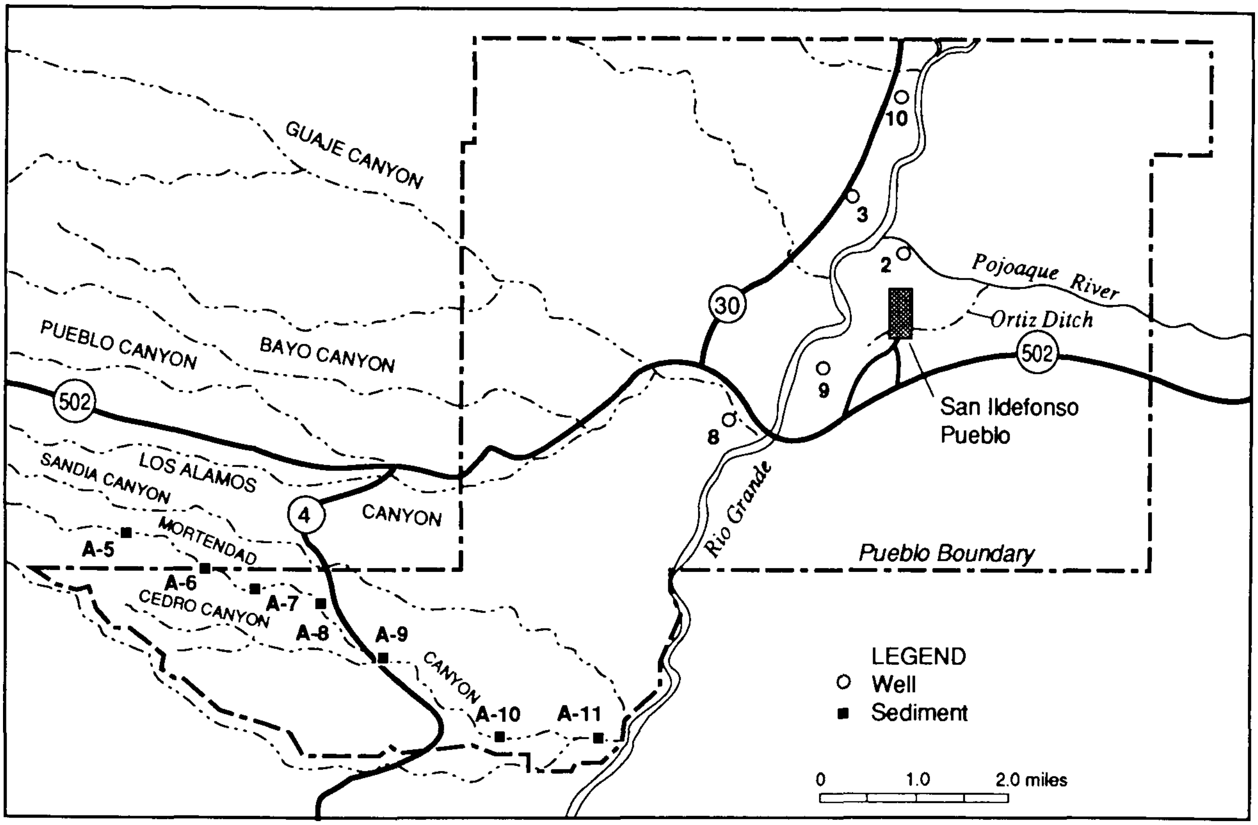

Fig. 29. Ground-water and sediment stations on Pueblo de San Ildefonso land.

Table 31. Radiochemical Quality of Ground Water from Wells, Pueblo of San Ildefonso

Station and Well	^{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^{-7} µCi/mL)
2 New Community Well	−0.3 (0.3)	−64 (54)	23 (2)	0.000 (0.010)	0.000 (0.000)	11 (3.0)	1.3 (0.4)
3 Pajarito Well	−0.3 (0.3)	−2 (53)	14 (2)	0.015 (0.011)	0.014 (0.011)	22 (6.0)	3.1 (0.5)
8 Halladay Well	−0.1 (0.3)	−51 (70)	2.5 (0.2)	0.000 (0.010)	0.006 (0.013)	2.1 (0.9)	−0.2 (0.4)
9 East-Side Artesian Well	−0.2 (0.3)	65 (54)	7.3 (0.7)	0.034 (0.019)	0.015 (0.011)	10 (3.0)	0.7 (0.4)
10 West-Side Artesian Well	0.2 (0.3)	−11 (53)	23 (2)	0.034 (0.021)	0.014 (0.013)	8.0 (2.0)	2.0 (0.5)
Summary							
Maximum concentration	0.2	65	23	0.034	0.015	22	—
Standard[a]	20	200	6 × 10^4[b]	15	15	15	—
Maximum as a percentage of standard	1	33	1	<1	<1	146	
Limits of detection	0.3	40	1	0.009	0.03	0.1	—

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[a] USEPA standard, used for comparison only (EPA 1976).

[b] Derived Concentration Guide, Appendix A.

and not radium. Subtracting the activity due to uranium yields 12×10^{-9} µCi/mL, which is less than the EPA drinking water standard (used for comparison only) that excludes activity from radon and uranium.

There was no significant change in the chemical quality of the ground water from stations 2, 8, 9, and 10 from the 1987 data to the 1988 data (Table 32). There was a significant increase in 10 chemical concentrations in the water at station 3 when a comparison was made of the 1987 data with the 1988 data (Table 33). The increase of the chemical constituents could be due to a seasonal change (data were taken during heavy production in late summer 1987 and during light production in December 1988) and could indicate a temporary lowering of water levels in poor-quality water-bearing beds or it could indicate that cumulative effects from continuous production have caused a permanent lowering of water levels in better-quality water-bearing beds. Additional sampling and analyses will be required to determine the cause of the anomaly in the quality of water from station 3.

The chloride (250 mg/L) and fluoride (4.0 mg/L) standards were exceeded in water at station 10 with concentrations of 383 and 7.0 mg/L, respectively. The total dissolved solids standard (500 mg/L) was exceeded with concentrations of 1091 mg/L at station 3 and 1053 mg/L at station 10. Other chemical constituents in water from stations 3 and 10 and from the other three stations were at or below the standards.

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 midreaches of the canyon within Laboratory boundaries. A large amount of the radionuclides in the effluent when first released as surface flow is adsorbed or attached to the sediments in the stream channel; thus the only means of transport would be in surface run-off. Mortandad Canyon heads on the Pajarito Plateau 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 has retained all the run-off since 1960 when hydrologic studies began in the canyon. There has been no run-off or transport of radionuclides from the Laboratory.

During 1988, 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 34). The analytical results of samples from the stations are compared with regional background of samples that were collected from flowing streams and rivers.

The ^{239,240}Pu concentrations at station A-5 (0.051 pCi/g) exceeded the regional background (0.023 pCi/g) by a factor of about 2. The station is located within the Laboratory boundaries.

The cesium concentration exceeded the background (0.44 pCi/g) at stations A-5 (0.58 pCi/g) and A-6 (0.73 pCi/g). Sediments are more like soils at these stations because of a lack of run-off to winnow out the silts and clay-size particles in the alluvium. If the concentrations are compared with the background for soils (1.09 pCi/g), the concentrations at stations A-5 and A-6 would be within the levels from worldwide fallout. The concentrations at the two stations are similar to those reported with the 1987 data.

The concentrations of the radionuclides in the sediments in Mortandad Canyon during the 1988 study indicated no transport of contaminants from the Laboratory onto the Pueblo.

C. Environmental Monitoring at the Fenton Hill Site (William Purtymun, Roger Ferenbaugh, Max Maes, and Mary Williams [HSE-9])

The Laboratory is currently evaluating the feasibility of extracting thermal energy from the hot dry rock geothermal reservoir at the Fenton Hill Geothermal Site (TA-57). The site 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 thermal 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 determined for use in geohydrologic and environmental studies.

Table 32. Chemical Quality of Ground Water from Wells, Pueblo of San Ildefonso (mg/L)

							Summary	
Constituent	Standard[a]	Station 2 New Community Well	Station 3 Pajarito Well	Station 8 Halladay Well	Station 9 East-Side Artesian Well	Station 10 West-Side Artesian Well	Maximum Concentration	Maximum Concentration as a Percentage of Standard
Chemical								
Ag	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2
As	0.05	0.003	0.005	0.006	0.006	0.012	0.012	24
Ba	1.0	0.006	0.118	0.037	0.002	0.042	0.118	12
Cd	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	10
Cr	0.05	0.008	0.009	0.008	0.008	0.003	0.009	18
F	4.0	0.2	1.1	0.7	0.9	7.0	7.0	175
Hg	0.002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	10
N	10	2	<1	<1	2	<1	2	20
Pb	0.05	0.001	0.002	<0.001	<0.001	<0.001	0.002	4
Cl	250	9	247	5	4	383	383	153
Cu	1.0	0.003	0.024	0.001	<0.001	0.001	0.024	2
Mn	0.05	<0.001	0.006	<0.001	<0.001	0.016	0.016	32
SO_4	250	37	57	15	18	81	81	32
Zn	5.0	0.013	0.180	0.007	0.001	0.015	0.180	4
TDS	500	263	1091	143	187	1053	1091	218
pH (no units)	—	8.5	7.7	8.4	8.7	8.5	—	—
SiO_2	—	37	59	40	66	28	—	—
Ca	—	5	62	4	3	3	—	—
Mg	—	0.2	6.5	<0.1	0.2	0.7	—	—
K	—	<0.1	4.7	0.7	0.6	1.6	—	—
Na	—	72	292	40	66	281	—	—
CO_3	—	7	0	2	7	8	—	—
HCO_3	—	174	567	84	155	338	—	—
P	—	<0.2	<0.2	<0.2	<0.2	<0.2	—	—
Total hardness	—	15	188	12	10	37	—	—
Conductivity (µmho)	—	450	1900	210	345	1920	—	—
Miscellaneous								
Ni	—	0.005	0.005	<0.001	<0.001	0.007		
Be	—	<0.001	<0.001	<0.001	<0.001	<0.001		

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[a] Primary and secondary drinking water standards, used for comparison (EPA 1976, 1979). Samples were collected December 4 and 12, 1988.

Table 33. Comparison of Chemical Quality of Water from Station 3 (Pajarito Well) from 1987 to 1988

Parameters[a]	1987	1988	Percentage of Increase 1987 to 1988
Cl	79	247	312
SO_4	28	57	204
TDS	506	1091	216
Ca	34	62	182
Mg	2.6	6.5	250
K	3.3	4.7	142
Na	160	292	183
HCO_3	291	567	195
Total hardness	96	188	196
Specific conductance (μmho)	900	1900	211
Gross alpha (10^{-7} μCi/mL)	10	22	220
Total uranium (μg/L)	8.4	14	167

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[a] Units are mg/L, except as noted.

Table 34. Radiochemical Analyses of Sediments from Mortandad Canyon, December 4, 1988

Station	Location	^{137}Cs (pCi/g)	Total Uranium (μg/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Gamma (Counts/min/g)
A-5	Laboratory	0.58 (0.13)	2.2 (0.2)	0.001 (0.001)	0.051 (0.005)	2.2 (0.4)
A-6	San Ildefonso	0.73 (0.16)	1.7 (0.2)	0.002 (0.001)	0.015 (0.003)	0.9 (0.4)
A-7	San Ildefonso	0.04 (0.09)	2.6 (0.3)	0.001 (0.001)	0.012 (0.002)	2.4 (0.4)
A-8	San Ildefonso	0.14 (0.11)	4.5 (0.5)	0.001 (0.001)	0.004 (0.001)	4.6 (0.6)
A-9[a]	San Ildefonso	0.21 (0.09)	2.9 (0.3)	0.001 (0.001)	0.004 (0.001)	4.5 (0.7)
A-10	San Ildefonso	0.03 (0.09)	1.9 (0.02)	−0.001 (0.001)	0.001 (0.001)	1.0 (0.4)
A-11[a]	San Ildefonso	−0.02 (0.10)	1.7 (0.2)	0.001 (0.001)	0.001 (0.001)	1.2 (0.4)
Background						
Sediments (1974–86)		0.44	4.4	0.006	0.023	7.9
Soils (1974–86)		1.09	3.4	0.005	0.025	6.6

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[a] Samples were collected at A-9 in Mortandad Canyon at State Road 4 on April 20, 1988 and at A-11 in Mortandad Canyon at the Rio Grande on October 18, 1988.

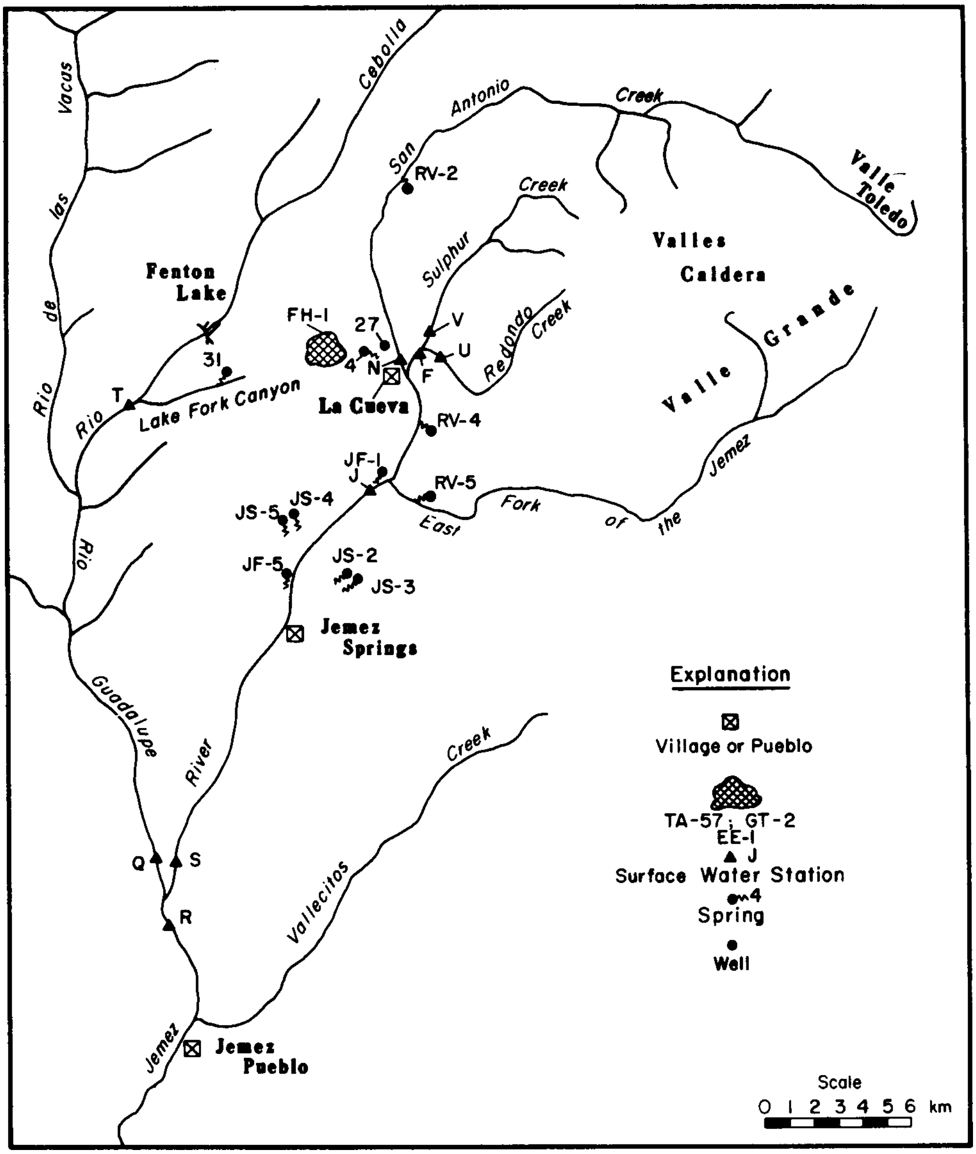

Fig. 30. Sampling stations for surface and ground water near the Fenton Hill Site (TA-57).

These water-quality studies began before construction and testing of the hot dry rock system (Purtymun 1974D). The most recent samples were collected in November 1988.

Surface water stations (13, located on the Jemez River, the Rio Guadalupe, and their tributaries) are divided into four general groups based on the predominant ions and TDS (Table 35). The predominant ions are (1) sodium and chloride, (2) calcium and bicarbonate, (3) calcium and sulfate, and (4) sodium and bicarbonate. Ground-water stations (five mineral and hot springs, one well, and five 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 35).

Table 35. Quality of Surface and Ground Waters at Fenton Hill Geothermal Site, November 1988 (Concentrations in mg/L)

Surface Water

	Na	Cl	TDS
Sodium Chloride			
Redondo Creek (U)	7	7	76
Jemez River (R)	61	78	334
Jemez River (S)	69	92	382

	Na	HCO_3	TDS
Calcium Bicarbonate			
San Antonio Creek (N)	14	67	98
Rio Cebolla (T)	10	72	170
Rio Guadalupe (Q)	12	172	200
Lake Fork 1 (LF-1)	10	59	104
Lake Fork 2 (LF-2)	15	99	142
Lake Fork 3 (LF-3)	12	54	144
Lake Fork 4 (LF-4)	13	72	146

	Ca	SO_4	TDS
Calcium Sulfate			
Sulphur Creek (V)	76	254	446
Sulphur Creek (F)	25	85	182

	Na	HCO_3	TDS
Sodium Bicarbonate			
Jemez River (J)	15	56	146

Ground Water

	Na	Cl	TDS
Sodium Chloride			
Location JF-1 (hot spring)	590	758	2370
Location JF-5 (hot spring)	1300	1610	4350

	Ca	HCO_3	TDS
Calcium Bicarbonate			
FH-1 (supply well)	90	142	366
Location 39 (spring)	14	39	198

	Na	HCO_3	TDS
Sodium Bicarbonate			
JS-2, 3 (spring)	18	82	208
JS-4, 5 (spring)	16	69	98
Location 4 (spring)	16	55	92
Location 31 (spring)	12	55	181
RV-2 (hot spring)	24	46	108
RV-4 (hot spring)	53	108	186
RV-5 (hot spring)	21	72	206

Note: See Fig. 30 for sampling locations. One sample was taken at each location.

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

D. Distribution of Radionuclides in Water and Sediment In and Adjacent to Sediment Traps in Mortandad Canyon (Donald VanEtten, William Purtymun, Max Maes, and Richard Peters [HSE-9])

Trace amounts of radionuclides remaining in effluent are released from the treatment plant at TA-50 into the adjacent Mortandad Canyon (Table G-12). The effluent recharges a shallow body of ground water in the alluvium. The radionuclides in the effluent are adsorbed or bound to the sediments in the channel, reducing the amount found in the water of the shallow aquifer. This shallow aquifer is of limited extent and lies within the Laboratory boundary.

The sediments and radionuclides in the stream channel alluvium are subject to transport by additional releases of effluent or by storm run-off. The small drainage area of the canyon and the ability of the thick section of unsaturated alluvium to store the run-off has prevented transport to the Laboratory boundary. To confine the surface run-off and contaminants within Laboratory boundaries, a series of sediment traps has been installed in the canyon since early 1970. The traps range from gravel-filled galleries to stilling basins that contain suspended solids as well as bed sediment (alluvium).

Several large thunderstorm run-off events occurred in early June that filled the three sediment traps in the lower reach of Mortandad Canyon to capacity. The berm of trap 3 was breached and about 38 m^3 (10 000 gal.) of the run-off was lost downgradient from the sediment traps. The end of the flow terminated about 100 m (330 ft) east of the lower trap.

Sediment samples were collected from trap 1 (clay to fine sand and sand to coarse sand) and from locations east of the breach at 10-, 35-, 70-, and 85-m intervals. As expected, the fine sediments in trap 1 contained larger concentrations of radionuclides than did the coarse sediments in the trap or sediments below the breach. The concentrations of the various radionuclides varied considerably and indicated no particular trend or correlation of concentration levels with distance from the trap (Table 36). The breach in trap 3 was repaired; at the same time, trap 1 was enlarged.

Storm run-off in the traps on October 13, 1988, was sampled along with water from several shallow wells in the alluvium. The ^{134}Cs concentrations were near or below the detection limits and did not show any particular trends. The ^{137}Cs was found in decreasing concentrations in the three traps and was present in water from observation well MCO-5. Although considerable concentrations were found in the traps, the ^{137}Cs in the shallow ground water at MCO-6 and in wells adjacent and below the traps at MCO-7 and -7.5 was below limits of detection (Table 37). The concentrations of ^{57}Co were detectable in the traps but not in the shallow aquifer. Concentrations of ^{60}Co were detectable in water from the traps and in the shallow aquifer. Concentrations of ^{75}Se were detectable in the traps only.

The absence of ^{137}Cs, ^{57}Co, and ^{75}Se in the shallow aquifer, while present in the sediment traps, may indicate slow rates of travel in the alluvial aquifer or, more likely, adsorption or attachment of the nuclide to the fine sediments in the stream channel and in the alluvial aquifer. Additional studies are in progress on the distribution of radionuclides in the shallow aquifer adjacent to the sediment traps.

E. National Atmospheric Deposition Program (NADP) Network Station (David Nochumson and Michael Trujillo)

Group HSE-8 operates a wet deposition station that is part of the NADP network. The station is located at the Bandelier National Monument. Annual and quarterly deposition rates for 1988 are presented in Table G-55.

The 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 windblown 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

Table 36. Radiochemical Analyses of Sediments In and Below Sediment Traps, June 20, 1988

Station and Well	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	^{241}Am (pCi/g)	^{75}Se (pCi/g)	^{134}Cs (pCi/g)	^{137}Cs (pCi/g)	^{57}Co (pCi/g)	^{60}Co (pCi/g)
Sediment Trap 1								
Clay to fine sand	10.6 (0.420)	33.3 (1.24)	7.7 (1.2)	7.22 (10.9)	0.784 (0.158)	72.6 (10.9)	40.1 (6.03)	5.78 (0.889)
Sand to coarse sand	1.82 (0.103)	8.38 (0.359)	0.18 (0.03)	1.22 (0.236)	0.205 (0.119)	13.1 (1.98)	1.16 (0.284)	0.489 (0.176)
Washout Below Sediment Trap 3								
10 m	0.183 (0.024)	0.492 (0.042)	5.8 (0.83)	1.48 (0.243)	0.053 (0.092)	2.53 (0.397)	0.808 (0.176)	0.732 (0.172)
35 m	1.14 (0.085)	2.78 (0.152)	0.18 (0.03)	1.83 (0.300)	0.067 (0.115)	7.41 (1.13)	1.96 (0.379)	0.148 (0.144)
70 m	4.12 (0.193)	9.87 (0.408)	7.3 (1.1)	0.470 (0.145)	0.167 (0.115)	38.3 (5.77)	5.53 (0.185)	0.815 (0.184)
85 m	2.02 (0.115)	3.87 (0.189)	0.18 (0.03)	0.185 (0.130)	0.043 (0.102)	14.0 (2.11)	0.819 (0.239)	0.116 (0.136)

Table 37. Radiochemical Analyses of Water in Sediment Traps and Observation Wells, October 13, 1988

	^{134}Cs (pCI/L)	^{137}Cs (pCi/L)	^{57}Co (pCi/L)	^{60}Co (pCi/L)	^{75}Se (pCi/L)
Sediment Traps					
1	−3.9 (52)	330 (83)	180 (58)	456 (109)	320 (56)
2	9.4 (89)	550 (110)	163 (67)	82 (110)	380 (76)
3	3.5 (54)	680 (120)	313 (70)	444 (110)	480 (80)
Observation Wells					
MCO-5	−113 (79)	180 (73)	52 (55)	151 (110)	−3 (41)
MCO-6	−28 (50)	−2 (54)	2.9 (39)	390 (110)	4 (26)
MCO-7	−19 (74)	20 (62)	42 (56)	184 (103)	22 (50)
MCO-7.5	−57 (57)	21 (57)	49 (48)	345 (110)	60 (29)

from entrained alkaline soil particles in the southwest, natural pH may be higher than 5.6, the pH of rainwater in 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. The audit provided the NADP with an updated evaluation of the site. The physical characteristics of the site and its operation were examined. Except for a few minor equipment flaws, the operation of the station was in compliance with NADP guidelines.

X. PUBLICATIONS

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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 (General Environmental Program), 5480.1 (Environmental Protection, Safety, and Health Protection Standards), and 5480.11 (Requirements for Radiation Protection for Occupational Workers); and DOE Order 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.

The 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 involves integrating the dose received from radionuclides over a standard period of time. For this report, 50-yr 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 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 (Ref. A5) lists currently applicable RPS for operations at the Laboratory. Off-site measurements are compared with DOE's Derived Concentration Guides (DCGs) for uncontrolled areas, based upon a revised RPS for the general public of 100 mrem/yr effective dose equivalent (Table A-2).[A6] These DCGs represent the smallest estimated concentrations in water or air, taken in continuously for a period of 50 yr, 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 of the National Commission on Radiation Protection and Measurements (NCRP).[A3,A4,A6]

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 to DCGs in this report. In addition to the 100 mrem/yr effective dose RPS, exposures from the air pathway are also limited by the EPA's standard of 25 mrem/yr (whole body) and 75 mrem/yr (any organ) (Table A-1).[A5] To demonstrate compliance with these standards, doses from the air pathway are compared directly with the EPA dose limits.

For chemical constituents in drinking water, standards have been promulgated by the EPA and adopted by the New Mexico Environmental Improvement Division (Table A-3). The EPA's primary Maximum Contaminant Level (MCL) is the maximum permissible level of a contaminant in water that is delivered to the outlet of the ultimate user of a public water system.[A7] The EPA's secondary water standards control contaminants in drinking water that primarily affect esthetic qualities associated with public acceptance of drinking water.[A8] At considerably higher concentrations of these contaminants, health implications may arise.

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[c] exposure	500 mrem/yr
Prolonged annual[c] 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
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 effective dose equivalent[e])
Extremity	50 rem (annual effective dose equivalent[e])
Skin of the whole body	50 rem (annual effective dose equivalent[e])
Organ or tissue	50 rem (annual effective 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. These Radiation Protection Standards apply 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 Radiation Protection Standard, a prolonged exposure will be one that lasts, or is predicted to last, longer than 5 yr.

[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 (µCi/mL)[a]

	DCGs for Uncontrolled Areas		
Nuclide	Air	Water	DACs for Controlled Areas
^{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[c]	1×10^{5}	8×10^{-1}	3×10^{7}

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[a] Guides for uncontrolled areas are based upon DOE's Radiation Protection Standard (RPS) for the general public;[A6] those for controlled areas are based upon 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 due to fallout.

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

[c] One curie of natural uranium is equivalent to 3000 kg of natural uranium. Therefore, uranium masses may be converted to DOE's "uranium special curie" by multiplying by 3.3×10^{-13} µCi/pg.

Radioactivity in drinking water is regulated by EPA regulations contained in 40 CFR 141.[A8] These regulations provide that combined ^{226}Ra and ^{228}Ra may not exceed 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 concentrations are limited to concentrations that would result in doses not exceeding 4 mrem/yr, calculated according to a specified procedure.

The EPA established minimum concentrations of certain contaminants in a water extract from wastes for designation of these wastes as hazardous by reason of toxicity.[A9] The Extraction Procedure (EP) must follow steps outlined by EPA in 40 CFR 261, Appendix II. In this report, the EP toxicity minimum concentrations (Table A-4) are used to compare to concentrations of selected constituents in extracts from the Laboratory's active waste areas.

Table A-3. Maximum Contaminant Level (MCL) in 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	^{3}H	20×10^{-6}
Cd	0.010	^{238}Pu	15×10^{-9}
Cr	0.05	^{239}Pu	15×10^{-9}
F[c]	2.0		
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	500		
pH	6.5–8.5		

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[a] Source: Refs. A7 and A8.

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

[c] Based on annual average of the maximum daily air temperature of 14.7 to 17.6°C.

Table A-4. Minimum Concentrations of Inorganic Contaminants for Meeting EPA's Extraction Procedure (EP) Toxicity Characteristic 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

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[a] Source: Ref. A9.

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A6. U.S. Department of Energy, "DOE-Derived Concentration Guides for Drinking Water and Breathing Air Contaminated with Radionuclides by Members of the Public [*sic*]," attachment to memorandum from R. J. Stern, Director, Office of Environmental Guidance, U.S. Department of Energy (February 28, 1986).

A7. U.S. Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," U.S. Environmental Protection Agency report EPA-570/9-70-003 (1976) and 40 CFR 141.

A8. U.S. Environmental Protection Agency, "National Secondary Drinking Water Regulations," Federal Register 44 (140) (July 19, 1979).

A9. U.S. Environmental Protection Agency, "Part 261, Identification and Listing of Hazardous Waste. Table I. Maximum Concentration of Contaminants for Characteristics of EP Toxicity," *Federal Register* **45**, 33122 (May 19, 1980).

APPENDIX B

PROCEDURES FOR SAMPLING, DATA HANDLING, AND QUALITY ASSURANCE

A. Thermoluminescent Dosimeters

The 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 h and then cooled rapidly to room temperature. This is followed by annealing at 100°C (212°F) for 1 h 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 at once into the ovens maintained at 400 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 rem (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 factors of 0.958 for muscle ^{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 (weighting factor is the variance).[B3]

The TLD chips used are 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 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 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-diam 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 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_20_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 calculated. This technique does not differentiate between ^{239}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 indicate 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 returned to the laboratory within a few hours of sample collection for filtration through a 0.45-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-m 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 ring is placed on the surface of the soil at the sampling point. The soil enclosed by the ring is then collected by undercutting the ring with a metal spatula. A second spatula is then placed on top of the ring and the sample is transferred into a plastic bag and labeled.

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.

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 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, dissected, and wet, dry, and ash weights determined. 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. Measurements include 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 s and averaged or summed over 15-min 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 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 also helps to detect problems with the instrumentation that might develop between the annual or semiannual (depending on the instrument) calibrations.

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

G. Data Handling

Measurements of the 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.[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(s) for the station and group (regional, perimeter, on-site) means are calculated using the following equation:

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

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 a 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 Health and Environmental Chemistry Group (HSE-9) issues to the collector a block of sample numbers (e.g., 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 delivered to 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 is provided by the 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 Environmental Protection Agency (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. C6–C70). 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 flow injection (without distillation) for chloride in drinking water and waste water. 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 in use are supported by the use of documented spike/recovery studies, method and field blanks, matrix spikes, surrogate spikes, and blind quality-control samples. EPA procedures are modified in order to take advantage of recent advances in analytical separation and analysis techniques. Volatile organics are analyzed using a modified form of EPA method 524. Our current target list of volatile compounds totals 70. Water samples are analyzed by purge-and-trap gas chromatography/mass spectrometry (PAT). Soils are analyzed using heated PAT. Semivolatile organics 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. Volatiles 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,

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, conductivity, COD	C6, C65
Color spectrophotometry	NO_3^-, PO_4^{-3}, Si, Pb, Ti, B	C6, C65
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, C65
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, C65
Thermal neutron capture gamma ray	Al, B, Ca, Cd, C, Gd, H, Fe, Mg, N, K, Si, Na, S, Ti	C7, C22–C29, C65
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, C65
Delayed neutron assay	U	C7, C8, C10, C11, C39, C40, C65
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, C65
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	C65
Ion chromatograpy	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{-2}, PO_4^{-3}, Na^+, K^+, Mg^{+2}, Ca^{+2}	C49, C65
Potentiometric	F^-, NH_4^+, pH, Br^-, Cl_2 (total), Cl_2 (free)	C50, C55, C65
Combustion	C, N, H, S, total organic carbon	C29, C62, C63, C65
Corrosivity	—	C56, C57
Ignitability (flash point)	—	C56, C58
Automated colorimetry	CN^-, NH_4^+, PO_4^{-3}, NO_3^-, NO_2^-, Cl^-, COD, TKN, Si, B, SO_4^{-2}, Cr^{+6}	C6, C59, C60–C62, C65
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	C66–C68

and electron capture. Also available is a high-pressure liquid chromatograph equipped with a ultra-violet (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 purge and trap. The methods used for analyses in 1988 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.

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 the analytical work. First, it provides quality control over analytical procedures so that problems that might occur can be identified and corrected. Second, 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. The former function is analytical quality control; the latter is quality assurance.

No attempt is made to conceal the identity of control samples from the analyst, although the concentration of the analytes of interest is not revealed. 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 inclined. We endeavor to run at least 10% of stable constituent, organic, and selected radioactive constituent analyses as quality assurance samples using the materials described above. A detailed description of our quality assurance program and a complete listing of our annual results are published annually.[C71–C81]

2. Radioactive Constituents. Quality control and quality assurance samples for radioactive constituents are obtained from outside agencies as well as 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 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 also been published elsewhere.[C81]

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.[C82] 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

Table C-2. Method Summary (Organics)

Analyte	Matrix	Method	Technique[a]	Reference
Volatiles	Air	—	GC/MS	C65
	Soil	CLP[b]/524	PAT/GC/MS	C64–C66
	Water	524	PAT/GC/MS	C64
EP[c] toxicity	Soil	1310, 8080 8150	GC/ECD	C66
PCBs	Water	606	GC/ECD	C64
	Soil	8080	GC/ECD	C66
	Oil	IH 320	GC/ECD	C65
Semivolatiles	Soil and waste	625	GC/MS	C69,C70

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

[b] Contract Laboratory Program (CLP).

[c] Extraction procedure (EP).

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 (VOCs and SVOCs), 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. Since homogeneity of the sample could not be ensured, the entire sample was analyzed. The VOCs are analyzed by gas chromatography/mass spectrometry. In the last 12 months, the detection limit for these compounds has decreased by a factor of 100 because of a change in the technique used to introduce the samples into the gas chromatograph. This was accomplished by using a heated purged-trap methodology instead of purge-and-trap performed at ambient temperatures. The in-house quality control samples are now spiked in the microgram-per-kilogram range to reflect this change in detection limits.

The majority of water samples submitted during 1988 were environmental compliance samples for the analysis of pesticides, herbicides, semivolatile and volatile organic compounds, and PCBs. Methods were developed and 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 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.

Table C-3. Volatiles Determined in Water by Purge and Trap

Compound	CAS #	Representative Limit of Quantification (µg/L)
Chloromethane	74-87-3	10
Vinyl chloride	75-01-4	10
Bromomethane	74-83-9	2
Chloroethane	75-00-3	10
Acetone	67-64-1	2
Trichlorofluoromethane	75-69-4	2
1,1-Dichloroethene	75-35-4	2
Methylene chloride	75-09-2	2
Carbon disulfide	75-15-0	10
t-1,2-Dichloroethene	156-60-5	2
1,1-Dichloroethane	75-34-3	2
c-1,2-Dichloroethene	156-59-2	2
Bromochloromethane	74-97-5	2
Chloroform	67-66-3	2
1,2-Dichloroethane	107-06-2	2
1,1-Dichloropropene	563-58-6	10
Vinyl acetate	108-05-4	20
2-Butanone (MEK)	78-93-3	10
2,2-Dichloropropane	590-20-7	2
1,1,1-Trichloroethane	71-55-6	2
Carbon tetrachloride	56-23-5	2
Benzene	71-43-2	2
1,2-Dichloropropane	78-87-5	2
Trichloroethene	79-01-6	2
Dibromomethane	74-95-3	2
Bromodichloromethane	75-27-4	2
t-1,3-Dichloropropene	1006-10-26	2
c-1,3-Dichloropropene	1006-10-15	20
1,1,2-Trichloroethane	79-00-5	2
1,3-Dichloropropane	142-28-9	2
Chlorodibromomethane	124-48-1	2
Bromoform	75-25-2	10
4-Methyl-2-pentanone (MIK)	10-81-1	10
Toluene	108-88-3	2
2-Hexanone	59-17-86	80
1,2-Dibromomethane	74-95-3	2
Tetrachloroethene	127-18-4	2
Chlorobenzene	108-90-7	2
1,1,1,2-Tetrachloroethane	630-20-6	2
1-Chlorohexane	544-10-5	2
Ethylbenzene	100-41-4	2
m,p-Xylene (total)	108-38-3 + 106-42-3	2
o-Xylene	95-47-6	2
Styrene	100-42-5	2
1,1,2,2-Tetrachloroethane	79-34-5	10
1,2,3-Trichloropropane	96-18-4	2

Table C-3 (Cont)

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

Column: Supelco SPB-5 60 m × 0.25 mm × 1.0 μm. Limits of detection estimated by minimum signal required to yield identifiable mass spectral scan.

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 are normalized to the known quality in the reference material to permit comparison among reference materials of 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):

$$R = \frac{\Sigma_i r_i}{N} .$$

The standard deviation(s) of R is 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;

Table C-4. Volatiles Determined in Solids by SW-846 Method 8010

Compound	CAS #	Limit of Quantification (µg/kg)
Chloromethane	74-87-3	10
Vinyl chloride	75-01-4	2
Bromomethane	74-83-9	2
Chloroethane	75-00-3	2
Acetone	67-64-1	2
Trichlorofluoromethane	75-69-4	2
1,1-Dichloroethene	75-35-4	2
Methylene chloride	75-09-2	10
Carbon disulfide	75-15-0	2
t-1,2-Dichloroethene	156-60-5	2
1,1-Dichloroethane	75-34-3	2
c-1,2-Dichloroethene	156-59-4	2
Bromochloromethane	74-97-5	2
Chloroform	67-66-3	2
1,2-Dichloroethane	107-06-2	2
1,1-Dichloropropene	563-58-6	2
Vinyl acetate	108-05-4	10
2-Butanone (MEK)	78-93-3	10
2,2-Dichloropropane	590-20-7	10
1,1,1-Trichloroethane	71-55-6	10
Carbon tetrachloride	56-23-5	2
Benzene	71-43-2	2
1,2-Dichloropropane	78-87-5	2
Trichloroethene	79-01-6	2
Dibromomethane	74-95-3	2
Bromodichloromethane	75-27-4	2
t-1,3-Dichloropropene	1006-10-26	10
c-1,3-Dichloropropene	1006-10-15	10
1,1,2-Trichloroethane	79-00-5	2
1,3-Dichloropropane	142-28-9	2
Chlorodibromomethane	124-48-1	2
Bromoform	75-25-2	2
4-Methyl-2-pentanone (MIK)	10-81-1	10
Toluene	108-88-3	2
2-Hexanone	59-17-86	20
1,2-Dibromomethane	74-95-3	2
Tetrachloroethene	127-18-4	2
Chlorobenzene	108-90-7	2
1,1,1,2-Tetrachloroethane	630-20-6	2
1-Chlorohexane	544-10-5	2
Ethylbenzene	100-41-4	2
m,p-Xylene (total)	108-38-3 + 106-42-3	2
o-Xylene	95-47-6	2
Styrene	100-42-5	2
1,1,2,2-Tetrachloroethane	79-34-5	10
1,2,3-Trichloropropane	96-18-4	2
Isopropylbenzene	98-82-8	2

Table C-4 (Cont)

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

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[a] Column: 60 m × 0.32 mm SPB-5 fused silica capillary, using a methanolic partition with purge and trap. Limits of quantification are calculated from the intercept of the external calibration curve using a flame-ionization detector.

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,

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

where X_E and X_c are the experimentally determined and certified or consensus mean elemental concentrations, respectively. The S_E and S_c parameters 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.[C81] 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-20. A summary of the overall state of statistical control for analytical work done by HSE-9 is provided in Table C-21.

For most radiochemical and inorganic analyses, more than 92% are within ±2 propagated-standard-deviations of the certified/consensus mean values (under control). Trace levels of these constituents in biological materials still provide more analytical difficulty, as illustrated by the slightly lower level of overall analytical control. Although the overall control of organic analyses in bulk materials (such as oils and solvents) is quite good, we have much too high a percentage of our organic determinations in water and silicate matrixes outside the ±3 propagated-standard-deviations of the certified/consensus mean values (out of control). This area will be the focus of increased quality assurance/quality control effort.

Table C-5. Semivolatile Organics in Water

Compound	CAS #	Limit 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

Table C-5 (Cont)

Compound	CAS #	Limit of Quantification (µg/L)
4,6-Dinitro-2-methylphenol	534-52-1	50
N-Nitrosodiphenylamine	86-30-6	10
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

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

The analysis of any organic on silicate materials is difficult because of the tremendous number and type of matrix complications. Our quality-control samples are matrix spikes that truly reflect what occurs in the extraction process. In addition to the blind quality-control samples, the analyst spikes samples for volatile and semivolatile 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 is 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-22.

Table C-6. Volatiles Determined in Air (Pore Gas)

Compound	CAS #	Limit 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 + 106-42-3	1.0
1,2,4-Trimethylbenzene	95-63-6	1.0

Table C-7. EP Toxicity 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 is calculated as 4 times the gas chromatography background noise found when an electron capture detector was used.

Table C-8. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses in Water)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Ag	194	100	—	—	1.01 ± 0.08
Al	26	89	12	—	1.03 ± 0.18
As	236	92	3	5	1.08 ± 0.20
Ba	184	97	1	2	1.01 ± 0.08
B	17	100	—	—	1.00 ± 0.07
Be	177	98	2	1	1.04 ± 0.12
Bi	4	100	—	—	0.97 ± 0.04
Ca	30	97	—	3	0.97 ± 0.07
Cd	277	99	1	—	1.01 ± 0.09
Cl	55	100	—	—	1.00 ± 0.04
Cl_2	12	100	—	—	0.88 ± 0.11
CN^-	137	100	—	—	0.87 ± 0.07
Co	32	100	—	—	1.06 ± 0.09
Chemical oxygen demand	66	100	—	—	0.98 ± 0.08
Conductivity	48	100	—	—	0.97 ± 0.04
Cr	297	100	—	—	1.01 ± 0.10
Cr^{+6}	166	99	—	1	0.98 ± 0.11
Cu	189	95	4	—	0.98 ± 0.08
F	69	100	—	—	1.04 ± 0.07
Fe	143	99	1	—	1.04 ± 0.10
Hardness	8	100	—	—	0.96 ± 0.06
Hg	174	99	—	1	1.01 ± 0.31
K	27	89	—	11	1.42 ± 2.63
Li	17	100	—	—	1.01 ± 0.06
Mg	27	100	—	—	0.95 ± 0.05
Mn	72	96	4	—	1.04 ± 0.12
Mo	35	80	3	17	1.18 ± 0.05
Na	39	92	3	5	0.98 ± 0.12
NH_3-N	116	100	—	—	1.00 ± 0.05
Ni	144	98	1	1	1.02 ± 0.11
NO_2-N	6	100	—	—	1.01 ± 0.04
NO_3-N	99	100	—	—	1.00 ± 0.05
P	113	100	—	—	0.97 ± 0.14
Pb	422	97	2	1	1.03 ± 0.12
pH	497	100	—	—	1.00 ± 0.01
PO_4-P	8	100	—	—	0.94 ± 0.06
Sb	14	95	7	—	0.96 ± 0.14
Se	179	97	—	1	1.13 ± 1.10
Si	35	100	—	—	1.05 ± 0.05
Sn	2	50	50	—	1.35
SO_4	60	100	—	—	0.99 ± 0.08

Table C-8 (Cont)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Sr	6	100	—	—	1.02 ± 0.03
Total alkalinity	36	100	—	—	0.98 ± 0.05
Total dissolved solids	23	100	—	—	0.98 ± 0.12
Th	24	100	—	—	1.05 ± 0.10
Tl	115	93	4	3	0.99 ± 0.14
Total organic carbon	8	100	—	—	0.95 ± 0.05
Total organic halogens	2	100	—	—	0.88
Total suspended solids	66	98	2	—	0.93 ± 0.06
Turbidity	2	100	—	—	1.01
U	292	100	—	—	1.05 ± 0.13
V	34	97	—	3	1.06 ± 0.14
Zn	179	97	1	1	1.01 ± 0.07

Table C-9. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses in Silicates)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Ag	3	99	—	—	1.06 ± 0.36
Al	199	91	4	5	1.01 ± 0.07
As	11	100	—	—	1.14 ± 0.36
Ba	223	96	3	1	0.99 ± 0.22
Be	37	100	—	—	1.15 ± 0.71
Ca	200	95	2	4	0.99 ± 0.21
Cd	29	100	—	—	0.93 ± 0.15
Ce	64	100	—	—	1.05 ± 0.09
Cl	147	79	1	4	1.41 ± 0.64
Co	61	89	7	5	1.03 ± 0.34
CO_2	69	91	7	1	1.07 ± 0.04
Cr	45	87	7	7	1.00 ± 0.10
Cs	40	100	—	—	1.09 ± 0.25
Cu	115	99	1	—	1.00 ± 0.21
Dy	162	80	12	8	0.94 ± 0.33
Eu	100	94	2	4	0.99 ± 0.09
F	27	85	11	4	1.26 ± 0.19
Fe	49	79	—	20	1.01 ± 0.06
Ga	85	100	—	—	1.15 ± 0.25
H_2O^+	20	100	—	—	1.08 ± 0.28
H_2O^-	20	100	—	—	1.17 ± 0.26
Hf	55	91	7	2	1.02 ± 0.08
Hg	1	100	—	—	0.98
I	46	100	—	—	0.99 ± 0.12
In	127	100	—	—	0.78 ± 0.18
K	171	89	8	3	1.03 ± 0.19
La	14	86	14	—	1.10 ± 0.09
Li	37	97	3	—	0.89 ± 0.38
Lu	18	94	6	—	1.12 ± 0.16
Mg	199	94	4	3	1.03 ± 0.18
Mn	197	98	2	—	1.01 ± 0.08
Na	211	96	4	—	0.98 ± 0.05
Ni	65	98	2	—	0.95 ± 0.24
Pb	80	100	—	—	1.02 ± 0.16
Rb	33	82	3	15	1.00 ± 0.11
S	23	87	13	—	0.73 ± 0.07
Sb	25	96	4	—	1.40 ± 0.68
Sc	55	95	5	—	0.96 ± 0.07
Se	1	100	—	—	1.43
Si	97	87	5	7	0.98 ± 0.08
Sm	144	96	3	1	0.97 ± 0.16

Table C-9 (Cont)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Sr	110	97	4	—	0.90 ± 0.19
Ta	36	94	3	3	1.06 ± 0.22
Tb	11	100	—	—	1.02 ± 0.21
Th	93	92	3	5	0.91 ± 0.20
Ti	163	94	5	1	1.00 ± 0.21
U	223	96	—	4	0.98 ± 0.09
V	201	99	1	—	0.95 ± 0.10
W	48	100	—	—	0.86
Yb	42	81	7	12	1.05 ± 0.16
Zn	21	86	—	14	0.92 ± 0.21

Table C-10. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses in Sludge)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Ag	22	100	—	—	1.03 ± 0.14
As	2	—	100	—	0.70
Cd	18	100	—	—	0.89 ± 0.07
Cr	25	100	—	—	1.02 ± 0.05
Hg	16	100	—	—	0.92 ± 0.20
Pb	42	100	—	—	1.12 ± 0.12
Se	4	50	—	50	0.60 ± 0.11

Table C-11. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses in Biological Materials)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Al	6	100	—	—	0.95 ± 0.05
As	2	100	—	—	1.10 ± 0.04
Ca	2	100	—	—	0.90 ± 0.02
Cl	2	100	—	—	0.89 ± 0.04
Cs	6	100	—	—	1.20 ± 0.32
F	6	100	—	—	0.94 ± 0.08
K	2	100	—	—	1.59 ± 0.14
Mg	2	100	—	—	0.80
Mn	2	100	—	—	1.02 ± 0.02
Mo	8	88	13	—	0.49
Na	2	100	—	—	0.45 ± 0.15
S	5	100	—	—	0.90 ± 0.02
Si	99	79	2	19	1.12 ± 0.27
U	21	95	5	—	1.06 ± 0.16
V	6	83	17	—	1.02 ± 0.19
W	8	75	25	—	0.69

Table C-12. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses on Filters)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
As	10	100	—	—	0.94 ± 0.09
Ba	3	100	—	—	0.99 ± 0.05
Be	89	99	—	1	1.00 ± 0.13
Cd	35	83	9	9	1.09 ± 0.43
Cr	2	100	—	—	0.97
Cu	2	100	—	—	1.00
Ga	4	100	—	—	1.01 ± 0.01
Pb	53	88	—	11	1.06 ± 0.18
Sb	2	100	—	—	1.03
Sc	13	100	—	—	1.04 ± 0.07
Se	4	100	—	—	0.98 ± 0.22
Tl	2	100	—	—	0.80
U	30	100	—	—	0.97 ± 0.07
Zn	35	92	9	—	1.04 ± 0.11

Table C-13. Summary of HSE-9 Quality Assurance Tests for 1988 (Stable Element Analyses in Bulk Materials)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Ag	27	97	—	4	0.99 ± 0.10
As	19	100	—	—	1.15 ± 0.12
Ba	17	100	—	—	0.99 ± 0.08
Cd	26	100	—	—	0.93 ± 0.09
Cr	21	100	—	—	1.00 ± 0.14
Flash point	24	100	—	—	1.00 ± 0.01
Heat capacity	7	100	—	—	1.00 ± 0.02
Hg	33	88	9	3	1.07 ± 0.48
Ni	6	100	—	—	1.03 ± 0.06
Pb	30	97	3	—	1.00 ± 0.14
Se	19	100	—	—	0.96 ± 0.12
Tl	11	100	—	—	1.04 ± 0.17
Zn	7	100	—	—	0.94 ± 0.03

Table C-14. Summary of HSE-9 Quality Assurance Tests for 1988 (Organic Analyses in Water)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Acenaphthene	5	60	—	40	0.64 ± 0.22
Acetone	1	100	—	—	1.32
Alachlor	2	100	—	—	1.00
Aldrin	1	100	—	—	0.61
Anthracene	4	75	—	25	0.77 ± 0.05
Aroclor 1242	5	80	20	—	0.94 ± 0.02
Aroclor 1254	1	100	—	—	2.14
Atrazine	2	100	—	—	0.80
1,2-Benzanthracene	2	100	—	—	0.89
Benzene	9	55	11	33	0.90 ± 0.11
Benzo(*g,h,i*)perylene	4	75	—	25	1.10 ± 0.57
Benzo-*a*-pyrene	4	75	—	25	1.22 ± 0.59
Benzo-*b*-fluoranthene	4	75	—	25	1.18 ± 0.50
Benzo-*k*-fluoranthene	2	100	—	—	0.82
bis(2-Chloroethoxy)methane	2	50	50	—	0.73
bis(2-Chloroethyl)ether	5	20	20	60	0.55 ± 0.38
bis(2-Chloroisopropyl)ether	4	50	—	50	0.98
bis(2-Ethylhexyl)phthalate	4	50	—	50	4.95 ± 2.63
Bromodichloromethane	14	85	—	14	0.91 ± 0.07
Bromoform	11	45	27	27	1.01 ± 0.31
4-Bromophenylphenyl ether	4	50	25	25	0.56 ± 0.05
tert-Butylbenzene	1	100	—	—	1.38
Butylbenzyl phthalate	3	100	—	—	1.43 ± 0.36
Carbon tetrachloride	12	50	17	33	0.79 ± 0.13
Chlordane	2	50	—	50	1.58
4-Chloro-3-methylphenol	8	25	13	63	0.70 ± 0.63
Chlorobenzene	15	74	7	20	0.96 ± 0.37
Chlorodibromomethane	10	90	10	—	1.07 ± 0.25
Chloroform	22	73	—	27	0.89 ± 0.06
2-Chloronaphthalene	4	25	25	50	0.64 ± 0.16
o-Chlorophenol	6	34	50	17	1.00 ± 0.90
p-Chlorophenol	1	—	—	100	—
4-Chlorophenylphenyl ether	4	75	—	25	0.88 ± 0.07
Chrysene	4	50	25	25	1.40 ± 0.60
2,4-D	7	100	—	—	1.07 ± 0.12
Di-*n*-butyl phthalate	2	100	—	—	0.97
Di-*n*-octyl phthalate	1	—	—	100	—
Dibenzo(*a,h*)anthracene	4	75	—	25	1.08 ± 0.42
1,2-Dibromo-3-chloropropane	1	100	—	—	—
1,2-Dibromoethane	1	100	—	—	—
o-Dichlorobenzene (1,2)	3	33	67	—	1.39 ± 0.86
m-Dichlorobenzene (1,3)	3	—	33	67	1.18 ± 1.21
p-Dichlorobenzene (1,4)	7	43	29	29	0.34 ± 0.06

Table C-14 (Cont)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
1,2-Dichloroethane	10	60	—	40	1.22 ± 0.40
1,1-Dichloroethene	1	—	—	100	—
trans-1,2-Dichloroethylene	1	—	—	100	—
cis-1,2-Dichloroethylene	1	-	—	100	—
2,4-Dichlorophenol	3	66	—	33	2.03 ± 1.93
Diethyl phthalate	2	100	—	—	0.63
Dimethyl phthalate	4	50	25	25	0.70 ± 0.08
2,4-Dimethylphenol	4	25	—	75	1.71 ± 1.86
2,4-Dinitrotoluene	4	25	25	50	0.70 ± 0.13
2,6-Dinitrotoluene	3	100	—	—	0.74 ± 0.05
1,4-Dioxane	1	100	—	—	—
Endrin	3	67	33	—	1.02 ± 0.19
Ethylbenzene	18	78	—	22	0.94 ± 0.11
Fluoranthene	4	50	—	50	0.72 ± 0.17
Fluorene	4	75	—	25	0.83 ± 0.04
Heptachlor	2	100	—	—	1.31
Heptachlor epoxide	2	100	—	—	0.46
Hexachlorobenzene	2	100	—	—	1.01
Hexachlorobutadiene	2	50	50	—	0.48
Hexachloroethane	4	—	25	75	0.33 ± 0.08
Isophorone	2	50	—	50	0.69
Lindane	8	100	—	—	1.17 ± 0.71
Methoxychlor	6	88	—	17	1.28 ± 0.58
4-Methyl-2-pentanone	15	66	7	27	0.93 ± 0.14
2-Methyl-4,6-dinitrophenol	2	100	—	—	0.53
Methylene chloride	1	100	—	—	—
2-Methylnaphthalene	2	—	—	100	0.35
Naphthalene	4	75	—	25	0.56 ± 0.16
Nitrobenzene	4	50	25	25	0.55 ± 0.12
o-Nitrophenol	8	63	—	38	1.74 ± 2.25
p-Nitrophenol	4	75	—	25	0.50 ± 0.44
N-Nitrosodi-*n*-propylamine	2	50	—	50	1.87
N-Nitrosodimethylamine	1	100	—	—	—
N-Nitrosodiphenylamine	2	—	—	100	—
Pentachlorophenol	13	84	—	15	0.87 ± 0.26
Phenanthrene	2	50	50	—	0.80
Phenol	7	—	29	71	0.61 ± 0.69
Pyrene	2	100	—	—	0.98
Silvex	7	100	—	—	0.91 ± 0.06
1,1,2,2-Tetrachloroethane	1	—	—	100	0.44
Tetrachloroethylene	5	60	—	40	0.88 ± 0.03
Toluene	20	75	10	15	0.92 ± 0.29
Toxaphene	2	100	—	—	—

Table C-14 (Cont)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
1,2,4-Trichlorobenzene	5	60	20	20	0.58 ± 0.26
1,1,1-Trichloroethane	9	55	33	11	0.94 ± 0.25
1,1,2-Trichloroethane	1	—	—	100	—
Trichloroethylene	4	—	25	75	1.14 ± 0.67
2,4,6-Trichlorophenol	4	50	25	25	0.97 ± 0.71
o-Xylene	7	57	14	29	0.98 ± 0.35
p-Xylene	1	—	—	100	—

Table C-15. Summary of HSE-9 Quality Assurance Tests for 1988 (Organic Analyses in Silicates)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
Acenaphthene	1	100	—	—	1.22
Aroclor 1242	31	91	6	3	0.91 ± 0.19
Aroclor 1260	1	100	—	—	0.78
Benzene	10	30	10	60	0.48 ± 0.38
Chlorobenzene	5	60	40	—	0.76 ± 0.27
Chloroform	1	—	—	100	0.35
o-Dichlorobenzene (1,2)	1	100	—	—	3.20
1,2-Dichloroethane	1	—	100	—	0.59
2,4-Dinitrotoluene	1	100	—	—	1.25
2-Hexanone	2	100	—	—	1.38
p-Nitrophenol	1	—	—	100	1.79
o-Nitrophenol	1	—	—	100	0.29
N-Nitrosodi-*n*-propylamine	1	100	—	—	1.07
Pentachlorophenol	2	50	—	50	2.56
Phenol	1	100	—	—	1.04
1,1,2,2-Tetrachloroethane	1	—	—	100	0.26
Toluene	10	70	—	30	0.68 ± 0.34
1,2,4-Trichlorobenzene	1	—	100	—	0.61
Trichloroethylene	1	—	100	—	0.56
Vinyl acetate	1	—	—	100	0.10
m-Xylene	2	50	—	50	0.51
o-Xylene	3	33	—	67	0.49 ± 0.08

Table C-16. Summary of HSE-9 Quality Assurance Tests for 1988 (Organic Analyses in Bulk Materials)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Acetone	3	100	—	—	0.97 ± 0.02
Mixed aroclor	1	100	—	—	1.05
Aroclor 1242	32	100	—	—	0.93 ± 0.12
Aroclor 1254	1	100	—	—	—
Aroclor 1260	1	100	—	—	—
Aroclor 1260	18	94	6	—	0.85 ± 0.12
Chlorobenzene	1	100	—	—	1.02
Chloroform	3	100	—	—	0.94 ± 0.10
n-Decane	2	100	—	—	1.07
o-Dichlorobenzene (1,2)	1	—	—	100	0.56
Hexane	5	80	20	—	1.07 ± 0.31
2-Hexanone	1	100	—	—	0.94
Toluene	2	100	—	—	1.22

Table C-17. Summary of HSE-9 Quality Assurance Tests for 1988 (Radiochemical Analyses in Water)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Alpha	652	99	—	—	1.01 ± 0.10
^{241}Am	84	100	—	—	0.95 ± 0.05
Beta	650	100	—	—	0.99 ± 0.06
^{57}Co	66	100	—	—	1.11 ± 0.11
^{60}Co	79	97	—	4	1.21 ± 0.93
^{134}Cs	81	100	—	—	0.93 ± 0.39
^{137}Cs	126	99	1	—	1.11 ± 0.42
Gamma	55	98	2	—	1.08 ± 0.12
^{3}H	270	98	2	—	0.98 ± 0.10
^{54}Mn	65	100	—	—	1.11 ± 0.06
^{22}Na	63	100	—	—	1.02 ± 0.07
^{238}Pu	62	98	—	2	1.01 ± 0.15
^{239}Pu	74	93	1	5	0.99 ± 0.12
^{226}Ra	31	100	—	—	0.98 ± 0.05
^{106}Ru	10	70	10	20	0.46 ± 0.55
^{90}Sr	16	63	6	31	0.86 ± 0.10
^{234}U	35	100	—	—	0.99 ± 0.10
^{235}U	31	100	—	—	0.95 ± 0.24
^{235}U/^{238}U	285	100	—	—	0.99 ± 0.08

Table C-18. Summary of HSE-9 Quality Assurance Tests for 1988 (Radiochemical Analyses on Filters)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
Alpha	37	100	—	—	0.90 ± 0.04
^{241}Am	14	83	7	—	0.92 ± 0.12
^{7}Be	2	100	—	—	0.95
Beta	36	100	—	—	0.92 ± 0.04
^{57}Co	2	100	—	—	1.14
^{60}Co	2	100	—	—	1.32
^{134}Cs	2	100	—	—	1.08
^{137}Cs	7	100	—	—	1.00 ± 0.07
^{54}Mn	2	100	—	—	1.01
^{238}Pu	4	100	—	—	0.99 ± 0.04
^{239}Pu	14	79	7	14	1.01 ± 0.34
^{90}Sr	2	—	50	50	0.53

Table C-19. Summary of HSE-9 Quality Assurance Tests for 1988 (Radiochemical Analyses in Biological Materials)

Analysis	Number of Tests	$<2\sigma$ (%)	$2–3\sigma$ (%)	$>3\sigma$ (%)	HSE-9 Ratio ± Std Dev
^{241}Am	6	84	17	—	0.96 ± 0.13
^{137}Cs	34	86	12	3	0.94 ± 0.20
^{131}I	6	100	—	—	0.93 ± 0.15
^{238}Pu	18	89	11	—	0.94 ± 0.08
^{239}Pu	23	87	9	4	1.02 ± 0.17
^{226}Ra	1	100	—	—	0.97
^{90}Sr	6	17	17	67	0.70 ± 0.18

Table C-20. Summary of HSE-9 Quality Assurance Tests for 1988 (Radiochemical Analyses in Silicates)

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)	HSE-9 Ratio ± Std Dev
^{241}Am	9	89	11	—	1.94 ± 2.18
^{60}Co	3	100	—	—	0.99 ± 0.24
^{137}Cs	45	100	—	—	0.93 ± 0.11
Gamma	50	100	—	—	1.04 ± 0.02
^{40}K	5	40	—	60	8.39 ± 6.08
^{238}Pu	26	96	—	4	0.89 ± 0.20
^{239}Pu	35	83	6	11	0.88 ± 0.29
^{226}Ra	5	100	—	—	1.02 ± 0.05
^{90}Sr	5	40	40	20	0.86 ± 0.48
^{235}U/^{238}U	2	100	—	—	1.02

Table C-21. Overall Summary of HSE-9 Quality Assurance Tests for 1988

Analysis	Number of Tests	<2σ (%)	2–3σ (%)	>3σ (%)
Stable Elements				
Biological materials	129	85	4	11
Filters	284	94.5	2.2	3.5
Bulk materials	247	97.6	1.6	0.8
Sludge	129	96.8	1.6	1.6
Silicate materials	4253	93.8	3.6	2.6
Water	5248	98.0	1.0	1.0
Radiochemical Elements				
Water	2735	99.0	0.4	0.6
Filters	124	95.2	2.4	2.4
Biological materials	94	85	11	4
Silicate materials	185	92.4	2.8	4.8
Organic Compounds				
Water	437	63	10	27
Silicate materials	79	66	10	24
Bulk materials	71	95.7	2.9	1.4

Table C-22. 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^{-18} µCi/m^3
^{239,240}Pu	2.0×10^4 m^3	8×10^4 s	3×10^{-18} µCi/m^3
^{241}Am	2.0×10^4 m^3	8×10^4 s	2×10^{-18} µCi/m^3
Gross alpha	6.5×10^3 m^3	100 min	4×10^{-16} µCi/m^3
Gross beta	6.5×10^3 m^3	100 min	4×10^{-16} 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	9×10^{-12} µCi/mL
^{239,240}Pu	0.5 L	8×10^4 s	3×10^{-11} µCi/mL
^{241}Am	0.5 L	8×10^4 s	2×10^{-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	0.003 pCi/g
^{239,240}Pu	10 g	8×10^4 s	0.002 pCi/g
^{241}Am	10 g	8×10^4 s	0.01 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 h/day, 365 day/yr).
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 dose conversion factors are taken from the DOE[D3] and are based on factors in Publication 30 of the International Commission on Radiological Protection (ICRP).[D4]

The 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-yr dose commitment for internal exposure. The 50-yr dose commitment is the total dose received by an organ during the 50-yr 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 U, ^{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-yr dose commitments. Following ICRP methods, doses are calculated for all organs that contribute over 10% of the total effective dose equivalent for each radionuclide (see Appendix A for definition of effective dose equivalent).

Table D-1. Dose Conversion Factors (rem/µCi Intake) for Calculating Internal Doses

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 ([mrem/yr]/[μCi/m^{3}]) for Calculating External Doses

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).

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 h). 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 foodstuff 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, ^{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-min, 10-min, 71-s, and 122-s 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-h half-life.

The radioisotopes ^{11}C, ^{13}N, ^{14}O, and ^{15}O are sources of photon radiation because of formation of two 0.511-MeV 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, 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 orher 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: shielding by buildings and self-shielding. Each shielding type is estimated to reduce the external radiation dose by 30%.[D8,D9]

Boundary and maximum individual doses from ^{41}Ar releases from the Omega West Reactor are estimated using a standard Gaussian dispersion model and measured stack releases (from Table G-2). Procedures used in making the calculations are described in the following section.

Neutron doses from the critical assemblies at TA-18 were based on 1988 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 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 202 616 persons in 1988 within 80 km [50 mi] of the boundary) to account for population changes between 1980 and 1988. These changes are extrapolated from an estimate of the 1987 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 over 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), due to 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 1988 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 due to 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

$$\gamma_\infty(r,\theta,t) \quad = \quad (DCF)\,\chi(r,\theta,t)\,,$$

where

$\gamma_\infty(r,\theta,t)$ = gamma dose rate (in mrem/yr) at time t, at distance r, and angle θ;

DCF = dose rate conversion factor from the DOE;[D5] 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.

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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 measurements. 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}	
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 + 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 32 active technical areas (TAs) operated by the Laboratory are shown in Fig. 4. The main programs conducted at each 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 in 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 department, the science museum, chemistry and materials science laboratories, physics laboratories, technical shops, cryogenics laboratories, a Van de Graaff accelerator, and the cafeteria.

TA-6, Two-Mile Mesa Site: This is one of three sites (TA-22 and TA-40 are the other two) used in development of special detonators for initiation of high-explosive systems. Fundamental and applied research in support of this activity includes investigation of phenomena associated with initiation of high explosives and research in rapid shock-induced reactions with shock tubes.

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 weapon components to checking of high-pressure dies and molds. Principal tools include radiographic techniques (x-ray machines to 1 000 000 V, a 24-MeV betatron), radioactive-isotope techniques, ultrasonic and penetrant testing, and electromagnetic 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 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 weapon functioning and weapon system 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 weapon warhead systems. Development and testing of high explosives, plastics and adhesives, and 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 asource 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 explosives storage areas.

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 here.

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 weapon behavior is studied here, primarily by photographic techniques. Investigations are also made into various phenomenological aspects of explosives, interactions of explosives, and explosions with other materials.

TA-40, DF-Site: See TA-6.

TA-41, W-Site: Personnel in 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 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 is piped to this site for treatment from most technical areas.

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 here.

TA-53, Meson Physics Facility: The Los Alamos Meson Physics Facility (LAMPF), a linear particle accelerator, is used to conduct research in the 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. Here, scientists 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-58, Two-Mile Mesa: This site is an undeveloped technical area.

TA-59, Occupational Health Site: Occupational health and environmental science activities are conducted here.

APPENDIX G

ENVIRONMENTAL DATA TABLES

Table G-1. Estimated Maximum Individual 50-yr Dose Commitments from 1988 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)	0.03	<0.1
^{11}C, ^{13}N, ^{14}O, ^{15}O, ^{41}Ar	Whole body	East Gate (station 6)	6.2	25
U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am	Bone surface	East Gate (station 6)	0.22	0.3

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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 a hypothetical 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 1988[a]

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)	Activation Products Gaseous[e] (Ci)	 Particulate/Vapor[f] (Ci)
TA-2				264				
TA-3	51.9	499	29.7			390		
TA-21	0.7	58.8	0.2			528		
TA-33						7 960		
TA-35	0.2					118		
TA-41						1 730		
TA-43	1.5				57.2			
TA-46								
TA-48	0.7	0.2	1 110					
TA-50	2.0		13.8					
TA-53						4.3	121 000	0.1
TA-54	<0.1							
TA-55	15.3					314		
Totals	72.3	558	1 150	264	57.2	11 000	121 000	0.1

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[a] As reported on DOE form F-5821.1.

[b] Plutonium values contain indeterminant 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 484 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 37 nuclides, dominated by ^{183}Os and ^{7}Be.

Table G-3. Thermoluminescent Dosimeter Measurements

Station Location	Annual[a] Measurement Coordinates	Dose (mrem)
Uncontrolled Areas		
Regional Stations (28–44 km)		
1. Española	—	79 (5)[a]
2. Pojoaque	—	99 (5)
3. Santa Fe	—	99 (6)
4. Fenton Hill	—	143 (3)
Perimeter Stations (0–4 km)		
5. Barranca School	N180 E130	106 (5)
6. Arkansas Avenue	N170 E030	91 (5)
7. Cumbres School	N150 E090	117 (5)
8. 48th Street	N110 W010	118 (5)
9. Los Alamos Airport	N110 E170	97 (5)
10. Bayo Canyon	N120 E250	136 (5)
11. Exxon Station	N090 E120	137 (5)
12. Royal Crest Trailer Court	N080 E080	140 (5)
13. White Rock	S080 E420	125 (5)
14. Pajarito Acres	S210 E380	93 (5)
15. Bandelier Lookout Station	S280 E200	109 (5)
16. Pajarito Ski Area	N150 W200	133 (5)
Controlled Areas		
On-Site Stations		
17. TA-21 (DP West)	N095 E140	117 (5)
18. TA-6 (Two-Mile Mesa)	N025 E030	101 (5)
19. TA-53 (LAMPF)	N070 E090	113 (5)
20. Well PM-1	N030 E305	129 (6)
21. TA-16 (S-Site)	S035 W025	119 (5)
22. Booster P-2	S030 E220	112 (5)
23. TA-54 (Area G)	S080 E290	106 (5)
24. State Hwy 4	N070 E350	176 (5)
25. Frijoles Mesa	S165 E085	113 (5)
26. TA-2 (Omega Stack)	N075 E120	128 (5)
27. TA-2 (Omega Canyon)	N085 E1210	206 (6)
28. TA-18 (Pajarito Site)	S040 E205	188 (6)
29. TA-35 (Ten Site A)	N040 E105	133 (5)
30. TA-35 (Ten Site B)	N040 E110	135 (5)
31. TA-59 (Occupational Health Lab)	N050 E040	129 (5)
32. TA-3 (Van de Graaff)	N050 E020	160 (6)
33. TA-3 (Guard Station)	N050 E020	137 (5)
34. TA-3 (Alarm Building)	N050 E020	211 (6)
35. TA-3 (Guard Building)	N050 E020	121 (5)
36. TA-3 (Shop)	N050 E020	123 (5)
37. Pistol Range	N040 E240	121 (5)
38. TA-55 (Plutonium Facility South)	N040 E240	120 (5)
39. TA-55 (Plutonium Facility West)	N040 E080	139 (5)
40. TA-55 (Plutonium Facility North)	N040 E080	126 (6)

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[a] Measurement (95% confidence increments).

Table G-4. Location of Air Sampling Stations

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

Table G-5. Average Background Concentrations of Radioactivity in the Atmosphere

Radioactive Constituent	Units	EPA[a] 1986–1988	Laboratory[b] 1988	Uncontrolled Area Guide[c]
Gross beta	10^{-15} µCi/mL	14 ± 21		9 000
^{3}H	10^{-12} µCi/mL	Not reported	2.5 ± 8.8	200 000
Uranium (natural)	pg/m^3	73 ± 35	159 ± 67	100 000
^{238}Pu	10^{-18} µCi/mL	0.7 ± 0.6	0.7 ± 0.7[d]	30 000
$^{239,240}Pu$	10^{-18} µCi/mL	0.6 ± 0.3	0.8 ± 0.8[e]	20 000
^{241}Am	10^{-18} µCi/mL	Not reported	2.6 ± 1.8[d]	20 000

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[a] Environmental Protection Agency, "Environmental Radiation Data," Reports 45 (Ref. G1) through 53 (Ref. G2). Data are from the Santa Fe, New Mexico, sampling location and were taken from January 1986 through March 1988.

[b] Data are annual averages from the regional stations (Española, Pojoaque, Santa Fe) and were taken during calendar year 1987.

[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	1988 Total Usage (kg)	Fraction Aerosolized (%)	Emissions (kg/yr)
Uranium	298	10	30
Beryllium	2.0	2	0.04
Lead	384	2	7.7

Table G-7. Airborne Tritiated Water Concentrations for 1988

Station Location^a	Total Air Volume (m^3)	No. of Monthly Samples	No. of Samples <MDL^b	Concentrations (pCi/m^3 [10^{-12} µCi/mL])			
				Max^c	Min^c	Mean^c	Mean as a Percentage of Guide^d
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	79.9	11	7	37.1 (3.7)	−4.4 (1.3)	4.8 (12.3)	<0.1
2. Pojoaque	92.8	12	10	25.1 (2.2)	−5.8 (1.6)	2.0 (8.1)	<0.1
3. Santa Fe	96.5	12	8	14.2 (1.6)	−5.8 (1.2)	1.0 (5.4)	<0.1
Group Summary	269.2	35	25	37.1 (3.7)	−5.8 (1.2)	2.5 (8.8)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	119.0	12	8	10.0 (6.4)	−3.6 (1.1)	2.4 (4.0)	<0.1
5. Arkansas Avenue	120.5	12	10	3.3 (0.5)	−1.3 (0.4)	0.6 (1.3)	<0.1
6. Philomena's	86.2	12	1	250.6 (20.9)	1.6 (1.2)	26.8 (70.6)	<0.1
7. 48th Street	109.8	12	9	85.3 (11.2)	−5.4 (1.6)	8.5 (24.5)	<0.1
8. Los Alamos Airport	78.9	12	3	152.4 (15.8)	0.4 (1.3)	20.0 (42.8)	<0.1
10. Exxon Station	104.1	12	5	25.7 (2.7)	−1.5 (1.5)	5.0 (7.1)	<0.1
11. Royal Crest Trailer Park	88.1	12	3	272.7 (12.6)	0.0 (1.0)	36.0 (77.4)	<0.1
12. White Rock	96.6	12	6	18.3 (2.0)	−1.0 (1.0)	4.3 (6.2)	<0.1
13. Pajarito Acres	90.0	12	9	11.6 (1.8)	−1.4 (1.4)	2.4 (3.9)	<0.1
14. Bandelier	75.6	12	3	25.6 (1.4)	−1.2 (1.2)	8.9 (8.3)	<0.1
Group Summary	968.8	120	57	272.7 (12.6)	−5.4 (1.6)	11.5 (37.2)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	75.6	12	0	192.5 (20.6)	8.3 (1.1)	40.0 (57.5)	<0.1
16. TA-6	107.0	12	9	79.6 (14.5)	−3.2 (1.1)	9.4 (24.8)	<0.1
17. TA-53 (LAMPF)	100.4	12	1	115.6 (23.1)	1.2 (0.5)	23.8 (40.7)	<0.1
18. Well PM-1	81.1	12	4	22.2 (2.6)	−10.4 (4.4)	7.2 (8.8)	<0.1
19. TA-52	81.6	12	3	115.2 (10.5)	0.8 (0.6)	15.3 (31.9)	<0.1
20. TA-16	126.0	12	8	26.7 (3.8)	−3.3 (1.4)	3.9 (8.4)	<0.1
21. Booster P-2	106.2	12	7	115.7 (11.3)	−2.5 (0.8)	12.5 (32.7)	<0.1
22. TA-54	98.7	12	1	75.2 (8.4)	4.7 (0.8)	23.2 (19.4)	<0.1
23. TA-49	80.1	12	8	59.5 (6.0)	−4.2 (1.4)	9.6 (20.1)	<0.1
24. TA-33	72.0	12	0	234.9 (27.1)	11.4 (1.3)	57.8 (60.6)	<0.1
25. TA-2 (Omega)	75.7	12	0	424.0 (8.6)	14.1 (1.7)	78.0 (114.2)	<0.1
26. TA-16-450	79.1	11	7	49.9 (21.4)	−7.0 (1.4)	4.6 (15.6)	<0.1
Group Summary	1083.5	143	48	424.0 (8.6)	−10.4 (4.4)	23.9 (49.8)	<0.1

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[a] See Fig. 8 for map of station locations.

[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 1988

				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]	Max[c]	Min[c]	Mean[c]	Mean as a Percentage of Guide[d]
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	65 751	4	4	2.1 (1.6)	–0.5 (0.7)	0.7 (1.1)	<0.1
2. Pojoaque	66 971	4	4	0.7 (0.5)	0.2 (0.5)	0.4 (0.2)	<0.1
3. Santa Fe	68 966	4	4	1.9 (1.0)	0.5 (1.0)	1.4 (0.7)	<0.1
Group Summary	201 688	12	12	2.1 (1.6)	–0.5 (0.7)	0.8 (0.8)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	77 657	4	4	0.8 (0.6)	0.0 (0.6)	0.4 (0.4)	<0.1
5. Arkansas Avenue	71 927	4	4	0.5 (0.7)	–0.7 (0.6)	0.0 (0.5)	<0.1
6. Philomena's	71 115	4	3	3.3 (1.0)	0.8 (0.9)	1.7 (1.1)	<0.1
7. 48th Street	46 840	3	2	2.7 (1.2)	0.0 (0.6)	1.0 (1.5)	<0.1
8. Los Alamos Airport	66 914	4	4	1.3 (0.7)	0.0 (0.6)	0.7 (0.6)	<0.1
10. Exxon Station	66 561	4	3	5.0 (1.6)	0.3 (0.8)	2.1 (2.0)	<0.1
11. Royal Crest Trailer Park	69 318	4	4	1.8 (0.6)	0.2 (0.7)	0.8 (0.7)	<0.1
12. White Rock	68 816	4	4	1.8 (1.2)	–0.3 (0.9)	0.6 (0.9)	<0.1
13. Pajarito Acres	77 414	4	4	1.2 (0.5)	0.0 (0.5)	0.6 (0.5)	<0.1
14. Bandelier	81 955	4	4	0.4 (0.4)	–0.2 (0.2)	0.2 (0.2)	<0.1
Group Summary	698 517	39	36	5.0 (1.6)	–0.7 (0.6)	0.8 (1.1)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	69 100	4	4	1.7 (0.8)	–0.2 (0.5)	0.8 (0.8)	<0.1
16. TA-6	71 344	4	4	1.6 (0.8)	0.2 (0.4)	0.7 (0.6)	<0.1
17. TA-53 (LAMPF)	68 653	4	2	5.4 (1.2)	0.5 (0.3)	2.3 (2.2)	<0.1
18. Well PM-1	71 298	4	4	1.9 (1.4)	0.0 (0.5)	0.7 (0.8)	<0.1
19. TA-52	72 618	4	4	0.4 (0.4)	0.0 (0.5)	0.2 (0.2)	<0.1
20. TA-16	64 175	4	3	3.8 (10.2)	–2.9 (2.9)	0.9 (2.9)	<0.1
21. Booster P-2	71 259	4	3	5.5 (1.1)	0.3 (0.5)	1.7 (2.5)	<0.1
22. TA-54	67 033	4	2	53.4 (47.0)	1.2 (0.8)	17.8 (24.5)	<0.1
23. TA-49	82 395	4	4	1.0 (0.4)	0.0 (0.5)	0.7 (0.5)	<0.1
24. TA-33	57 573	4	4	1.1 (0.8)	0.0 (0.7)	0.4 (0.5)	<0.1
25. TA-2 (Omega)	66 917	4	2	81.7 (6.5)	1.2 (0.6)	22.7 (39.4)	<0.1
26. TA-16-450	69 348	4	4	2.6 (1.4)	–0.6 (0.9)	0.8 (1.3)	<0.1
Group Summary	831 713	48	40	81.7 (6.5)	–2.9 (2.9)	4.1 (13.9)	<0.1

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[a] See Fig. 8 for map of station locations.

[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 1988

				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]	Max[c]	Min[c]	Mean[c]	Mean as a Percentage of Guide[d]
Regional Station (44 km), Uncontrolled Area							
3. Santa Fe	68 966	4	3	4.3 (1.5)	0.9 (0.9)	2.6 (1.8)	<0.1
Group Summary	68 966	4	3	4.3 (1.5)	0.9 (0.9)	2.6 (1.8)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
6. Philomena's	71 115	4	1	12.0 (3.1)	0.5 (1.2)	4.3 (5.3)	<0.1
8. Los Alamos Airport	66 914	4	1	4.8 (1.8)	1.4 (4.3)	3.3 (1.4)	<0.1
12. White Rock	40 491	2	0	6.3 (1.4)	3.4 (1.4)	4.8 (2.0)	<0.1
Group Summary	249 020	10	2	12.0 (3.1)	0.5 (1.2)	3.3 (3.0)	<0.1
On-Site Stations, Controlled Areas							
16. TA-6	35 950	2	1	11.5 (2.8)	1.3 (1.0)	6.4 (7.2)	<0.1
17. TA-53 (LAMPF)	51 683	3	2	2.9 (1.1)	1.6 (0.7)	2.1 (0.7)	<0.1
20. TA-16	15 404	1	1	1.9 (1.4)	1.9 (1.4)	1.9 (1.4)	<0.1
21. Booster P-2	54 237	3	1	3.9 (1.1)	1.5 (0.9)	2.5 (1.3)	<0.1
22. TA-54	50 932	3	2	9.0 (1.7)	0.2 (0.6)	3.8 (4.6)	<0.1
23. TA-49	61 037	3	2	17.6 (2.1)	0.8 (0.5)	6.6 (9.5)	<0.1
Group Summary	309 917	15	9	17.6 (2.1)	0.0 (0.5)	3.5 (4.7)	<0.1

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[a] See Fig. 8 for map of station locations.
[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 1988

				Concentrations (pg/m^3)			
Station Location[a]	**Total Air Volume (m^3)**	**No. of Quarterly Samples**	**No. of Samples <MDL[b]**	**Max[c]**	**Min[c]**	**Mean[c]**	**Mean as a Percentage of Guide[d]**
Regional Stations (28–44 km), Uncontrolled Areas							
1. Española	65 751	4	0	304.9 (30.5)	97.8 (9.8)	163.6 (95.8)	<0.1
2. Pojoaque	66 971	4	0	256.8 (25.7)	114.0 (11.4)	178.5 (68.2)	<0.1
3. Santa Fe	68 966	4	0	168.6 (16.9)	87.4 (8.7)	135.0 (37.9)	<0.1
Group Summary	201 688	12	0	304.9 (30.5)	87.4 (8.7)	159.0 (67.2)	<0.1
Perimeter Stations (0–4 km), Uncontrolled Areas							
4. Barranca School	77 657	4	0	58.0 (5.8)	30.8 (3.1)	46.8 (11.9)	<0.1
5. Arkansas Avenue	71 927	4	0	33.8 (3.4)	27.0 (2.7)	30.7 (2.8)	<0.1
6. Philomena's	71 115	4	0	59.9 (6.0)	40.9 (4.1)	49.0 (9.4)	<0.1
7. 48th Street	63 503	4	0	51.4 (5.2)	26.4 (2.6)	38.3 (13.3)	<0.1
8. Los Alamos Airport	66 914	4	0	193.6 (19.4)	78.7 (7.9)	112.2 (54.5)	<0.1
10. Exxon Station	66 561	4	0	193.5 (19.4)	44.4 (4.5)	118.4 (76.8)	<0.1
11. Royal Crest Trailer Park	69 318	4	0	74.8 (7.5)	27.9 (2.8)	54.2 (19.4)	<0.1
12. White Rock	68 816	4	0	62.5 (6.3)	30.5 (3.1)	48.8 (14.6)	<0.1
13. Pajarito Acres	77 414	4	0	40.4 (4.0)	27.3 (2.7)	34.2 (5.7)	<0.1
14. Bandelier	81 955	4	1	33.1 (33.0)	22.9 (2.3)	28.1 (5.2)	<0.1
Group Summary	715 180	40	1	193.6 (19.4)	22.9 (2.3)	56.1 (41.6)	<0.1
On-Site Stations, Controlled Areas							
15. TA-21	69 100	4	0	63.6 (6.4)	41.3 (4.1)	52.1 (9.3)	<0.1
16. TA-6	71 344	4	0	83.7 (8.4)	23.8 (2.4)	52.0 (24.6)	<0.1
17. TA-53 (LAMPF)	68 653	4	0	66.8 (6.7)	48.8 (4.9)	57.3 (8.5)	<0.1
18. Well PM-1	71 298	4	0	41.9 (4.2)	34.0 (3.4)	38.1 (3.2)	<0.1
19. TA-52	72 618	4	0	94.0 (9.5)	51.3 (5.1)	70.4 (19.5)	<0.1
20. TA-16	64 175	4	0	54.0 (5.5)	34.4 (3.4)	41.4 (9.2)	<0.1
21. Booster P-2	71 259	4	0	57.0 (5.7)	32.3 (3.2)	46.4 (10.3)	<0.1
22. TA-54	67 033	4	0	318.6 (31.9)	89.9 (9.0)	160.3 (106.7)	<0.1
23. TA-49	82 395	4	0	32.3 (3.3)	26.0 (2.6)	29.7 (2.7)	<0.1
24. TA-33	57 573	4	0	133.2 (13.3)	53.5 (5.4)	96.3 (36.2)	<0.1
25. TA-2 (Omega)	66 917	4	0	59.8 (6.0)	33.6 (3.4)	46.0 (10.8)	<0.1
26. TA-16-450	69 348	4	0	29.6 (2.9)	21.9 (2.2)	26.5 (3.4)	<0.1
Group Summary	848 047	48	0	318.6 (31.9)	21.9 (2.2)	61.6 (48.0)	<0.1

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[a] See Fig. 8 for map of station locations.

[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. 1988 Emissions and Fuel Consumption from the TA-3 Power Plant and Steam Plants

Pollutant	TA-3	TA-16	TA-21	Western Area	Total
Emissions (ton/yr)					
Particulate Matter					
1987	1.5	0.5	0.1	0.00	2.1
1988	0.8	0.5	0.1	0.00	1.4
Oxides of Nitrogen					
1987	12.8	21.8	5.4	0.07	40.1
1988	7.0	21.2	5.6	0.13	34.0
Carbon Monoxide					
1987	20.1	5.5	1.4	0.02	27.0
1988	11.2	5.3	1.4	0.03	17.9
Hydrocarbons					
1987	0.9	0.9	0.2	0.00	2.0
1988	0.5	0.9	0.2	0.01	1.6
Fuel Consumption (10^9 Btu/yr)					
1987	1098	341	85	1	1525.0
1988	593	322	85	2	1001.3

Table G-12. Quality of Effluent from the TA-50 Liquid Radioactive Waste Treatment Plant for 1988

Radionuclide	Activity[a] Released (mCi)	Mean Concentration (µCi/mL)
^{3}H	21 300	7.3×10^{-4}
^{89}Sr	81	2.8×10^{-6}
^{90}Sr	0.2	6.8×10^{-9}
^{137}Cs	31	1.1×10^{-6}
^{234}U	0.8	2.7×10^{-8}
^{238}Pu	1.1	3.8×10^{-8}
^{239,240}Pu	3.2	1.1×10^{-7}
^{241}Am	3.7	1.3×10^{-7}

Nonradioactive Constituents	Mean Concentration (mg/L)
Cd[b]	2.9×10^{-4}
Ca	205
Cl	102
Total Cr[b]	1.6×10^{-2}
Cu[b]	0.18
F	6
Hg[b]	4.2×10^{-4}
Mg	0.4
Na	693
Pb[b]	4.6×10^{-2}
Zn[b]	8.1×10^{-2}
CN	0.26
COD	38
NO_3-N	384
PO_4	0.24
TDS	3120
pH[b]	7.0–7.9

Total effluent volume = 2.93×10^{7} L.

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[a] As reported on DOE form F-5821.1.

[b] Constituents regulated by National Pollutant Discharge Elimination System permit.

Table G-13. Quality of Effluent from the Los Alamos Meson Physics Facility (TA-53) Lagoons for 1988

Radionuclide	Activity[a] Released (mCi)	Mean Concentration (µCi/mL)
^{3}H	4 900	2.1×10^{-3}
^{7}Be	Not detected	—
^{22}Na	19	8.1×10^{-6}
^{54}Mn	9.8	4.1×10^{-6}
^{57}Co	16	6.8×10^{-6}
^{60}Co	4	1.7×10^{-6}
^{134}Cs	8.9	3.8×10^{-6}

Total effluent volume = 2.36×10^{6} L.

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[a] As reported on DOE form F-5821.1.

Table G-14. Location 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	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 5A	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-14 (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	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-14 (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
MCO-8				
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	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-14 (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, 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-15. 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	−0.4 (0.3)	86 (68)	2 (1)	0.004 (0.010)	0.000 (0.010)	−130 (90)
Rio Grande						
Embudo	0.5 (0.3)	93 (67)	2 (1)	0.017 (0.012)	0.013 (0.010)	−60 (90)
Otowi	−0.5 (0.3)	145 (69)	2 (1)	0.011 (0.011)	−0.004 (0.009)	−180 (90)
Cochiti	−0.5 (0.3)	−65 (66)	3 (1)	−0.008 (0.012)	0.004 (0.007)	−90 (90)
Bernalillo	−0.5 (0.3)	185 (67)	4 (1)	0.011 (0.013)	−0.004 (0.010)	30 (90)
Jemez River						
Jemez	−0.3 (0.3)	1 (59)	1 (1)	−0.009 (0.007)	0.005 (0.012)	140 (90)
Maximum	0.5 (0.3)	145 (69)	4 (1)	0.017 (0.012)	0.013 (0.010)	30 (90)
Limits of detection	0.7	40	1	0.009	0.03	50

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[a] Samples were collected in March 1988; counting uncertainty is in parentheses.

Table G-16. 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	N	TDS	Total Hard-ness	pH	Conduc-tivity (mS/m)
Rio Chama																
Chamita	13	45	10	2.0	24	1	89	<0.2	92	6	0.3	<0.2	268	160	8.3	39
Rio Grande																
Embudo	24	27	5.7	2.8	20	0	77	<0.2	37	6	0.5	0.3	189	95	8.2	26
Otowi	24	27	5.7	2.8	20	0	78	<0.2	36	6	0.5	0.2	183	96	8.1	27
Cochiti	19	37	7.8	2.9	22	1	97	<0.2	51	8	0.5	0.2	228	127	8.3	34
Bernalillo	19	37	7.8	3.1	24	0	100	<0.2	54	9	0.5	0.3	220	133	8.2	35
Jemez River																
Jemez	14	17	1.7	4.0	9	0	48	<0.2	4	9	0.3	0.2	98	52	7.9	15
Maximum	24	45	10	4.0	24	1	100	<0.2	92	9	0.5	0.3	268	160	8.3	39

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[a] Samples were collected in March 1988.

Table G-17. 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	−1.2 (0.3)	77 (60)	1 (1)	0.000 (0.010)	−0.009 (0.010)	−140 (90)
Guaje Reservoir	−0.8 (0.3)	6 (60)	1 (1)	0.000 (0.010)	0.007 (0.009)	20 (90)
Frijoles Canyon	−0.7 (0.3)	86 (60)	1 (1)	0.013 (0.016)	−0.008 (0.006)	−90 (90)
La Mesita Spring	−0.8 (0.3)	19 (59)	1 (1)	0.019 (0.013)	0.016 (0.010)	70 (90)
Sacred Spring	−1.0 (0.3)	71 (67)	2 (1)	0.004 (0.009)	0.019 (0.010)	−100 (90)
Indian Spring	−0.7 (0.3)	145 (63)	4 (1)	0.004 (0.011)	−0.009 (0.008)	−170 (90)
Maximum	−1.2 (0.3)	145 (63)	4 (1)	0.019 (0.013)	0.019 (0.010)	70 (90)
Limits of detection	0.7	40	1	0.009	0.03	50

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[a] Samples were collected in March 1988; counting uncertainty is in parentheses.

Table G-18. Radiochemical Quality Surface and Spring Waters from White Rock Canyon[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)
Group I						
Sandia Spring	0.2 (0.3)	21 (68)	1 (1)	0.016 (0.018)	0.016 (0.012)	0 (70)
Spring 3	0.2 (0.3)	−111 (66)	1 (1)	0.000 (0.010)	0.000 (0.010)	90 (70)
Spring 3A	0.0 (0.3)	−105 (70)	1 (1)	0.013 (0.016)	0.018 (0.012)	−30 (70)
Spring 3AA	−0.1 (0.3)	−82 (67)	1 (1)	0.005 (0.005)	0.000 (0.010)	10 (70)
Spring 4	0.0 (0.3)	0 (60)	2 (1)	0.000 (0.010)	0.000 (0.010)	−30 (70)
Spring 4A	0.4 (0.3)	−59 (61)	1 (1)	0.000 (0.010)	0.005 (0.005)	−70 (70)
Spring 5	0.1 (0.3)	−5 (62)	1 (1)	0.013 (0.010)	0.000 (0.010)	−100 (70)
Spring 5AA	0.8 (0.3)	0 (62)	1 (1)	0.000 (0.010)	0.000 (0.010)	−60 (70)
Ancho Spring	0.1 (0.3)	20 (60)	1 (1)	0.026 (0.014)	0.009 (0.011)	0 (70)
Maximum	0.8 (0.3)	21 (60)	2 (1)	0.026 (0.014)	0.018 (0.012)	90 (70)
Group II						
Spring 5A	0.0 (0.3)	3 (61)	1 (1)	0.000 (0.010)	0.009 (0.007)	−110 (70)
Spring 5B	0.2 (0.3)	101 (79)	1 (1)	0.004 (0.008)	0.032 (0.015)	−70 (70)
Spring 6	0.2 (0.3)	−82 (55)	1 (1)	0.000 (0.010)	0.005 (0.005)	30 (70)
Spring 6A	0.3 (0.3)	50 (67)	1 (1)	0.004 (0.004)	0.000 (0.010)	−80 (70)
Spring 7	0.4 (0.3)	−35 (59)	1 (1)	0.008 (0.006)	−0.004 (0.007)	−80 (70)
Spring 8A	0.2 (0.3)	71 (67)	1 (1)	0.010 (0.007)	0.000 (0.010)	−100 (70)
Spring 9	−0.4 (0.3)	−15 (60)	1 (1)	0.000 (0.010)	0.000 (0.010)	−40 (70)
Spring 9A	0.0 (0.3)	100 (70)	1 (1)	0.015 (0.013)	0.000 (0.010)	−40 (70)
Doe Spring	0.2 (0.3)	—	1 (1)	−0.004 (0.004)	0.004 (0.008)	−60 (70)
Maximum	0.4 (0.3)	101 (79)	1 (1)	0.015 (0.013)	0.032 (0.015)	30 (70)
Group III						
Spring 1	0.1 (0.3)	65 (69)	1 (1)	0.004 (0.008)	0.005 (0.013)	−100 (70)
Spring 2	0.4 (0.3)	−16 (52)	3 (1)	0.019 (0.019)	0.005 (0.008)	−50 (70)
Maximum	0.4 (0.3)	65 (69)	3 (1)	0.019 (0.019)	0.005 (0.013)	−100 (70)
Group IV						
Spring 3B	0.2 (0.3)	21 (67)	13 (1)	0.012 (0.013)	−0.004 (0.011)	−100 (70)

Table G-18 (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	−0.1 (0.3)	101 (62)	1 (1)	−0.004 (0.004)	0.004 (0.010)	−20 (70)
Ancho	0.1 (0.3)	47 (69)	1 (1)	0.004 (0.012)	0.012 (0.014)	−60 (70)
Frijoles	0.7 (0.3)	−43 (53)	1 (1)	0.000 (0.010)	0.000 (0.010)	−20 (70)
Maximum	0.7 (0.3)	101 (62)	1 (1)	0.004 (0.012)	0.012 (0.010)	
−60	(70)					
Sanitary Effluent						
Mortandad	0.3 (0.3)	47 (67)	1 (1)	0.005 (0.011)	0.024 0.011	−30 (70)

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[a] Samples were collected in October 1988; counting uncertainty is 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	N	TDS	Total Hard-ness	pH	Conduc-tivity (mS/m)
Los Alamos Reservoir	30	6	1.9	1.6	5	0	23	<0.2	5	3	0.1	0.3	68	21	7.4	7.2
Guaje Canyon	50	6	2.5	2.5	6	0	30	<0.2	6	2	0.2	<0.2	99	25	7.6	8.5
Frijoles Canyon	29	6	1.9	1.6	5	0	20	<0.2	5	3	0.1	0.8	75	22	7.1	7.2
La Mesita Spring	48	7	2.4	2.5	6	0	29	<0.2	6	2	0.2	<0.2	105	28	7.5	8.4
Sacred Spring	29	20	0.3	2.6	20	0	83	<0.2	7	3	0.6	<0.2	155	56	7.5	19
Indian Spring	42	12	2.1	2.2	20	0	85	<0.2	5	12	0.5	0.7	172	73	8.1	24
Maximum	50	20	2.5	2.6	20	0	85	<0.2	7	12	0.6	0.8	172	73	8.1	24

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[a] Samples were collected in March 1988.

Table G-20. Chemical Quality of Surface and Spring Waters from White Rock Canyon (mg/L)

Station	SiO_2	Ca	Mg	K	Na	CO_2	HCO_3	P	SO_4	Cl	F	N	TDS	Total Hard-ness	pH	Conduc-tivity (mS/m)
Group I																
Sandia Spring	44	33	3.2	2.6	15	0	116	<0.2	6	4	0.7	<0.2	177	100	8.2	27
Spring 3	49	20	1.6	2.7	15	0	82	<0.2	5	3	0.5	0.8	132	57	8.2	18
Spring 3A	50	20	1.8	3.6	14	0	80	<0.2	5	4	0.5	0.6	137	63	8.1	18
Spring 3AA	40	24	0.5	4.4	17	0	101	<0.2	6	5	0.6	<0.2	151	60	8.0	23
Spring 4	51	24	4.6	2.4	13	0	90	<0.2	11	7	0.6	1.4	159	80	8.2	22
Spring 4A	57	20	5.0	1.9	11	0	80	<0.2	8	6	0.6	1.3	165	71	8.2	19
Spring 5	64	19	5.0	2.2	12	0.7	82	<0.2	6	5	0.6	0.4	162	65	8.3	18
Spring 5AA	62	31	6.5	2.5	14	0	130	<0.2	7	7	0.6	<0.2	198	105	8.2	28
Ancho Spring	70	13	3.2	2.1	10	0	61	<0.2	3	3	0.5	0.3	140	42	8.2	13
Maximum	70	33	6.5	4.4	17	0.7	130	<0.2	11	7	0.7	1.4	198	105	8.3	28
Group II																
Spring 5A	52	24	2.9	2.6	21	2.0	106	<0.2	11	5	0.5	0.4	169	78	8.4	25
Spring 5B	42	23	5.7	2.1	14	0	75	<0.2	14	8	0.5	5.7	180	79	8.2	25
Spring 6	66	12	3.8	1.8	10	0	63	<0.2	3	3	0.4	0.5	140	43	8.2	13
Spring 6A	72	9	2.7	1.9	9	0	53	<0.2	2	2	0.3	0.4	127	35	8.2	12
Spring 7	64	20	4.5	2.3	17	1.7	96	<0.2	11	4	0.4	1.1	193	68	8.3	23
Spring 8A	61	11	3.2	2.0	11	0	62	<0.2	3	2	0.5	<0.2	149	42	8.2	13
Spring 9	71	10	3.2	1.4	10	0	62	<0.2	3	2	0.5	<0.2	132	41	8.2	13
Spring 9A	66	10	3.2	1.4	10	0	59	<0.2	2	2	0.6	<0.2	134	41	8.0	13
Doe Spring	73	12	3.7	1.4	12	0	66	<0.2	2	3	0.6	<0.2	139	46	8.1	14
Maximum	73	24	5.7	2.6	21	2.0	106	<0.2	14	8	0.6	5.7	193	79	8.4	25
Group III																
Spring 1	32	16	1.1	1.6	28	3.7	102	<0.2	6	3	0.7	0.9	123	49	8.4	22
Spring 2	39	24	1.3	1.6	60	2.1	183	<0.2	7	4	1.2	<0.2	230	75	8.4	37
Maximum	39	24	1.3	1.6	60	3.7	183	<0.2	7	4	1.2	0.9	230	75	8.4	37

Table G-20 (Cont)

Station	SiO_2	Ca	Mg	K	Na	CO_2	HCO_3	P	SO_4	Cl	F	N	TDS	Total Hard-ness	pH	Conduc-tivity (mS/m)
Group IV																
Spring 3B	40	32	4.2	3.0	139	6.6	359	<0.2	25	4	1.1	<0.2	469	96	8.4	72
Streams																
Pajarito	67	20	4.6	3.5	13	2.1	85	<0.2	7	5	0.5	0.6	173	66	8.4	19
Ancho	69	13	3.5	1.3	10	6.5	67	<0.2	2	2	0.4	<0.2	133	45	8.7	14
Frijoles	57	10	3.5	2.4	10	0	55	<0.2	3	3	<0.2	<0.2	110	38	8.2	12
Maximum	69	20	4.6	3.5	13	6.5	85	<0.2	7	5	0.5	0.6	173	66	8.7	19
Sanitary Effluent																
Mortandad	83	26	7.9	1.3	76	0	125	9.5	32	4	14	7.8	389	93	7.8	59

Table G-21. Trace Elements in Surface and Spring Waters from White Rock Canyon (µg/L)[a]

Station	As	B	Ba	Br	Co	Cr	Cu	Fe	I	Li	Mn	Mo	Rb	Sc	Sr	U	V
Group I																	
Sandia Spring	<10	<10	180	90	<1	<10	<1	<100	—	100	820	<1	<1	55	800	<1	<1
Spring 3	<10	<10	<1	90	<1	<10	<1	<100	<10	75	<1	<1	<1	60	480	<1	34
Spring 3A	<10	60	<1	90	<1	<10	<1	<100	<10	90	<1	<1	<1	120	500	<1	60
Spring 3AA	<10	50	<1	<10	<1	<10	<1	1200	<10	80	260	<1	<1	70	400	<1	50
Spring 4	<10	<10	150	180	10	<10	<1	2300	<10	90	1100	<1	<1	30	380	2	60
Spring 4A	<10	<10	<1	130	<1	<10	<1	<100	<10	80	<1	<1	<1	130	210	<1	20
Spring 5	<10	<10	<1	80	<1	<10	<1	<100	<10	80	40	<1	<1	140	220	<1	40
Spring 5AA	<10	50	130	130	<1	<10	<1	300	10	<10	530	<1	<1	130	400	<1	<1
Ancho Spring	<10	<10	<1	25	<1	<10	<1	<100	<10	70	170	<1	<1	140	130	<1	22
Maximum	<10	60	180	180	10	<10	<1	2300	10	100	1100	<1	<1	140	800	2	60
Group II																	
Spring 5A	<10	<10	<1	<10	<1	20	<1	<100	10	90	140	<1	<1	60	440	1	<1
Spring 5B	<10	<10	<1	130	<1	<10	<1	<100	<10	70	70	<1	<1	30	290	<1	20
Spring 6	<10	<10	<1	50	<1	<10	<1	<100	<10	70	<1	<1	<1	100	120	<1	<1
Spring 6A	<10	<10	<1	30	<1	<10	<1	<100	<10	60	15	<1	<1	100	100	<1	<1
Spring 7	<10	<10	<1	<10	<1	<10	<1	<100	10	70	15	<1	10	80	240	1	50
Spring 8A	<10	10	<1	10	<1	<10	<1	<100	<10	70	10	<1	<1	80	110	<1	<1
Spring 9	<10	<10	<1	20	<1	<10	<1	<100	<10	17	14	<1	<1	50	80	<1	<1
Spring 9A	<10	<10	<1	40	<1	<10	<1	<100	<10	20	12	<1	<1	40	80	<1	<1
Doe Spring	<10	<10	<1	<10	<1	<10	<1	<100	<10	72	110	<1	<1	11	114	<1	<1
Maximum	<10	10	<1	130	<1	20	<1	<100	10	90	140	<1	10	100	440	1	50
Group III																	
Spring 1	<10	<10	<1	40	<1	<10	10	<100	14	100	24	<1	<1	<1	400	1	24
Spring 2	60	100	15	70	10	10	<1	<100	16	150	950	<1	<1	<1	600	2	150
Maximum	60	100	15	70	10	10	10	<100	16	150	950	<1	<1	<1	600	2	150

Table G-21 (Cont)

Station	As	B	Ba	Br	Co	Cr	Cu	Fe	I	Li	Mn	Mo	Rb	Sc	Sr	U	V
Group IV																	
Spring 3B	24	170	<1	30	<1	<10	20	<100	32	300	240	8	<1	<1	930	13	74
Streams																	
Pajarito	<10	<10	<1	62	<1	<10	<1	<100	10	85	10	<1	<1	30	230	<1	<1
Ancho	<10	<10	<1	<10	<1	<10	<1	<100	<10	66	11	<1	<1	32	86	<1	<1
Frijoles	<10	<10	<1	<10	<1	<10	12	<100	<10	40	28	<1	8	<1	92	<1	<1
Maximum	<10	<10	<1	62	<1	<10	12	<100	<10	85	28	<1	8	32	23	<1	<1
Sanitary Effluent																	
Mortandad	<10	<10	<1	140	<1	<10	56	<100	<10	112	66	<1	26	88	218	<1	34

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[a] Samples were collected in October 1988.

NOTE: Analyses were performed on samples from 21 springs, 3 surface waters, and 1 sanitary effluent station, as listed above. The analyses also included the following elements, which were found to be below limits of detection at all stations (units are µg/L):

Ag	<1	Dy	<1	Hg	<1	Nb	<1	Pt	<1	Sn	<1	Tm	<1
Au	<1	Er	<1	Ho	<1	Nd	<1	Re	<1	Ta	<1	W	<1
Be	<10	Eu	<1	In	<1	Ni	<1	Rh	<1	Tb	<1	Y	<1
Bi	<1	Ga	<1	Ir	<1	Os	<1	Ru	<1	Te	<1	Yb	<1
Cd	<1	Gd	<1	La	<1	Pb	<1	Sb	<1	Th	<1	Zn	<1
Ce	<1	Ge	<1	Lu	<1	Pd	<1	Se	<10	Ti	<100	Zr	<1
Cs	<1	Hf	<1	Na	<10 000	Pr	<1	Sm	<1	Tl	<1		

Table G-22. Radiochemical Quality of Surface and Ground Waters from On-Site Stations

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*[a] *(Main Aquifer)						
Test well 1	−0.1 (0.3)	101 (56)	2 (1)	0.019 (0.013)	0.027 (0.013)	90 (90)
Test well 2	Well inactive					
Test well 3	−0.8 (0.3)	32 (60)	1 (1)	0.000 (0.010)	0.000 (0.010)	70 (90)
Test well DT-5A	−0.9 (0.3)	74 (74)	1 (1)	0.010 (0.007)	0.002 (0.006)	10 (90)
Test well 8	−0.4 (0.3)	−110 (52)	1 (1)	0.008 (0.009)	−0.004 (0.010)	−80 (90)
Test well DT-9	−1.6 (0.3)	−31 (66)	1 (1)	0.009 (0.006)	0.000 (0.010)	50 (90)
Test well DT-10	−1.3 (0.3)	−21 (66)	1 (1)	0.004 (0.007)	0.000 (0.010)	120 (90)
Maximum	−0.1 (0.3)	32 (60)	2 (1)	0.019 (0.013)	0.027 (0.013)	120 (90)
***Surface Water*[a]**						
Cañada del Buey	−0.6 (0.3)	−62 (54)	1 (1)	0.024 (0.014)	0.000 (0.010)	−80 (90)
Pajarito Canyon	−0.5 (0.3)	−86 (63)	2 (1)	0.000 (0.010)	0.006 (0.006)	150 (90)
Water Canyon at Beta Hole	−0.7 (0.3)	−103 (57)	1 (1)	−0.004 (0.004)	−0.006 (0.005)	−30 (90)
Maximum	−0.5 (0.3)	−62 (54)	2 (1)	0.024 (0.014)	0.006 (0.006)	150 (90)
Observation Wells*[b] *(Pajarito Canyon)						
PCO-1	−0.7 (0.3)	−95 (54)	1 (1)	0.016 (0.010)	0.016 (0.008)	−180 (90)
PCO-2	−0.5 (0.3)	−81 (60)	1 (1)	0.008 (0.008)	0.008 (0.006)	−190 (90)
PCO-3	−0.8 (0.3)	−30 (55)	1 (1)	0.020 (0.014)	0.000 (0.010)	−270 (100)
Maximum	−0.5 (0.3)	−30 (55)	1 (1)	0.020 (0.014)	0.016 (0.008)	−180 (90)
Limits of detection	0.7	40	1	0.009	0.03	50

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[a] Samples were collected in March 1988; counting uncertainty is in parentheses.
[b] Samples were collected in April 1988.

Table G-23. Chemical Quality of Surface and Ground Waters from On-Site Stations (mg/L)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	Be	Mo	Sn	Th	Tl	Total Hardness	Conductivity (mS/m)
Ground Water*[a] *(Main Aquifer)															
Test well 1	48	47	11	3.6	15	0	89	<0.2	<0.001	0.002	<0.001	<0.001	<0.001	164	39
Test well 2	Well inactive														
Test well 3	30	6	2.0	1.6	5	0	24	<0.2	<0.001	<0.001	<0.001	<0.001	<0.001	21	7
Test well DT-5A	70	8	2.5	1.6	12	0	45	<0.2	<0.001	0.002	0.002	<0.001	<0.001	30	10
Test well 8	<2	5	1.4	1.4	91	0	33	<0.2	<0.001	0.025	—	<0.001	<0.001	21	8.5
Test well DT-9	68	8	2.5	1.7	12	0	45	<0.2	<0.001	0.001	<0.001	<0.001	<0.001	30	11
Test well DT-10	69	8	2.5	1.6	12	0	45	<0.2	<0.001	0.001	<0.001	<0.001	<0.001	30	10
Maximum	70	47	11	3.6	91	0	89	<0.2	<0.001	0.025	0.002	<0.001	<0.001	164	39
***Surface Water*[a]**															
Cañada del Buey	32	12	3.4	2.4	28	0	30	<0.2	<0.001	0.003	<0.001	<0.001	<0.001	46	24
Pajarito Canyon	39	135	23	5.5	130	0	245	<0.2	<0.001	0.002	<0.001	<0.001	<0.001	413	140
Water Canyon at Beta Hole	32	8	3.1	2.6	15	0	43	<0.2	<0.001	0.001	<0.001	<0.001	<0.001	36	13
Maximum	39	135	23	5.5	130	0	245	<0.2	<0.001	0.003	<0.001	<0.001	<0.001	413	140
Observation Wells*[b] *(Pajarito Canyon)															
PCO-1	43	85	17	2.7	30	0	253	<0.2	0.001	0.008	—	<0.001	<0.001	322	71
PCO-2	43	84	18	2.6	29	0	249	<0.2	<0.001	0.006	—	<0.001	<0.001	317	72
PCO-3	43	85	18	2.6	30	0	256	<0.2	<0.001	0.008	—	<0.001	<0.001	324	72
Maximum	43	85	18	2.7	30	0	256	<0.2	0.001	0.008	—	<0.001	<0.001	324	72

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[a] Samples were collected in March 1988.
[b] Samplers were collected in April 1988.

Table G-24. Chemical Quality (EPA's Primary and Secondary Constituents) of Surface and Ground Waters from On-Site Stations (mg/L)

Station	Ag	As	Ba	Cd	Cr	F	N	Pb	Se
Ground Water*[a] *(Main Aquifer)									
Test well 1	<0.001	0.003	0.078	<0.001	0.002	0.6	6.0	<0.001	<0.001
Test well 2	Well inactive								
Test well 3	<0.001	<0.001	0.019	<0.001	0.001	0.1	<0.2	<0.001	<0.001
Test well DT-5A	<0.001	<0.001	0.024	<0.001	0.004	0.2	0.4	0.048	<0.001
Test well 8	<0.001	<0.001	0.006	<0.001	<0.001	0.2	<0.2	0.060	<0.001
Test well DT-9	<0.001	0.002	0.024	<0.001	0.003	0.2	0.3	0.017	<0.001
Test well DT-10	<0.001	<0.001	0.024	<0.001	0.003	0.2	0.2	0.039	0.001
Maximum	<0.001	0.003	0.078	<0.001	0.004	0.6	6.0	0.060	0.001
***Surface Water*[a]**									
Cañada del Buey	<0.001	0.002	0.065	<0.001	0.002	1.1	<0.2	0.001	0.001
Pajarito Canyon	<0.001	0.011	0.360	<0.001	0.002	0.4	<0.2	<0.001	0.003
Water Canyon at Beta Hole	<0.001	0.001	0.295	<0.001	0.001	0.3	<0.2	<0.001	0.003
Maximum	<0.001	0.011	0.360	<0.001	0.002	1.1	<0.2	0.001	0.003
Observation Wells*[b] *(Pajarito Canyon)									
PCO-1	<0.001	0.024	0.513	<0.001	0.012	0.7	<0.2	0.010	0.004
PCO-2	<0.001	0.022	0.435	<0.001	0.009	0.7	<0.2	0.008	<0.001
PCO-3	<0.001	0.018	0.310	<0.001	0.003	0.7	<0.2	0.006	<0.001
Maximum	<0.001	0.024	0.513	<0.001	0.012	0.7	<0.2	0.010	0.004

Table G-24 (Cont)

Station	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Ground Water [a] ***(Main Aquifer)***								
Test well 1	31	0.001	0.06	0.001	23	0.242	278	8.1
Test well 2	----------	----------	----------	Well inactive	----------	----------	----------	----------
Test well 3	3	0.001	0.08	0.006	5	0.001	79	7.5
Test well DT-5A	2	0.002	0.20	0.007	2	0.128	140	7.9
Test well 8	2	0.024	0.15	0.003	0.7	0.989	39	8.1
Test well DT-9	2	<0.001	0.11	0.003	2	0.105	132	8.0
Test well DT-10	2	<0.001	0.19	0.006	2	0.126	126	7.9
Maximum	31	0.024	0.20	0.007	23	0.989	278	8.1
Surface Water [a]								
Cañada del Buey	40	0.010	0.15	0.053	9	0.016	185	7.0
Pajarito Canyon	174	0.002	4.7	—	9	0.054	743	7.5
Water Canyon at Beta Hole	9	0.001	0.13	0.014	7	<0.001	106	7.8
Maximum	174	0.010	4.7	<0.053	9	0.054	743	7.8
Observation Wells [b] ***(Pajarito Canyon)***								
PCO-1	58	0.108	32	10.1	3	0.147	451	7.2
PCO-2	58	0.090	21	9.7	3	0.125	450	7.5
PCO-3	56	0.060	13	8.8	3	0.094	464	7.2
Maximum	58	0.108	32	10.1	3	0.147	464	7.5

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[a] Samples were collected in March 1988.
[b] Samples were collected in April 1988.

Table G-25. 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 Canyons						
Acid Weir	−0.7 (0.3)	−50 (52)	1 (1)	0.011 (0.012)	0.339 (0.038)	30 (90)
Pueblo 1	−0.7 (0.3)	−16 (60)	1 (1)	0.015 (0.012)	0.000 (0.010)	−250 (100)
Pueblo 2	−0.9 (0.3)	14 (46)	1 (1)	−0.004 (0.006)	0.039 (0.015)	−60 (90)
Pueblo 3	−1.0 (0.3)	11 (63)	1 (1)	0.000 (0.010)	0.011 (0.006)	−20 (90)
Hamilton Bend Spring				Dry		
Test well 1A	−0.5 (0.3)	50 (74)	1 (1)	0.007 (0.005)	0.011 (0.006)	−110 (90)
Test well 2A	0.2 (0.3)	−4 (53)	1 (1)	−0.004 (0.004)	0.012 (0.010)	−180 (90)
Basalt Spring	−0.9 (0.3)	14 (53)	1 (1)	−0.004 (0.004)	0.007 (0.005)	−260 (100)
Maximum	0.2 (0.3)	14 (53)	1 (1)	0.015 (0.012)	0.339 (0.038)	30 (90)
Los Alamos Canyon						
DPS-1	0.7 (0.3)	43 (60)	1 (1)	0.000 (0.005)	0.008 (0.005)	170 (90)
DPS-4	1.1 (0.4)	−60 (63)	1 (1)	0.000 (0.005)	0.002 (0.006)	−240 (100)
LAO-C	−0.7 (0.3)	63 (55)	1 (1)	0.002 (0.007)	0.000 (0.005)	−50 (90)
LAO-1	2.8 (0.5)	−78 (55)	1 (1)	−0.004 (0.005)	0.010 (0.007)	−90 (90)
LAO-2	0.5 (0.3)	92 (62)	2 (1)	0.002 (0.005)	0.002 (0.005)	−10 (90)
LAO-3	0.9 (0.3)	−10 (62)	2 (1)	0.002 (0.004)	−0.002 (0.005)	40 (90)
Maximum	1.1 (0.4)	92 (62)	2 (1)	0.002 (0.004)	0.010 (0.007)	170 (90)
Sandia Canyon						
SCS-1	−0.5 (0.3)	67 (71)	1 (1)	0.003 (0.009)	−0.007 (0.005)	−70 (90)
SCS-2	−0.7 (0.3)	−47 (56)	1 (1)	0.000 (0.010)	−0.004 (0.004)	0 (90)
SCS-3	−0.5 (0.3)	68 (61)	1 (1)	0.008 (0.011)	0.012 (0.010)	−50 (90)
Maximum	−0.5 (0.3)	68 (61)	1 (1)	0.008 (0.011)	0.012 (0.010)	0 (90)

Table G-25 (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	–0.1 (0.3)	–12 (61)	1 (1)	0.597 (0.070)	2.50 (0.164)	2400 (300)
MCO-3	0.1 (0.3)	59 (62)	1 (1)	1.38 (0.135)	5.70 (0.238)	3200 (300)
MCO-4	490 (50)	–79 (55)	6 (1)	0.140 (0.025)	0.373 (0.041)	1500 (200)
MCO-5	490 (50)	7 (61)	6 (1)	0.224 (0.032)	0.618 0.056)	1700 (200)
MCO-6	240 (20)	–52 (63)	3 (1)	0.041 (0.019)	0.138 (0.027)	250 (100)
MCO-7	450 (50)	–33 (59)	2 (1)	0.033 (0.013)	0.025 (0.010)	130 (90)
MCO-7.5	240 (20)	100 (63)	2 (1)	0.004 (0.007)	0.035 (0.012)	–60 (90)
MCO-8	—	—	—	—	—	—
Maximum	490 (50)	100 (63)	6 (1)	1.38 (0.135)	5.70 (0.238)	2400 (300)
Limits of detection	0.7	40	1	0.009	0.003	50

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[a] Samples were collected in April 1988; counting uncertainty is in parentheses.

Table G-26. 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	Be	Mo	Th	Tl	Total Hardness	Conductivity (mS/m)
Acid-Pueblo Canyons														
Acid Weir	14	34	4.8	5.7	125	0	34	<0.2	<0.001	0.002	<0.001	<0.001	112	95
Pueblo 1	21	27	5.0	4.4	69	0	45	0.8	<0.001	<0.001	<0.001	<0.001	96	55
Pueblo 2	38	22	4.2	8.1	85	0	65	4.6	<0.001	0.002	<0.001	<0.001	76	60
Pueblo 3	58	12	2.6	12	85	0	101	10	<0.001	0.003	<0.001	<0.001	47	48
Hamilton Bend Spring								Dry						
Test well 1A	14	18	4.4	5.8	58	0	93	0.7	<0.001	0.005	<0.001	<0.001	67	40
Test well 2A	2	25	5.1	3.6	19	0	58	<0.2	<0.001	0.004	<0.001	<0.001	92	30
Basalt Spring	37	25	6.4	2.9	15	0	74	<0.2	<0.001	0.002	<0.001	<0.001	96	27
Maximum	58	34	6.4	12	125	0	101	10	<0.001	0.005	<0.001	<0.001	112	95
DP-Los Alamos Canyons														
DPS-1	17	25	2.2	5.0	125	0	91	<0.2	0.005	0.003	<0.001	<0.001	76	75
DPS-4	21	29	3.3	14	130	0	92	<0.2	<0.001	0.009	<0.001	<0.001	93	85
LAO-C	31	12	2.9	2.4	27	0	30	<0.2	<0.001	0.001	<0.001	<0.001	46	26
LAO-1	39	15	3.9	2.8	41	0	46	<0.2	<0.001	0.002	<0.001	<0.001	56	32
LAO-2	35	11	3.3	3.2	25	0	39	<0.2	<0.001	0.008	<0.001	<0.001	46	23
LAO-3	36	31	7.2	15	84	0	75	<0.2	<0.001	0.009	<0.001	<0.001	112	68
Maximum	39	31	7.2	15	130	0	92	<0.2	0.005	0.009	<0.001	<0.001	112	85
Sandia Canyon														
SCS-1	43	13	3.1	5.4	90	0	67	0.7	<0.001	0.001	<0.001	<0.001	46	58
SCS-2	74	20	4.2	8.5	98	0	90	2.4	<0.001	0.004	<0.001	<0.001	70	61
SCS-3	75	20	4.2	8.5	98	0	94	2.4	<0.001	0.007	<0.001	<0.001	70	61
Maximum	75	20	4.2	8.5	98	0	94	2.4	<0.001	0.007	<0.001	<0.001	70	61

Table G-26 (Cont)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	Be	Mo	Th	Tl	Total Hard-ness	Conduc-tivity (mS/m)
Mortandad Canyon														
GS-1	48	21	2.6	12	32	0	82	<0.2	<0.001	0.003	<0.001	<0.001	69	33
MCO-3	48	22	2.4	12	34	0	86	<0.2	<0.001	0.003	<0.001	<0.001	72	34
MCO-4	26	40	6.8	33	213	0	157	<0.2	<0.001	0.006	<0.001	<0.001	136	150
MCO-5	24	43	7.5	35	217	0	156	<0.2	<0.001	0.006	<0.001	<0.001	117	147
MCO-6	48	6	1.4	2.7	240	0	86	<0.2	<0.001	0.006	<0.001	<0.001	24	48
MCO-7	30	21	5.5	2.7	236	0	145	<0.2	<0.001	0.020	<0.001	<0.001	80	135
MCO-7.5	30	21	4.5	4.6	236	0	146	<0.2	<0.001	0.015	<0.001	<0.001	78	140
MCO-8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maximum	48	43	7.5	35	240	0	157	<0.2	<0.001	0.020	<0.001	<0.001	136	150

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[a] Samples were collected in April 1988.

Table G-27. Chemical Quality (EPA's Primary and Secondary Constituents) of Surface and Ground Waters from Effluent Release Areas (mg/L)[a]

Station	Ag	As	Ba	Cd	Cr	F	N	Pb	Se
Acid-Pueblo Canyons									
Acid Weir	<0.001	0.012	0.083	<0.001	<0.001	0.6	0.8	0.002	0.001
Pueblo 1	<0.001	0.009	0.058	<0.001	<0.001	0.4	<0.2	<0.001	<0.001
Pueblo 2	<0.001	0.016	0.039	<0.001	<0.001	0.9	4.2	0.002	<0.001
Pueblo 3	<0.001	0.016	0.012	<0.001	<0.001	1.3	5.7	0.001	<0.001
Hamilton Bend Spring	Dry								
Test well 1A	<0.001	0.010	0.167	<0.001	<0.001	0.9	<0.2	0.098	<0.001
Test well 2A	<0.001	0.004	0.027	<0.001	<0.001	0.4	<0.2	0.109	<0.001
Basalt Spring	<0.001	0.004	0.079	<0.001	0.014	0.7	1.7	<0.001	0.001
Maximum	<0.001	0.016	0.167	<0.001	0.014	1.3	5.7	0.109	0.001
DP-Los Alamos Canyons									
DPS-1	<0.001	0.013	0.083	<0.001	0.001	1.4	<0.2	<0.001	0.001
DPS-4	<0.001	0.017	0.105	<0.001	0.001	2.7	1.0	0.001	<0.001
LAO-C	<0.001	0.004	0.043	<0.001	0.001	0.2	<0.2	0.001	<0.001
LAO-1	<0.001	0.011	0.052	<0.001	0.003	0.4	<0.2	0.001	<0.001
LAO-2	<0.001	0.014	0.158	<0.001	0.003	0.6	<0.2	0.005	<0.001
LAO-3	<0.001	0.015	0.169	<0.001	0.002	1.8	1.5	0.006	0.002
Maximum	<0.001	0.017	0.169	<0.001	0.003	2.7	1.5	0.006	0.002
Sandia Canyon									
SCS-1	<0.001	0.014	0.111	0.002	0.015	0.6	0.8	0.046	0.001
SCS-2	<0.001	0.011	0.041	0.001	0.001	1.2	5.2	0.006	<0.001
SCS-3	<0.001	0.010	0.040	0.001	0.001	1.2	5.1	0.005	<0.001
Maximum	<0.001	0.014	0.111	0.002	0.015	1.2	5.2	0.046	0.001
Mortandad Canyon									
GS-1	—	0.002	0.031	<0.001	0.016	1.0	7.4	0.001	<0.001
MCO-3	<0.001	0.003	0.031	<0.001	0.014	1.1	8.9	0.002	0.002
MCO-4	—	0.003	0.218	<0.001	0.002	2.9	123	0.002	0.001
MCO-5	—	0.004	0.219	<0.001	0.002	2.8	110	0.002	0.001
MCO-6	—	0.004	0.206	<0.001	0.001	2.0	19	0.006	<0.001
MCO-7	—	0.003	0.195	<0.001	0.002	2.8	111	0.004	0.001
MCO-7.5	—	0.004	0.288	<0.001	0.001	2.8	109	0.007	<0.001
Maximum	<0.001	0.004	0.288	<0.001	0.016	2.9	123	0.007	0.002

Table G-27 (Cont)

Station	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Acid-Pueblo Canyons								
Acid Weir	262	0.007	0.19	0.015	20	0.015	517	6.9
Pueblo 1	125	0.003	0.16	0.063	15	0.012	330	7.7
Pueblo 2	121	0.011	0.21	0.152	24	0.028	375	7.7
Pueblo 3	45	0.011	0.16	0.099	29	0.020	339	7.9
Hamilton Bend Spring				Dry				
Test well 1A	49	0.037	5.4	0.076	20	12.8	239	7.9
Test well 2A	37	0.005	0.49	0.060	20	5.13	166	8.1
Basalt Spring	16	0.002	0.13	0.015	18	0.004	188	8.2
Maximum	262	0.037	5.4	1.52	29	12.8	517	8.2
DP-Los Alamos Canyons								
DPS-1	147	0.002	<0.01	0.005	16	0.001	417	7.8
DPS-4	175	0.002	0.02	0.002	23	0.003	481	7.8
LAO-C	53	<0.001	0.10	0.010	8	0.002	179	7.6
LAO-1	66	0.001	0.05	0.004	10	0.003	224	8.0
LAO-2	37	0.011	0.39	0.141	9	0.007	173	8.0
LAO-3	131	0.016	0.87	0.165	20	0.009	412	7.3
Maximum	175	0.016	0.87	0.165	23	0.009	481	8.0
Sandia Canyon								
SCS-1	125	0.058	1.7	0.213	18	0.295	357	7.3
SCS-2	46	0.043	0.68	0.086	101	0.184	452	7.8
SCS-3	45	0.040	0.68	0.081	94	0.164	456	8.0
Maximum	125	0.058	1.7	0.213	101	0.295	456	8.0
Mortandad Canyon								
GS-1	14	0.008	0.45	0.099	11	0.004	222	7.7
MCO-3	17	0.010	0.46	0.104	12	0.009	247	7.7
MCO-4	38	0.010	0.23	0.018	50	0.014	1041	7.9
MCO-5	35	0.008	0.21	0.025	43	0.012	1086	7.6
MCO-6	30	0.014	1.1	0.145	20	0.025	338	6.8
MCO-7	36	0.004	0.27	0.116	41	0.025	968	7.5
MCO-7.5	36	0.007	0.61	0.308	41	0.026	938	7.3
Maximum	38	0.014	1.1	0.308	50	0.026	1086	7.9

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[a] Samples were collected in April 1988.

Table G-28. Radiochemical Quality of Water from Supply Wells and 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-2	—	—	—	—	—	3.0 (1.0)	3.9 (0.6)	100 (100)
Well LA-3	—	—	—	—	—	1.2 (0.8)	4.7 (0.6)	0 (100)
Guaje Field								
Well G-1	−1.1 (0.3)	33 (67)	1 (1)	0.009 (0.006)	0.004 (0.004)	1.9 (0.9)	3.5 (0.6)	−110 (70)
Well G-1A	−0.8 (0.3)	−41 (93)	1 (1)	0.000 (0.010)	0.005 (0.005)	0.6 (0.8)	3.3 (0.5)	−60 (70)
Well G-2	−1.1 (0.3)	65 (61)	1 (1)	0.008 (0.006)	0.004 (0.010)	1.6 (1.0)	2.5 (0.5)	−80 (70)
Well G-3	(Well inactive)							
Well G-4	−0.7 (0.3)	0 (71)	1 (1)	0.004 (0.004)	0.000 (0.010)	−0.1 (0.7)	3.2 (0.5)	−60 (70)
Well G-5	−1.0 (0.3)	−79 (60)	1 (1)	0.004 (0.004)	0.007 (0.005)	0.8 (0.7)	2.1 (0.4)	−60 (70)
Well G-6	−0.6 (0.3)	52 (72)	1 (1)	0.009 (0.013)	0.009 (0.009)	−0.3 (0.6)	1.5 (0.4)	−10 (70)
Pajarito Field								
Well PM-1	—	—	1 (1)	−0.005 (0.014)	0.024 (0.014)	11 (3.0)	7.8 (0.9)	—
Well PM-2	—	—	1 (1)	−0.007 (0.007)	0.000 (0.010)	1.0 (0.7)	2.5 (0.5)	—
Well PM-3	—	—	2 (1)	0.004 (0.010)	0.018 (0.014)	9.0 (2.0)	5.9 (0.8)	—
Well PM-4	(Well inactive)							
Well PM-5	—	—	1 (1)	0.006 (0.010)	0.006 (0.006)	2.7 (1.0)	4.4 (0.6)	—
Water supply maximum	−0.6 (0.3)	65 (61)	2 (1)	0.009 (0.013)	0.024 (0.014)	11 (3.0)	7.8 (0.9)	−10 (70)
Distribution System								
Fire Station 1	−1.1 (0.3)	−34 (59)	1 (1)	0.008 (0.011)	−0.015 (0.009)	4.0 (1.0)	6.0 (0.7)	−190 (90)
Fire Station 1	−1.3 (0.3)	30 (61)	1 (1)	0.019 (0.014)	0.000 (0.010)	7.0 (2.0)	4.5 (0.6)	−20 (70)
Fire Station 2	−1.1 (0.3)	113 (63)	1 (1)	0.032 (0.014)	0.016 (0.010)	1.7 (0.9)	6.1 (0.8)	40 (90)
Fire Station 2	−0.8 (0.3)	27 (58)	1 (1)	0.012 (0.010)	0.008 (0.006)	2.0 (0.8)	2.5 (0.5)	−120 (70)

Table G-28 (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 (Cont)								
Fire Station 3	−1.0 (0.3)	86 (67)	1 (1)	−0.004 (0.010)	−0.004 (0.012)	0.5 (0.6)	5.7 (0.7)	−180 (90)
Fire Station 3	−1.0 (0.3)	−10 (77)	1 (1)	0.008 (0.011)	0.008 (0.009)	0.7 (0.7)	2.5 (0.5)	−120 (70)
Fire Station 4	−1.6 (0.3)	135 (69)	1 (1)	0.000 (0.010)	0.008 (0.008)	0.8 (0.8)	6.8 (0.8)	1100 (100)
Fire Station 4	−0.7 (0.3)	−44 (60)	1 (1)	−0.004 (0.009)	0.008 (0.006)	0.6 (0.7)	2.5 (0.5)	−90 (70)
Fire Station 5	−0.8 (0.3)	36 (75)	1 (1)	0.008 (0.014)	0.008 (0.009)	0.2 (0.5)	5.3 (0.7)	30 (90)
Fire Station 5	−1.0 (0.3)	−43 (68)	1 (1)	0.000 (0.010)	0.004 (0.011)	1.6 (0.9)	2.5 (0.5)	—
Bandelier National Monument	—	—	1 (1)	−0.025 (0.025)	−0.025 (0.019)	1.3 (0.9)	5.2 (0.7)	—
Distribution system maximum	−0.8 (0.3)	135 (69)	1 (1)	0.032 (0.014)	0.016 (0.010)	7.0 (2.0)	6.8 (0.8)	30 (90)
Fenton Hill Supply								
TA-57	—	5 (62)	2 (1)	0.007 (0.010)	0.014 (0.009)	0.0 (0.9)	6.2 (0.8)	−190 (90)
Standby Well								
Well LA-6	—	—	—	—	—	1.4 (0.9)	5.1 (0.7)	100 (100)

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[a] Counting uncertainty is in parentheses.

Table G-29. Chemical Quality (EPA's Primary and Secondary Constituents) of Water from Supply Wells and Distribution System (mg/L)

Station	Ag	As	Ba	Cd	Cr	F	Hg	N	Pb	Se
Supply Wells										
Guaje Field										
Well G-1	<0.001	0.001	0.073	<0.001	0.004	0.4	<0.0002	0.6	0.001	0.001
Well G-1A	<0.001	0.002	0.070	<0.001	0.004	0.4	—	0.6	<0.001	0.001
Well G-2	<0.001	0.034	0.077	<0.001	0.006	0.5	<0.0002	0.5	0.002	<0.001
Well G-3					Well inactive					
Well G-4	<0.001	0.004	0.017	<0.001	0.005	0.8	<0.0002	0.4	<0.001	0.001
Well G-5	<0.001	0.004	0.016	<0.001	0.005	0.3	<0.0002	0.6	<0.001	0.001
Well G-6	<0.001	0.002	0.017	<0.001	0.003	0.5	<0.0002	0.5	<0.001	0.001
Pajarito Field										
Well PM-1	<0.001	<0.001	0.056	<0.001	0.004	0.4	<0.0002	0.5	0.007	<0.001
Well PM-2	<0.001	<0.001	0.028	<0.001	0.002	<0.2	<0.0002	0.3	0.002	<0.001
Well PM-3	<0.001	<0.001	0.086	<0.001	0.003	0.4	<0.0002	0.5	0.006	<0.001
Well PM-4					Well inactive					
Well PM-5	<0.001	0.002	0.034	<0.001	0.001	0.3	<0.0002	0.3	<0.001	0.001
Water supply maximum	<0.001	0.034	0.086	<0.001	0.006	0.8	<0.0002	0.6	0.007	0.001
Distribution System										
Fire Station 1	<0.001	<0.001	0.019	<0.001	<0.001	<0.2	<0.0002	0.5	0.002	<0.001
Fire Station 1	<0.001	<0.001	0.025	<0.001	0.005	<0.2	<0.0002	0.4	0.002	0.001
Fire Station 2	0.002	0.001	0.052	<0.001	0.003	0.4	<0.0002	0.5	0.002	<0.001
Fire Station 2	<0.001	0.010	0.037	<0.001	0.006	0.5	<0.0002	0.5	0.002	0.001
Fire Station 3	0.002	0.002	0.058	<0.001	0.003	0.4	<0.0002	0.5	0.002	<0.001
Fire Station 3	<0.001	<0.001	0.030	<0.001	0.004	0.6	<0.0002	0.4	<0.001	0.001
Fire Station 4	0.001	0.001	0.055	<0.001	0.003	0.4	<0.0002	0.5	0.002	<0.001
Fire Station 4	<0.001	0.011	0.038	<0.001	0.006	0.5	<0.0002	0.5	0.001	0.001
Fire Station 5	0.002	0.002	0.019	<0.001	<0.001	0.2	<0.0002	0.3	0.001	<0.001
Fire Station 5	<0.001	<0.001	0.025	<0.001	0.003	<0.2	<0.0002	0.4	0.002	0.001
Bandelier National Monument	<0.001	<0.001	0.024	<0.001	0.003	0.3	<0.0002	0.4	0.001	<0.001
Distribution system maximum	0.002	0.011	0.058	<0.001	0.006	0.6	<0.0002	0.5	0.002	0.001
Fenton Hill Supply										
TA-57	0.002	0.002	0.105	<0.001	0.001	<0.2	—	<0.2	0.002	<0.001
USEPA and NMEID primary maximum concentration levels	0.05	0.05	1.0	0.01	0.05	2.0	0.002	10	0.05	0.01

Table G-29 (Cont)

Station	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Supply Wells								
Guaje Field								
Well G-1	3	0.013	0.026	<0.001	4	0.009	149	8.2
Well G-1A	3	0.006	0.009	<0.001	4	0.010	147	8.2
Well G-2	2	<0.001	0.008	<0.001	4	0.011	163	8.3
Well G-3	---------- Well inactive ----------							
Well G-4	3	0.002	0.003	<0.001	4	0.018	192	8.4
Well G-5	3	0.002	0.009	<0.001	4	0.010	151	8.2
Well G-6	3	0.002	0.002	<0.001	5	0.008	163	8.3
Pajarito Field								
Well PM-1	7	0.003	0.042	<0.001	6	0.081	230	8.0
Well PM-2	2	0.002	0.008	0.002	2	0.008	129	7.9
Well PM-3	7	0.104	0.036	<0.001	6	0.063	202	8.0
Well PM-4	---------- Well inactive ----------							
Well PM-5	2	0.005	<0.001	<0.001	3	0.004	164	7.8
Water supply maximum	7	0.104	0.042	0.002	6	0.081	230	8.4
Distribution System								
Fire Station 1	2	<0.001	0.350	0.001	2	0.032	92	6.7
Fire Station 1	2	0.001	0.023	<0.001	2	0.093	136	7.9
Fire Station 2	8	0.024	<0.001	<0.001	6	0.001	223	7.8
Fire Station 2	3	0.003	0.056	0.001	4	0.009	168	8.2
Fire Station 3	8	0.030	0.032	<0.001	6	0.002	222	7.8
Fire Station 3	4	0.008	0.018	<0.001	3	0.013	176	7.9
Fire Station 4	8	0.033	<0.004	<0.001	6	0.003	211	7.7
Fire Station 4	3	<0.001	0.031	<0.001	4	0.013	169	8.2
Fire Station 5	2	<0.001	0.300	<0.001	2	0.038	121	7.7
Fire Station 5	2	<0.001	0.040	<0.001	2	0.230	141	7.6
Bandelier National Monument	2	0.023	0.230	<0.001	2	0.075	129	8.0
Distribution system maximum	8	0.033	0.350	0.001	6	0.230	223	8.2
Fenton Hill Supply								
TA-57	30	<0.001	0.02	<0.001	9	0.121	279	8.0
USEPA and NMEID secondary maximum concentration levels	250	1.0	0.3	0.05	250	5.0	500	6.5–8.5

Table G-30. Chemical Quality of Water from Supply Wells and Distribution System (mg/L)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	P	Total Hardness	Conductivity (mS/m)
Supply Wells										
Guaje Field										
Well G-1	50	12	0.2	2.2	15	0	77	<0.2	55	16
Well G-1A	50	12	0.3	2.3	14	0	76	<0.2	58	16
Well G-2	72	10	0.3	1.9	21	0	73	<0.2	34	16
Well G-3	Well inactive									
Well G-4	64	16	3.2	1.4	14	0	94	<0.2	31	19
Well G-5	47	17	3.3	1.3	15	0	76	<0.2	55	16
Well G-6	73	17	3.3	1.3	15	0	73	<0.2	34	16
Pajarito Field										
Well PM-1	73	24	7.9	3.0	20	0	114	<0.2	92	25
Well PM-2	68	9	2.6	1.3	10	0	53	<0.2	34	11
Well PM-3	68	25	6.2	3.1	19	0	117	<0.2	91	26
Well PM-4	Well inactive									
Well PM-5	76	11	3.7	1.5	13	0	66	<0.2	43	14
Water supply maximum	76	25	7.9	3.1	21	0	117	<0.2	92	26
Distribution System										
Fire Station 1	45	7	3.1	1.4	7	0	35	<0.2	29	8.8
Fire Station 1	74	10	2.6	1.0	9	0	55	<0.2	36	11
Fire Station 2	82	21	8.1	3.1	18	0	102	<0.2	95	26
Fire Station 2	61	12	1.4	1.3	19	0	82	<0.2	41	17
Fire Station 3	85	21	8.0	3.1	18	0	102	<0.2	95	26
Fire Station 3	75	12	2.9	1.1	9	0	72	<0.2	52	16
Fire Station 4	84	21	7.9	3.1	19	0	101	<0.2	94	26
Fire Station 4	58	12	1.4	1.4	18	0	81	<0.2	38	17
Fire Station 5	63	8	3.2	1.6	10	0	47	<0.2	35	11
Fire Station 5	69	9	2.8	0.7	7	0	53	<0.2	35	11
Bandelier National Monument	62	11	2.7	1.2	10	0	56	<0.2	40	12
Distribution system maximum	85	21	8.1	3.1	19	0	102	<0.2	95	26
Fenton Hill Supply										
TA-57	66	8	3.2	4.6	—	0	113	<0.2	150	37

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′	105°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			
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 Canyons			
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	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			
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	S115
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.

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	−0.2 (0.3)	0.16 (0.08)	1.3 (0.2)	0.000 (0.001)	0.002 (0.001)	0.5 (0.5)
Embudo	−0.2 (0.3)	0.11 (0.11)	2.2 (0.2)	0.014 (0.003)	0.011 (0.003)	2.5 (0.3)
Otowi	−0.8 (0.3)	0.26 (0.09)	3.1 (0.3)	0.000 (0.001)	0.004 (0.003)	5.4 (0.7)
Near Santa Cruz Lake	−0.5 (0.3)	1.4 (0.26)	3.5 (0.4)	0.005 (0.003)	0.019 (0.004)	5.5 (0.7)
Cochiti	−0.4 (0.3)	0.34 (0.10)	2.7 (0.3)	0.002 (0.001)	0.010 (0.002)	4.4 (0.6)
Bernalillo	−0.1 (0.3)	0.38 (0.13)	1.4 (0.2)	0.002 (0.001)	0.008 (0.002)	1.8 (0.5)
Jemez	−3.0 (2.0)	0.62 (0.13)	1.8 (0.2)	0.000 (0.001)	0.012 (0.003)	1.5 (0.5)
Maximum	−0.5 (0.3)	1.4 (0.26)	3.5 (0.4)	0.014 (0.003)	0.019 (0.004)	5.5 (0.7)
$\overline{X}(s)$	−0.4 (0.2)	0.47 (0.44)	2.3 (0.8)	0.003 (0.005)	0.009 (0.006)	3.1 (2.0)
Sediments						
Rio Chama						
Chamita	—	0.11 (0.08)	1.1 (0.2)	0.002 (0.002)	0.002 (0.001)	−1.1 (0.5)
Rio Grande						
Embudo	—	0.10 (0.09)	1.0 (0.2)	0.004 (0.002)	0.002 (0.001)	−0.8 (0.5)
Otowi	—	0.09 (0.07)	1.1 (0.2)	0.001 (0.001)	0.003 (0.001)	−0.4 (0.5)
Sandia	—	—	—	0.002 (0.001)	0.003 (0.001)	1.1 (0.4)
Ancho	—	—	—	−0.004 (0.001)	0.004 (0.001)	1.5 (0.4)
Bernalillo	—	0.10 (0.09)	2.6 (0.3)	0.008 (0.002)	0.003 (0.002)	1.7 (0.5)
Jemez River						
Near Jemez	—	0.17 (0.09)	4.4 (0.4)	0.001 (0.001)	0.004 (0.001)	6.1 (0.5)
Maximum	—	0.17 (0.09)	4.4 (0.4)	0.008 (0.002)	0.004 (0.001)	6.1 (0.5)
$\overline{X} + 2s$						

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[a] Samples were collected in April 1988; counting uncertainty is 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						
Sportmen's Club	−1.1 (0.3)	1.3 (0.24)	3.2 (0.3)	0.001 (0.001)	0.022 (0.004)	6.0 (0.8)
North Mesa	0.9 (0.3)	0.61 (0.08)	3.9 (0.4)	0.003 (0.001)	0.002 (0.001)	5.1 (0.7)
TA-8	−0.7 (0.3)	1.2 (0.22)	3.3 (0.3)	0.001 (0.001)	0.026 (0.004)	3.6 (0.6)
TA-49	0.0 (0.3)	0.36 (0.12)	5.3 (0.5)	0.001 (0.001)	0.018 (0.003)	6.6 (0.8)
White Rock	0.0 (0.3)	0.13 (0.12)	4.1 (0.4)	0.001 (0.001)	0.004 (0.001)	6.8 (0.8)
Tsankawi	−0.2 (0.3)	0.08 (0.09)	5.9 (0.6)	−0.001 (0.001)	0.001 (0.001)	10 (1.0)
Maximum	0.9 (0.3)	1.3 (0.24)	5.9 (0.6)	0.003 (0.001)	0.026 (0.004)	10 (1.0)
Perimeter Sediments						
Guaje at SR-4	—	0.05 (0.09)	4.5 (0.5)	0.002 (0.001)	0.003 (0.002)	6.4 (0.8)
Bayo at SR-4	—	−0.06 (0.07)	2.5 (0.3)	0.001 (0.001)	0.002 (0.001)	2.2 (0.5)
Sandia at SR-4	—	0.08 (0.09)	2.9 (0.3)	0.000 (0.001)	0.002 (0.001)	2.7 (0.5)
Mortandad at SR-4	—	0.21 (0.09)	2.9 (0.3)	0.001 (0.001)	0.004 (0.001)	4.5 (0.7)
Cañada del Buey at SR-4	—	0.11 (0.11)	1.7 (0.2)	0.001 (0.001)	0.003 (0.001)	1.5 (0.5)
Pajarito at SR-4	—	0.10 (0.08)	2.3 (0.2)	0.001 (0.001)	0.009 (0.002)	2.3 (0.5)
Potrillo at SR-4	—	−0.02 (0.10)	2.4 (0.2)	0.000 (0.001)	0.003 (0.002)	4.4 (0.6)
Water at SR-4	—	0.27 (0.10)	3.5 (0.4)	0.001 (0.001)	0.007 (0.002)	4.4 (0.7)
Ancho at SR-4	—	−0.05 (0.09)	1.8 (0.2)	0.000 (0.000)	0.002 (0.001)	2.0 (0.5)
Frijoles at Bandelier	—	−0.02 (0.08)	1.8 (0.2)	0.000 (0.001)	0.003 (0.002)	1.4 (0.5)
Sandia at Rio Grande	—	0.27 (0.10)	2.2 (0.2)	0.003 (0.002)	0.004 (0.001)	2.5 (0.4)
Mortandad at Rio Grande	—	−0.02 (0.10)	1.7 (0.2)	0.001 (0.001)	0.001 (0.001)	1.2 (0.4)
Pajarito at Rio Grande	—	0.12 (0.10)	1.8 (0.2)	0.000 (0.001)	0.003 (0.001)	0.5 (0.4)
Water at Rio Grande	—	0.18 (0.11)	1.7 (0.2)	0.000 (0.000)	0.002 (0.011)	2.1 (0.4)
Ancho at Rio Grande	—	0.09 (0.08)	2.4 (0.2)	−0.001 (0.000)	0.001 (0.001)	1.1 (0.4)
Chaquihui at Rio Grande	—	0.49 (0.13)	5.0 (0.5)	−0.001 (0.000)	0.010 (0.002)	4.5 (0.6)
Frijoles at Rio Grande	—	0.10 (0.09)	1.9 (0.2)	−0.002 (0.001)	0.002 (0.001)	2.0 (0.4)
Maximum	—	0.49 (0.13)	5.0 (0.5)	0.003 (0.002)	0.010 (0.002)	6.4 (0.8)

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[a] Samples were collected in April and October 1988; counting uncertainty is 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)	Gross Gamma (Counts/min/g)
On-Site Soils							
TA-21	1.1 (0.4)	—	0.00 (0.09)	3.7 (0.4)	0.164 (0.010)	0.103 (0.008)	4.9 (0.7)
East of TA-53	1.0 (0.4)	—	0.12 (0.08)	4.0 (0.4)	0.002 (0.001)	0.009 (0.002)	6.4 (0.8)
TA-50	2.0 (0.4)	—	0.17 (0.12)	4.6 (0.5)	0.002 (0.001)	0.024 (0.004)	5.8 (0.7)
Two-Mile Mesa	−0.2 (0.3)	—	0.98 (0.18)	4.0 (0.4)	0.002 (0.001)	0.033 (0.004)	6.4 (0.8)
East of TA-54	−0.2 (0.3)	—	0.29 (0.11)	4.8 (0.5)	0.001 (0.002)	0.012 (0.003)	6.7 (0.8)
R-Site Road	0.3 (0.3)	—	0.35 (0.11)	3.8 (0.4)	0.001 (0.001)	0.018 (0.002)	4.6 (0.7)
Potrillo Drive	−0.4 (0.3)	—	0.18 (0.09)	3.4 (0.4)	0.000 (0.001)	0.005 (0.002)	4.1 (0.6)
S-Site	−0.2 (0.3)	—	0.31 (0.10)	3.5 (0.4)	0.004 (0.002)	0.013 (0.002)	4.5 (0.6)
Near Test Well DT-9	−0.3 (0.3)	—	1.4 (0.25)	6.2 (0.6)	0.008 (0.002)	0.048 (0.005)	5.6 (0.7)
Near TA-33	7.8 (0.9)	—	0.35 (0.11)	3.5 (0.4)	0.003 (0.002)	0.008 (0.002)	5.4 (0.7)
Maximum	7.8 (0.9)	—	1.4 (0.25)	6.2 (0.4)	0.164 (0.010)	0.103 (0.008)	6.7 (0.8)
Sediments from Effluent Release Areas							
Acid-Pueblo Canyons							
Acid Weir	—	—	0.35 (0.11)	2.2 (0.2)	0.052 (0.014)	12.4 (0.471)	1.7 (0.5)
Pueblo 1	—	—	0.14 (0.07)	1.5 (0.2)	0.001 (0.001)	0.002 (0.001)	1.1 (0.5)
Pueblo 2	—	0.28 (0.05)	0.06 (0.11)	3.8 (0.4)	0.004 (0.001)	0.904 (0.039)	4.5 (0.7)
Hamilton Bend Spring	—	—	0.23 (0.08)	2.9 (0.3)	0.004 (0.002)	0.459 (0.029)	3.5 (0.6)
Pueblo 3	—	—	0.09 (0.10)	2.5 (0.3)	0.000 (0.001)	0.004 (0.002)	3.1 (0.6)
Pueblo at SR-4	—	0.10 (0.05)	0.05 (0.08)	1.6 (0.2)	0.002 (0.001)	0.419 (0.018)	1.0 (0.5)
Maximum	—	0.28 (0.05)	0.35 (0.11)	3.8 (0.4)	0.052 (0.014)	12.4 (0.471)	4.5 (0.7)
DP-Los Alamos Canyons							
DP Canyon at DPS-1	—	0.55 (0.05)	0.14 (0.08)	1.1 (0.2)	0.004 (0.009)	0.025 (0.011)	0.4 (0.4)
DP Canyon at DPS-4	—	1.5 (0.10)	5.9 (0.90)	2.4 (0.2)	0.074 (0.006)	0.290 (0.015)	7.4 (0.9)
Los Alamos Canyon at Bridge	—	−0.02 (0.08)	0.23 (0.09)	2.7 (0.3)	0.001 (0.002)	0.000 (0.001)	2.6 (0.5)
Los Alamos Canyon at LAO-1	—	0.09 (0.05)	0.30 (0.11)	3.6 (0.4)	0.001 (0.002)	0.361 (0.020)	5.6 (0.7)
Los Alamos Canyon at GS-1	—	0.97 (0.06)	4.3 (0.66)	5.7 (0.6)	0.112 (0.009)	0.669 (0.032)	11 (1.0)
Los Alamos Canyon at LAO-3	—	1.0 (0.10)	5.2 (0.80)	12 (1.2)	0.069 (0.006)	0.257 (0.014)	6.1 (0.8)

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)	Gross Gamma (Counts/min/g)
DP-Los Alamos Canyons (Cont)							
Los Alamos Canyon at LAO-4.5	—	0.39 (0.09)	5.1 (0.78)	4.4 (0.4)	0.098 (0.006)	0.367 (0.017)	9.0 (1.0)
Los Alamos Canyon at SR-4	—	0.68 (0.05)	3.7 (0.58)	5.0 (0.5)	0.077 (0.007)	0.659 (0.032)	9.0 (1.0)
Los Alamos Canyon at Totavi	—	0.52 (0.09)	0.97 (0.18)	4.2 (0.4)	0.027 (0.005)	0.604 (0.036)	6.9 (0.8)
Los Alamos Canyon at LA-2	—	0.12 (0.07)	0.77 (0.16)	2.4 (0.2)	0.025 (0.004)	0.341 (0.020)	2.4 (0.5)
Los Alamos Canyon at Otowi	—	0.48 (0.09)	1.1 (0.20)	3.2 (0.3)	0.040 (0.005)	0.528 (0.027)	4.9 (0.7)
Maximum	—	1.0 (0.10)	5.9 (0.90)	12 (1.2)	0.112 (0.009)	0.669 (0.032)	11 (1.0)
Mortandad Canyon							
Mortandad at CMR	—	0.20 (0.08)	−0.07 (0.09)	1.6 (0.2)	0.004 (0.002)	0.005 (0.002)	0.8 (0.5)
Mortandad west of GS-1	—	0.30 (0.08)	0.04 (0.09)	2.0 (0.2)	0.007 (0.012)	0.080 (0.018)	3.3 (0.6)
Mortandad at GS-1	—	0.51 (0.09)	30 (4.6)	2.5 (0.3)	8.78 (0.680)	33.5 (1.30)	980 (100)
Mortandad at MCO-5	—	3.1 (0.10)	43 (6.5)	1.9 (0.2)	6.08 (0.266)	19.9 (0.890)	56 (6.0)
Mortandad at MCO-7	—	—	14 ts				
(2.2)	2.2 (0.2)	1.86 (0.075)	7.35 (0.285)	24 (3.0)			
Mortandad at MCO-9	—	—	0.32 (0.12)	4.8 (0.5)	0.004 (0.002)	0.013 (0.003)	9.0 (1.0)
Mortandad at MCO-13	—	—	0.77 (0.16)	2.6 (0.3)	0.004 (0.002)	0.024 (0.004)	5.7 (0.7)
Maximum	—	3.1 (0.10)	43 (6.5)	4.8 (0.5)	8.78 (0.680)	33.5 (1.30)	980. (100)

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[a] Samples were collected in March and April; counting uncertainty is in parentheses.

Table G-35. Radiochemical Analyses of Sediments from an Active Waste Management Area (TA-54)

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	0.6 (0.3)	0.19 (0.09)	2.1 (0.2)	0.003 (0.011)	0.006 (0.002)	6.6 (0.9)
2	0.6 (0.3)	0.47 (0.13)	2.7 (0.3)	0.000 (0.001)	0.017 (0.003)	6.6 (0.9)
3	0.2 (0.3)	0.36 (0.12)	1.6 (0.2)	0.003 (0.001)	0.003 (0.001)	4.9 (0.8)
4	0.5 (0.3)	0.24 (0.11)	2.5 (0.3)	0.015 (0.003)	0.163 (0.010)	4.3 (0.7)
5	0.4 (0.3)	0.18 (0.09)	3.1 (0.3)	0.013 (0.002)	0.120 (0.008)	5.8 (0.8)
6	0.1 (0.3)	0.08 (0.09)	1.4 (0.2)	0.001 (0.001)	0.011 (0.002)	2.8 (0.6)
7	0.4 (0.3)	0.74 (0.15)	3.7 (0.4)	0.343 (0.018)	0.493 (0.024)	4.6 (0.7)
8	0.0 (0.3)	0.23 (0.10)	3.4 (0.4)	0.017 (0.003)	0.015 (0.003)	6.4 (0.9)
9	0.3 (0.3)	0.24 (0.10)	3.9 (0.4)	0.416 (0.005)	0.026 (0.004)	8.0 (1.0)
Maximum concentration	0.6 (0.3)	0.74 (0.15)	3.9 (0.4)	0.416 (0.005)	0.493 (0.024)	8.0 (1.0)
Background (1974–1986)	7.2	0.44	4.4	0.006	0.023	7.9
Maximum concentration as a percentage of background	8	168	88	5720	2140	111
Analytical limits of detection	0.7	0.1	0.3	0.003	0.002	0.1

Table G-36. Radionuclides in Local and Regional Produce[a]

	^{3}H (pCi/mL)	^{137}Cs (10^{-3} pCi/dry g)	Uranium (ng/dry g)	^{238}Pu (10^{-5} pCi/dry g)	^{239,240}Pu (10^{-5} pCi/dry g)
Cochiti/Santo Domingo					
N	7	7	6	7	7
Mean	−0.4	51	1.9	3.0	3.9
Std dev	0.6	56	1.9	2.8	7.8
Minimum	−1.4 (0.4)	−23 (110)	0.04 (0.01)	0.0 (14)	−5.5 (9.2)
Maximum	0.2 (0.4)	150 (96)	5.0 (0.5)	8.3 (12)	17 (12)
Española					
N	8	8	5	8	8
Mean	0.0	46	1.9	2.8	2.5
Std dev	0.4	76	1.5	16	4.9
Minimum	−0.7 (0.4)	−30 (120)	0.6 (0.06)	−24 (17)	−4.6 (11)
Maximum	0.6 (0.4)	220 (165)	4.2 (0.4)	35 (16)	11 (11)
San Ildefonso					
N	2	2	1	2	2
Mean	0.2	13	4.9	0.4	0.0
Std dev	0.4	25	—	0.6	0.0
Minimum	0.6 (0.4)	−5 (120)	—	0.0 (6.7)	—
Maximum	0.5 (0.5)	31 (29)	—	0.9 (3.3)	—
Los Alamos/White Rock					
N	20	20	18	19	19
Mean	0.6	57	2.2	17	28
Std dev	0.8	63	1.6	35	33
Minimum	−0.1 (0.4)	−30 (52)	0.02 (0.02)	−61 (86)	−11 (11)
Maximum	3.7 (0.5)	210 (76)	5.3 (0.5)	90 (31)	98 (40)
On-Site					
N	6	6	6	6	6
Mean	5.2	14	3.6	26	1.4
Std dev	6.5	75	3.5	52	22
Minimum	0.3 (0.4)	−82 (47)	1.1 (0.1)	−1.2 (1.2)	−40 (28)
Maximum	18 (2.0)	100 (50)	10 (1.0)	130 (63)	25 (18)
Minimum detectable limit	0.7	100		20	10

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[a] Counting uncertainties are in parentheses.

Table G-37. Radionuclides in Fish[a]

	^{137}Cs (10^{-3} pCi/dry g)	Uranium (ng/dry g)	^{238}Pu (10^{-5} pCi/dry g)	^{239}Pu (10^{-5} pCi/dry g)
Catfish				
Abiquiu				
N	10	10	10	10
Mean	54	2.9	3	3
Std dev	150	2.3	4	4
Minimum	–67 (85)	0.3 (0.03)	0 (8)	–6 (6)
Maximum	450 (140)	6.4 (0.6)	12 (8)	10 (7)
Cochiti				
N	10	10	10	10
Mean	77	8.2	7	4
Std dev	51	2.9	9	7
Minimum	22 (82)	3.5 (0.4)	0 (6)	–4 (10)
Maximum	170 (120)	12 (1.2)	23 (11)	23 (10)
Crappie				
Abiquiu				
N	10	10	10	10
Mean	71	1.4	3	8
Std dev	96	0.38	7	5
Minimum	–180 (100)	0.66 (0.06)	–9 (10)	0 (10)
Maximum	150 (120)	2.0 (0.2)	14 (16)	14 (14)
Cochiti				
N	10	10	10	10
Mean	120	2.5	2	4
Std dev	50	1.0	7	4
Minimum	57 (92)	0.78 (0.08)	–7 (8)	0 (10)
Maximum	200 (86)	4.0 (0.4)	18 (10)	13 (7)
Minimum detectable limit	10	3	30	20

NOTE: Counting uncertainties are in parentheses.

Table G-38. Locations of Beehives

Stations	North-South Coordinate	East-West Coordinate
Regional Stations (28–44 km)—Uncontrolled Areas		
1. Chimayo	—	—
13. San Pedro	—	—
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-39. Selected Radionuclides in Local and Regional Honey[a]

	^{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)
Chimayo	5 000	860	−78	41	220	−34	120
		(910)[b]	(79)	(61)	(96)	(140)	(78)
San Pedro	6 000	2000	−48	3.1	150	140	−7.0
		(1200)	(77)	(62)	(95)	(140)	(74)
San Juan	400	−1200	19	170	200	75	93
		(1100)	(69)	(78)	(93)	(140)	(76)
Pajarito Acres	20 000	−200	−59	8.4	100	27	21
		(890)	(84)	(69)	(70)	(150)	(72)
Lower Mortandad	7 700	1100	−6.3	93	50	−110	120
		(980)	(71)	(72)	(120)	(140)	(79)
TA-8	5 900	520	19	100	110	13	57
		(870)	(49)	(59)	(72)	(110)	(62)
TA-9	1 000	400	−80	15	−48	−72	−5.6
		(910)	(86)	(60)	(80)	(140)	(86)
TA-15	500	610	−43	330	230	130	140
		(1100)	(109)	(110)	(120)	(150)	(102)
TA-16	0	1500	−40	13	200	−110	−20
		(1500)	(83)	(80)	(120)	(180)	(100)
TA-21	14 000	900	52	−6.3	170	240	22
		(630)	(53)	(36)	(54)	(99)	(44)
TA-33	14 000	1300	−16	160	280	77	−25
		(800)	(56)	(61)	(82)	(109)	(60)
TA-49	2 200	510	−51	5.8	190	170	−70
		(910)	(88)	(71)	(84)	(140)	(75)
TA-50	11 000	1500	32	88	80	88	−1.4
		(820)	(58)	(54)	(60)	(120)	(47)
TA-53	65 000	880	86	84	310	−87	61
		(970)	(73)	(72)	(100)	(140)	(65)
TA-54	92 000	1400	37	37	120	36	160
		(720)	(64)	(53)	(62)	(86)	(68)

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[a] Density of honey was about 1860 g/L; data are from 1987.

[b] Counting uncertainty is in parentheses.

Table G-40. Selected Radionuclides in Local and Regional Bees[a]

	^{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)
Chimayo	4 000	−0.093	−0.042	0.028	−0.13	−0.12	−0.21	17
	(600)[b]	(0.094)	(0.15)	(0.099)	(0.17)	(0.096)	(0.19)	(2)
San Pedro	1 100	0.15	−0.042	0.19	0.15	−0.032	0.21	23
	(400)	(0.10)	(0.21)	(0.12)	(0.18)	(0.12)	(0.23)	(2)
San Juan	3 200	−0.074	0.13	0.12	0.054	0.0047	−0.21	23
	(500)	(0.15)	(0.19)	(0.099)	(0.48)	(0.11)	(0.20)	(2)
Pajarito Acres	3 100	0.16	−0.11	0.038	−0.11	0.049	−0.013	16
	(500)	(0.076)	(0.14)	(0.084)	(0.13)	(0.11)	(0.14)	(2)
Lower Mortandad	5 700	0.095	0.080	0.097	0.46	0.045	−0.072	18
	(700)	(0.091)	(0.11)	(0.082)	(0.25)	(0.082)	(0.12)	(2)
TA-8	4 700	0.054	0.14	0.014	0.39	0.093	0.12	18
	(600)	(0.075)	(0.12)	(0.087)	(0.24)	(0.089)	(0.12)	(2)
TA-9	1 600	0.014	0.0019	0.21	0.13	0.083	0.078	15
	(600)	(0.059)	(0.10)	(0.078)	(0.12)	(0.081)	(0.12)	(2)
TA-15	2 200	0.074	0.21	0.068	0.70	−0.021	0.14	<1
	(400)	(0.081)	(0.11)	(0.090)	(0.26)	(0.072)	(0.13)	(1)
TA-16	1 100	−0.0039	−0.011	0.089	0.62	0.073	−0.20	73
	(400)	(0.093)	(0.14)	(0.096)	(0.30)	(0.098)	(0.14)	(7)
TA-21	23 000	0.0078	0.031	0.14	0.15	0.046	0.16	<1
	(2 000)	(0.11)	(0.16)	(0.10)	(0.17)	(0.11)	(0.18)	(1)
TA-33	30 000	0.047	−0.046	0.12	0.50	0.057	0.16	<1
	(3 000)	(0.071)	(0.10)	(0.073)	(0.20)	(0.073)	(0.12)	(1)
TA-49	2 000	0.0035	0.065	0.052	−0.013	−0.030	0.16	<1
	(400)	(0.069)	(0.11)	(0.062)	(0.12)	(0.071)	(0.13)	(1)
TA-50	3 600	0.14	0.088	0.018	0.083	0.040	0.15	16
	(500)	(0.078)	(0.12)	(0.074)	(0.14)	(0.090)	(0.14)	(2)
TA-53	16 000	0.036	0.016	0.053	0.053	0.12	0.27	<1
	(2 000)	(0.11)	(0.14)	(0.085)	(0.19)	(0.10)	(0.17)	(1)
TA-54	260	−0.042	0.045	0.061	0.020	0.075	−0.11	<1
	(30)	(0.081)	(0.11)	(0.075)	(0.13)	(0.076)	(0.12)	(1)

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[a] Data are from 1987.

[b] Counting uncertainty is in parentheses.

Table G-41. Hazardous Waste Management Facilities at Los Alamos National Laboratory

Technical Area	Facility Type	Interim Status or <90-Day Storage	Inclusion in Part B Permit Application	NMEID Application Closure
TA-54 Area L	Tank treatment	Yes	Interim status	
	Container storage	Yes	Interim status	
	Landfill[a]	No	Neither	FY 91
	Oil storage tanks	No	Neither	FY 89
TA-54 Area G	Landfill[a]	No	Neither[b]	
TA-50-1	Batch treatment	Yes	Interim status	
	Container storage	Yes	Interim status	
TA-50-37	Controlled-air incinerator	Yes	Interim status	
	Container storage (feed bay)	<90 day	Neither	
	Container storage (Rm 117)	No	Interim status	
TA-3-102	Container storage	<90 day	Neither	
TA-3-40	Container storage	<90 day	Neither	
TA-14	Miscellaneous unit	Yes	Interim status	
TA-15	Miscellaneous unit	Yes	Interim status	
TA-36	Miscellaneous unit	Yes	Interim status	
TA-39-6	Miscellaneous unit	Yes	Interim status	
TA-39-57	Miscellaneous unit	Yes	Interim status	
TA-22-24	Container storage	No	Neither	Closed
TA-53-2	Container storage	<90 day	Neither	
TA-40-2	Container storage	No	Neither	Closed
TA-40 SDS	Miscellaneous unit	Yes	Neither	FY 90
TA-16 (6 units)	Miscellaneous unit	Yes	Interim status	
TA-16 Area P	Landfill[a]	No	Neither	FY 90
TA-46	Tank storage	<90 day	Neither	
TA-16	Surface impoundment	No	Neither	FY 89
TA-54 Area H	Landfill	No	Neither	FY 90
TA-35-85	Surface impoundment	No	Neither	FY 89
TA-35-125	Surface impoundment	No	Neither	FY 89

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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-42. 1988 RCRA Interactions Among the Laboratory, Environmental Protection Agency (EPA), and New Mexico's Environmental Improvement Division (NMEID)

January 12, 1988	Received Notice of Violation (NOV) letter (January 8) as a result of July 14, 1987, EPA/NMEID inspection.
January 1988	Biennial Inventory of Federal Hazardous Waste Sites submitted.
February 3, 1988	Submitted revised Area P Closure Plan to NMEID.
February 11, 1988	Submitted to NMEID the response to the January 12, 1988, NOV. Submitted hazardous waste questionnaires for generators to EPA.
February 1988	Submitted revised underground storage tank (UST) notification to NMEID.
March 16, 1988	Responded to NMEID's request (January 14, 1988) for the annual groundwater monitoring report.
March 28, 1988	Submitted closure certification for TA-3-102 to NMEID.
March 31, 1988	Submitted supplemental questionnaires for generators to EPA (see February 3, 1988).
April 8, 1988	Received confirmation of TA-3-102 closure.
April 20, 1988	Letter from NMEID in response to revised Part A/B submitted November 25, 1987.
April 24, 1988	Submitted to the NMEID a revised UST notification.
April 29, 1988	Submitted 1987 biennial hazardous waste report for generators, storers, treaters, and disposers.
May 18, 1988	Submitted closure certification for TA-22-24 and TA-40-2 to the NMEID.
June 17, 1988	Received confirmation of TA-22-24 and TA-40-2 closure.
July 14, 1988	Submitted revised Part A to NMEID. Expands storage capacity of hazardous waste.
August 1, 1988	Received compliance order addressing continued violations from previous NOVs.
August 8–12, 1988	EPA/NMEID RCRA compliance inspection.
August 26, 1988	Submitted annual UST registration fees to NMEID.
August 30, 1988	Received compliance order (CO) revising August 1 CO. Clarifies legal issues.
November 23, 1988	NOV letter as a result of the August 8–12, 1988, inspection.

Table G-43. Types of Discharges and Parameters Monitored at the Laboratory under its NPDES Permit NM0028355

EPA ID No.	Type of Discharge	Number of Outfalls	Monitoring Required and Sample Frequency
01A	Power plant	1	Total suspended solids, free available chlorine, pH, flow (monthly)
02A	Boiler blowdown	1	pH, total suspended solids, flow copper, iron, phosphorus, sulfite, total chromium (weekly)
03A	Treated cooling water	34	Total suspended solids, free available chlorine, phosphorus, pH, flow (weekly)
04A	Noncontact cooling water	29	pH, flow (weekly)
050 051	Radioactive waste treatment plants	2	Ammonia, chemical oxygen demand, total suspended solids, cadmium, chromium, copper, iron lead, mercury, zinc, pH, flow (weekly)
05A	High-explosive discharge	18	Chemical oxygen demand, pH, flow, total suspended solids (weekly)
06A	Photo wastes	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 wastes	9	Biochemical oxygen demand, flow, pH, total suspended solids, fecal coliform bacteria (variable frequency, from three per month to one quarterly)

Table G-44. NPDES Permit Monitoring of Effluent Quality at Sanitary Sewage Treatment Outfalls

Discharge Location	Permit Parameters	Number of Deviations	Range of Deviation
TA-3	BOD[a]	2	73.8–111.0
	TSS[b]	2	56.8–60.0
	Fecal coliform bacteria[c]	1	6 000
	pH[d]	0	—
TA-9	BOD	0	—
	TSS	0	—
	pH	0	—
TA-16	BOD	0	—
	TSS	0	—
	pH	0	—
TA-18	BOD	0	—
	TSS (90)	0	—
	pH	2	9.5–9.8
TA-21	BOD	1	45.9
	TSS	0	—
	pH	0	—
TA-35	BOD	1	49.3
	TSS (90)	1	125.6
	pH	0	—
TA-41	BOD	0	—
	TSS	0	—
	Fecal coliform bacteria	0	—
	pH	0	—
TA-46	BOD	0	—
	TSS	0	—
	pH	1	5.5
TA-53	BOD	1	—
	TSS (90)	0	—
	pH	2	9.7

---

[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 >6.0 and <9.0 standard units.

Table G-45. 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 units
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 units
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 units
Radioactive waste treatment plants	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 units
	pH[b]	6–9	6–9	standard units
High explosives	COD	150.0	250.0	mg/L
	TSS	30.0	45.0	mg/L
	pH	6–9	6–9	standard units
Photo wastes	CN	0.2	0.2	mg/L
	Ag	0.5	1.0	mg/L
	pH	6–9	6–9	standard units

Table G-45 (Cont)

Discharge Category	Permit Parameter	Daily Average	Daily Maximum	Unit of Measurement
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 units

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[a] Limitations for outfall 050 located at TA-21-257.

[b] Limitations for outfall 051 located at TA-50-1.

Table G-46. NPDES Permit Monitoring of Effluent Quality at Industrial Outfalls[a]

Discharge Category	Number of Outfalls	Permit Parameter	Number of Deviations	Range of Deviations	Number of Outfalls with Deviations
Power plant	1	TSS[b]	0	—	0
		Free Cl	0	—	0
		pH	0	—	0
Boiler blowdown	1	pH	2	10.0–12.3	1
		TSS	9	121.0–633.0	1
		Cu	0	—	0
		Fe	0	—	0
		P	0	—	0
		SO_3	0	—	0
		Cr	0	—	0
Treated cooling water	34	TSS	0	—	0
		Free Cl	4	0.54–3.5	4
		P	0	—	0
		pH	1	9.2	1
Noncontact cooling water	29	pH	0	—	0
Radioactive waste treatment plant	2	COD[c]	0	—	0
		TSS	1	69.1	1
		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 explosives	18	COD	1	336.0	1
		TSS	0	—	0
		pH	0	—	0
Photo wastes	13	CN	0	—	0
		Ag	1	12.0	1
		TSS	0	—	0
		pH	0	—	0
Printed circuit board	1	pH	2	5.5–10.1	2
		COD	1	4.8	1
		Ag			
		Fe	2	0.112–0.216	1
		Cu	0	—	0
		TSS	0	—	0

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[a] Limits set by the NPDES permit are presented in Table G-45.

[b] Total suspended solids.

[c] Chemical oxygen demand.

Table G-47. Schedule and Status of Upgrading the Laboratory's Waste-Water Outfalls

Outfalls	Date	Status
01A		
Final design complete	August 1986	Completed
Advertisement of construction contract	September 1986	Completed
Award of construction contract	October 1986	Completed
Construction completion	December 1986	Completed
In compliance with final limits	January 1987	Completed
03A		
Final design complete	August 1986	Completed
Advertisement of construction contract	September 1986	Completed
Award of construction contract	October 1986	Completed
Construction completion	December 1986	Completed
In compliance with final limits	January 1987	Completed
05A		
Final design complete	September 1986	Completed
Advertisement of construction contract	October 1986	Completed
Award of construction contract	November 1986	Completed
Construction completion	May 1987	Completed
In compliance with final limits	June 1987	Completed
01S		
Final design complete	—	Completed
Advertisement of construction contract	—	Completed
Award of construction contract	July 1986	Completed
Construction completion	May 1987	Completed
In compliance with final limits	August 1987	Completed
04S		
Final design complete	January 1987	Completed
Advertisement of construction contract	February 1987	Completed
Award of construction contract	March 1987	Completed
Construction complete	December 1987	Completed
In compliance with final limits	January 1988	Completed
05S		
Final design complete	—	Completed
Advertisement of construction contract	—	Completed
Award of construction contract	July 1986	Completed
Construction completion	January 1988	Completed
In compliance with final limits	May 1988	Completed
06S		
Final design complete	—	Completed
Advertisement of construction contract	July 1986	Completed
Award of construction contract	August 1986	Completed
Construction completion	August 1987	Completed
In compliance with final limits	September 1987	Completed

Table G-47 (Cont)

Outfalls	Date	Status
10S		
Final design complete	—	Completed
Advertisement of construction contract	—	Completed
Award of construction contract	—	Completed
Construction completion	—	Completed
In compliance with final limits	September 1986	Completed
11S		
Final design complete	—	Completed
Advertisement of construction contract	—	Completed
Award of construction contract	July 1986	Completed
Construction complete	November 1986	Completed
In compliance with final limits	January 1987	Completed

Table G-48. Federal Facility Compliance Agreement: Interim Compliance Limits

	Discharge Limitation		
Effluent Characteristic	**Daily Average (lb/day)**	**Daily Average (mg/L)**	**7-Day Average (mg/L)**
Industrial Outfalls			
Outfall 01A (Power Plant)			
Flow[a]	N/A	N/A	N/A
Total suspended solids	N/A	30	100
Free available chlorine	N/A	1.0	5.0
Outfall 03A (Treated Cooling Water)			
Flow	N/A	N/A	N/A
Total suspended solids	N/A	30	100
Free available chlorine	N/A	1.0	5.0
Total phosphorous	N/A	5	5
Outfall 05A (High Explosive)			
Flow	N/A	N/A	N/A
Chemical oxygen demand	N/A	1000	2000
Total suspended solids	N/A	60	90
Sanitary Waste-Water Outfalls			
Outfall 01S (Located at TA-3)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	225.2	70	105
Total suspended solids	225.2	55	105
Fecal coliform	N/A	10 000	200 000
Outfall 04S (Located at TA-18)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	10	60	95
Total suspended solids	10	70	125
Outfall 05S (Located at TA-21)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	6.8	60	95
Total suspended solids	7.3	60	100
Outfall 06S (Located at TA-41)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	11.4	55	60
Total suspended solids	6.2	30	45
Fecal coliform bacteria	N/A	20 000	100 000
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

Table G-48 (Cont)

Effluent Characteristic	Discharge Limitation Daily Average (lb/day)	Daily Average (mg/L)	7-Day Average (mg/L)
Sanitary Waste-Water Outfalls (Cont)			
Outfall 11S (Located at TA-8)			
Flow	N/A	N/A	N/A
Biochemical oxygen demand	N/A	60	95
Total suspended solids	N/A	70	125

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[a] Flows must be monitored and reported (in millions of gallons per day).

Note: The pH shall not be less than 6.0 nor greater than 9.0.

Table G-49. Environmental Documentation Approved by the Laboratory Environmental Review Committee in 1988

Action Description Memorandums

Laboratory-Wide

Live Firing Range Extension (revision)

Water Wells: Otowi-1, Pueblo Canyon, and Otowi-4, Los Alamos Canyon (Utilities Restoration, Phase II)

TA-3

Arms Control Verification and Intelligence Center

Materials Science Laboratory (revision)

TA-49

Laboratory Hazardous Devices Team Firing Site

TA-52

Ultra-High-Temperature Reactor Experiment (UHTREX) Decommissioning (revision)

Environmental Assessment

TA-55

Special Nuclear Materials Research and Development Laboratory

Table 50. Summary of 1988 Emissions of Toxic Air Pollutants at Los Alamos

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 F	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
Fluorides, as F	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 glocol vapor	50	Nitrobenzene	1
N-Amyl acetate	38	1,1-Dichloroethane	1
Trichloroacetic acid	37	Aluminum	1
Hhydrogen 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 Ba	1
Ethyl ether	18	Vinyl acetate	1

Table G-51. Los Alamos, New Mexico,[a] Climatological Survey (1911–1988) Temperature and Precipitation Means[b] and Extremes

	Temperature (°F)[c]										
	Normals			Extremes							
Month	Mean Max	Mean Min	Avg	High Avg	Year	Low Avg	Year	High Daily Max	Date	Low Daily Min	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	71	3/27/86[d]	−3	3/11/48
April	57.6	33.7	45.6	54.3	1954	39.7	1973	79	4/23/38	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[d]
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[d]	−18	1/13/63

Table G-51 (Cont)

	Precipitation (in.)[c]										Mean Number of Days Per Year		
	Precipitation[e]					Snow							
Month	Mean	Max	Year	Daily Max	Date	Mean	Max	Year	Daily Max	Date	Precip >0.10 in.	Max Temp >90°F	Min 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 based on standard 30-year period: 1951–1980.
[c] Metric conversions: 1 in. = 2.5 cm; °F = 9/5 °C + 32.
[d] Most-recent occurrence.
[e] Includes liquid water equivalent of frozen precipitation.

Table G-52. Los Alamos Climatological Summary for 1988

	Temperature (°F)[a]						
	Means			Extremes			
Month	Mean Max	Mean Min	Avg	High	Date	Low	Date
January	35.1	14.6	24.9	50	29	1	21
February	46.2	22.9	34.5	59	29	14	18
March	50.5	24.7	37.6	70	27	9	18
April	59.9	33.8	46.9	71	3 dates	19	2
May	66.4	40.4	53.4	82	15	28	2
June	77.0	51.4	64.2	87	22	39	1
July	79.3	54.8	67.0	88	25	50	11
August	74.7	54.6	64.7	86	14	46	29
September	69.4	47.1	58.2	83	8	35	29,30
October	65.2	41.7	53.5	72	17,18	32	28
November	48.6	26.8	37.7	66	3,6	13	28
December	39.9	17.3	28.6	53	13	2	28
Annual	59.4	35.8	47.6	88	7/25	1	1/21

Table G-52 (Cont)

	Precipitation (in.)[a]						Number of Days		
	Water Equivalent			Snow					
Month	Total	Daily Max	Date	Total	Daily Max	Date	Precip >0.10 in.	Max Temp >90°F	Min Temp <32°F
January	0.95	0.52	18	16.0	8.0	18	2	0	31
February	0.20	0.09	17	1.8	1.5	17	0	0	26
March	1.10	0.49	31	17.9	8.0	31	3	0	25
April	1.75	1.22	16	1.2	1.0	1	4	0	12
May	1.97	0.81	16	0	0	—	3	0	5
June	4.36	2.05	10	0	0	—	7	0	0
July	4.71	0.73	27	0	0	—	10	0	0
August	4.56	0.86	22	0	0	—	12	0	0
September	3.28	0.93	12	0	0	—	6	0	0
October	0.54	0.30	5	0	0	—	3	0	1
November	0.59	0.13	18	6.4	2.0	18	2	0	21
December	0.32	0.14	19	6.0	2.2	7	2	0	31
Annual	24.33	2.05	6/10	49.3	8.0	1/18,3/31	54	0	152

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[a] Metric conversions: 1 in. = 2.5 cm; °F = 9/5 °C + 32.

Table G-53. Los Alamos Precipitation (in.) for 1988[a,b]

	S-Site (1)	North Community (2)	TA-59 (3)	Bandelier (4)	East Gate (5)	Area G (6)	White Rock Y (7)	White Rock (8)
January	1.12	1.26	0.95	0.97	0.81	0.59	0.68	0.86
February	0.29	0.31	0.20	0.24	0.09	0.15	0.10	0.18
March	1.04	1.18	1.10	1.21	0.68	0.54	0.44	0.55
April	1.98	1.83	1.75	1.51	1.45	1.30	1.18	1.25
May	1.75	1.99	1.97	1.57	1.87	1.47	1.65	1.59
June	3.32	2.40	4.36	1.84	2.64	2.09	1.55	0.99
July	2.20	3.29	4.71	2.62	3.59	2.26	4.33	2.14
August	5.89	4.35	4.56	6.18	3.29	3.06	2.72	3.43
September	3.33	3.78	3.28	3.63	3.79	3.90	2.90	3.47
October	0.58	0.72	0.54	1.22	0.54	0.92	0.67	0.74
November	0.64	0.74	0.59	0.44	0.30	0.29	0.25	0.23
December	0.46	0.49	0.32	0.33	0.22	0.15	0.14	0.18
Annual	22.60	22.34	24.33	21.76	19.27	16.72	16.61	15.61

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[a] Metric conversion: 1 in. = 2.5 cm.

[b] See Fig. 28 for site locations.

Table G-54. 1988 Weather Highlights

January

Cold and snowy.
Mean temperature = 24.9°F (normal = 29.1°F).
Snowfall = 16.0 in. (normal = 10.7 in.).
SMDS on the 18th: 8.0 in.

February

Dry and mild.
Precipitation = 0.20 in. (normal = 0.68 in.)
Snowfall = 1.8 in. (normal = 7.3 in.).
Strong winds with peak gusts = 56 mph on the 10th.
Rare and complex display of lights from cirrus clouds on the 25th.
Record warm minimum temperatures of 38 and 36°F on the 27th and 28th, respectively.

March

Snowy.
Snowfall = 17.9 in. (normal = 9.7 in.).
SMDP on the 17th: 0.30 in.
SMDS on the 17th: 7.5 in.
Only reached 30°F on the 17th; record low for this date.
SMDL on the 18th: 9°F.
SMDH on the 20th: 63°F.
TMDH on the 21st: 65°F.
SMDP on the 31st: 0.49 in.
SMDS on the 31st: 8.0 in.
North Community received 14.0 in. snowfall on the 31st.
Strong winds with gusts = 56 and 62 mph on the 10th and 24th, respectively.

April

Wet.
Precipitation = 1.75 in. (normal = 0.86 in.).
Temperature reached only 33°F on the 1st; record low for this date.
SMDH on the 13th: 71°F.
SMDP on the 16th: 1.22 in.
Strong winds with peak gusts = 57 and 56 mph on the 21st and 30th, respectively.

May

Wet and windy.
Precipitation = 1.97 in. (normal = 1.13 in.).
Windy, with peak gusts >50 mph on the 1st, 2nd, 5th, and 6th.
TMDH on the 14th: 80°F.
TMDH on the 15th: 82°F.
SMDP on the 16th: 0.81 in.
Hail (0.5 in. diameter) on the 24th and 28th.

Table G-54 (Cont)

June

Very wet, fourth wettest June on record.
Precipitation = 4.36 in. (normal = 1.12 in.).
Haze on the 6th–7th and 10th–11th.
Heavy thunderstorm on the 10th, with 2 in. of hail accumulation and 2.05 in. of rainfall. A 2-h rainfall = 1.80 in. (25-yr return).
Strong thunderstorm wind on the 11th, with peak gusts = 53 mph.
Temperature only reached 65°F on the 28th; record low for this date.

July

Wet.
Precipitation = 4.71 in. (normal = 3.18 in.).
Albuquerque Northeast Heights flash flood on the 9th, with up to 7.8 in. rain in 1.5 h. One person was killed.
Haze from Wyoming forest fires on the 26th and 27th.

August

Flash flooding in Albuquerque on the 10th; 1.49 in. of rainfall in White Rock, with 1 in. falling in 1 h.
Record low maximum temperatures of 58 and 60°F on the 27th and 28th, respectively.
Haze on the 29th.

Summer (June–August)

Precipitation = 13.63 in., third wettest on record (wettest, 16.50 in., 1952; second wettest, 13.65 in., 1967).

September

Wet, with cool daytime temperatures.
Precipitation = 3.28 in. (normal = 1.63 in.).
Mean high temperature = 69.4°F (normal = 72.1°F).
Haze from northern Rocky Mountain forest fires (including Yellowstone) on the 3rd and 6th–10th; thick haze on the 8th and 9th, with visibility <20 mi.
SMDP on the 12th: 0.93 in.
Funnel cloud reported in Los Lunas on the 13th.

October

Warm and dry.
Mean temperature = 53.5°F (normal = 50.3°F).
Precipitation = 0.54 in. (normal = 1.52 in.).

November

Windy and slightly dry.
TMDH on the 6th: 66°F.
Windy on the 15th, with peak gust = 60 mph.
Windy on the 20th, with peak gust = 77 mph (at East Gate).
Windy on four other dates, with gusts ≥45 mph.

Table G-54 (Cont)

December

Dry and cool.
Precipitation = 0.32 in. (normal = 0.96 in.).
Snowfall = 6.0 in. (normal = 11.4 in.).
Mean low temperature = 17.3°F (normal low = 20.3°F).
Windy, with peak gust = 57 mph.
Windy, with peak gusts ≥40 mph on the 22nd, 25th, and 26th.

Annual

1988 mean temperature = 47.5°F (normal = 48.1°F).
1988 precipitation = 24.33 in. (normal = 17.83 in.).
Fourth consecutive year with precipitation >30% above normal.
1988 snowfall = 49.3 in. (normal = 50.8 in.).
1987–88 winter season snowfall = 80.2 in.

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.
SMDS	Set maximum daily snowfall record.

Table G-55. Deposition (μequiv/m^2)

	Quarters				
	First	Second	Third	Fourth	Total
Mean field pH	4.92	4.97	4.66	4.71	4.80
Minimum pH	4.18	4.47	4.35	4.51	4.18
Maximum pH	5.46	5.75	4.93	5.24	5.75
Precipitation (in.)	2.61	5.18	10.73	2.03	20.55
Ca	939	2549	1820	325	5633
Mg	124	320	232	41	717
K	19	139	100	17	274
Na	311	495	465	76	1347
NH_4	361	308	644	54	1366
NO_3	1022	1619	2866	392	5900
Cl	159	367	484	28	1038
SO_4	1161	3007	3880	262	8309
PO_4	1	97	21	10	130

REFERENCES

G1. U.S. Environmental Protection Agency, "Environmental Radiation Data," U.S. Environmental Protection Agency report 45 (1986).

G2. U.S. Environmental Protection Agency, "Environmental Radiation Data," U.S. Environmental Protection Agency report 53 (1988).

GLOSSARY

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.
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."
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 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 for 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 reontgen).
external radiation	Radiation originating from a source outside the body.
fission products	Those atoms created through 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 (microwaves, visible light, radiowaves, etc.) 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-III). The MCLs are specified by the Environmental Protection Agency.
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 yr 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	A standard for external and internal exposure to radioactivity as defined in Department of Energy Order 5480.1A, Chap. XI (see Appendix A and Table A-II 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 from cosmic-ray-induced radionuclides in the soil.
thermoluminescent dosimeter (TLD)	A material (the Laboratory users 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 yr. 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).
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.

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