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Environmental Surveillance At Los Alamos During 1973

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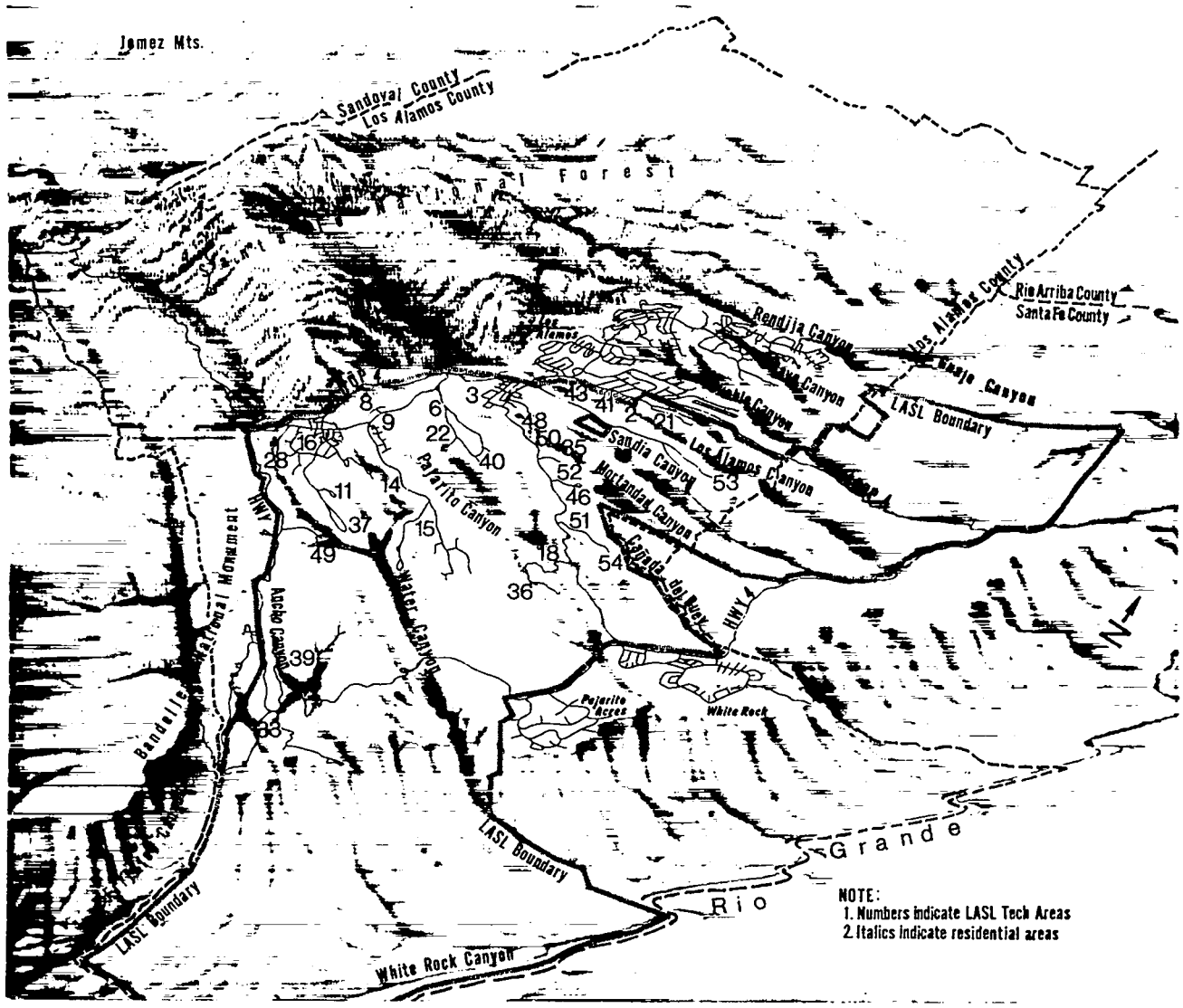

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ABSTRACT

The CY 73 environmental monitoring program of the Los Alamos Scientific Laboratory (LASL) is described. Data are presented for concentrations of radioactivity measured in air, ground and surface waters, liquid effluents, sediments, and soils and are compared with those of AEC guides and/or data from other reporting periods. Levels of external penetrating radiation measured in LASL environs are given. The average whole body radiation dose to residents of Los Alamos County resulting from LASL operations was calculated. Chemical and biological qualities of liquid effluents and surface and ground waters of LASL environs were determined, and are compared to applicable standards. Results of related environmental studies are presented. Ecological investigations include (a) an environmental inventory of LASL and environs, (b) the honeybee as a potential tritium indicator organism, (c) radionuclides in Los Alamos area canyon ecosystems, and (d) physical and chemical characterization of Los Alamos area soils. Results are given of meteorological investigations of Los Alamos climatological records, rainfall distributions, and windfield patterns. There are also data pertaining to the geo-hydrological determination of flood frequencies and maximum discharges of Los Alamos area canyons. Environmental control activities are described which should be of benefit to LASL planning.

I. INTRODUCTION

A. Scope and Objectives

This report presents the results of the environmental monitoring programs conducted at the Los Alamos Scientific Laboratory (LASL) during the calendar year 1973. This facility is administered by the University of California for the U.S. Atomic Energy Commission (AEC) under Contract W-7405-ENG-36. The monitoring programs and evaluations of environmental quality were conducted mainly by the Environmental Studies Group (Group H-8) as portions of a continuing comprehensive environmental investigation.

Despite the use of highly efficient systems for treatment and purification of effluent streams, both gaseous and liquid, small quantities of radionuclides routinely escape from the LASL site. *Effluent monitoring* is conducted continuously at all major release locations to document concentrations at points of release and total quantities released. *Environmental monitoring* is conducted throughout the area, both on the LASL site and in its environs, to evaluate the behavior of radioactive and nonradioactive contaminants in the biosphere.

Although the main objective of this report is to satisfy contractual requirements of the AEC as specified in AEC Manual Chapter 0513, the report also serves a broader function in providing public documentation of additional data on environmental quality in the vicinity of the Laboratory. Consequently, this report contains substantial amounts of material that go beyond the minimal requirements of the AEC. This additional information is provided in keeping with the philosophy of the AEC and the Laboratory to make available to the public information relating to environmental quality and controls.

B. Physical Setting of the Laboratory

The Laboratory and the town of Los Alamos are located in north-central New Mexico (Fig. 1) on the Pajarito Plateau, situated west of the Rio Grande on the eastern slopes of the Jemez Mountains (p. iv). The Laboratory site covers about 110 km^2 in and adjacent to Los Alamos County. The location was chosen for the atomic weapons laboratory during World War II because of its relative isolation; the area surrounding Los Alamos, including all of Los Alamos County and large portions of Sandoval, Rio Arriba, and Santa Fe Counties, remains largely undeveloped except for those areas occupied by the Laboratory facilities and associated communities. Large tracts of land in the Jemez Mountains to the north, west, and south of the Laboratory site are held by the U.S. Forest Service and U.S. National Park Service. This land is largely covered by evergreen and aspen forests which support the usual variety of western mountain wildlife. A sacred portion of Indian land borders the Laboratory to the east.

C. Population and Economy of the Area

The north-central portion of New Mexico contains approximately one-half million people. Nearly 70% of this population is concentrated in Albuquerque, slightly more than 100 km to the south. Another 10% is located in Santa Fe, about 40 km to the southeast. Except for the population of Los Alamos, the remainder is distributed among small towns, ranging in size from a few hundred to a few thousand people, and Indian pueblos of a few hundred people. The nearest community is Española, about 20 km to the northeast, with a population of about 2 000. Within Los Alamos County about 12 000 people live in the residential area of Los Alamos proper and the remaining 5 000 reside in the White Rock area.

The economy of the Santa Fe-Los Alamos area is based largely on government operations, the large tourist trade, arts and crafts, agriculture, and some light and service industries, mostly associated with the tourist trade. LASL accounts for much of the federal employment, and the New Mexico state governmental offices, located in Santa Fe, provide many state jobs.

Agriculture is practiced to a limited extent within 20-40 km of Los Alamos. In this area many people raise vegetables in home gardens, but very rarely depend on this activity for more than half of their subsistence. Outside this area, much of the rural population practices agriculture, either for subsistence and income augmentation or on a strictly commercial basis. Limited truck farming has been made possible by irrigation in the river valleys. The principal crops of tree fruits, chili peppers, corn, and alfalfa are consumed primarily within the local area.

D. Environmental Releases from LASL Operations

The principal mission of the Laboratory is, as it has been since its inception in 1943, the design and development of nuclear weapons. This program is supported by extensive research programs in nuclear physics, hydrodynamics, conventional explosives, chemistry, metallurgy, radiochemistry, and biology. In addition to the weapons program, considerable effort is directed toward the peaceful uses of nuclear energy, including medium-energy physics (Clinton P. Anderson Los Alamos Meson Physics Facility), space nuclear propulsion, controlled thermonuclear fusion (Sherwood Program), laser and geothermal research, nuclear safeguards, biomedical research, and space physics. These activities are located in 29 active Technical Areas (TA) widely spread over the LASL site, as shown on p. iv and in Fig. 2.

Because the Laboratory is a large, diversified organization employing several thousand people engaged in fundamental and applied research in the natural sciences, with emphasis on nuclear materials, the facilities include hundreds of potential sources of effluents and wastes. Processes with the potential for significant releases are confined to only a few locations and are rigorously controlled and monitored. However, there are many laboratory hoods, drains, and waste receptacles for which procedural controls are relied upon.

The radioactive materials released to the atmosphere from LASL operations are shown in Table I. Except for the entries in the last line of the table (for TA-15), the data were obtained by stack effluent monitoring.

The major emphases of the environmental monitoring program are dictated by the types and quantities of potentially hazardous materials used in LASL programs and by the unique ecology and geology of this location. Substantial emphasis is placed on the analysis for tritium, uranium, and plutonium in samples of environmental media. Fission product radionuclides are of lesser concern, although specific analyses are made for radioactive species of cesium and iodine in selected samples. Because of the minimal agricultural activities in the immediate vicinity of the LASL site, monitoring of radionuclides in human food chains is not emphasized in this program as it is in most other comparable environmental monitoring programs.

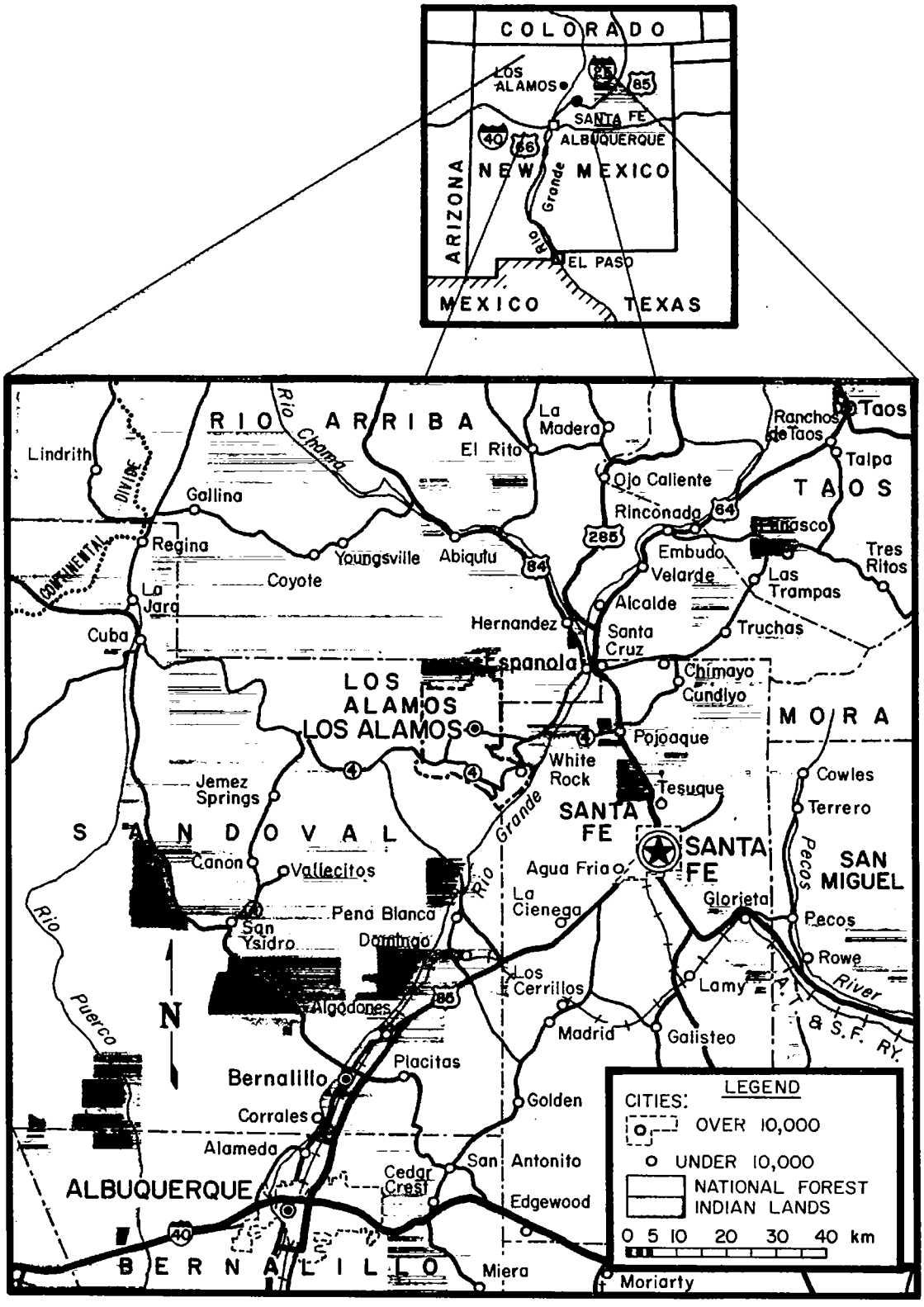

Fig. 1.
North-central New Mexico.

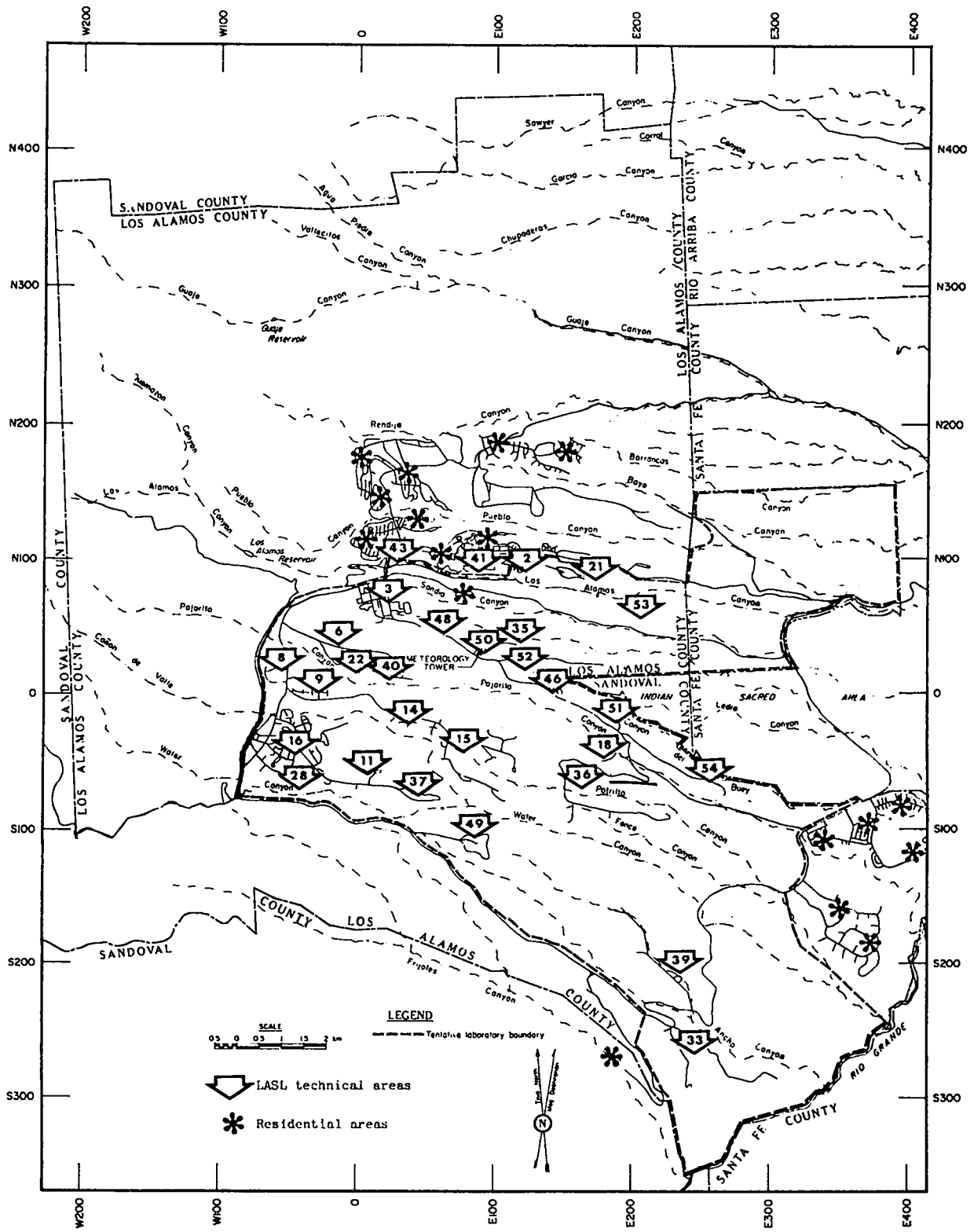

Fig. 2.
Los Alamos County residential areas and LASL technical areas (numbered).

TABLE I

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTALS FOR 1973

Location	^{241}Am ^{238}Pu ^{239}Pu (μCi)	^{233}U ^{234}U ^{235}U (μCi)	^{238}U[a] (kg)	^{232}Th (kg)	MFP[b] (mCi)	^{131}I (mCi)	^{88}Rb (mCi)	^{133}Xe ^{135}Xe (Ci)	^{41}Ar (Ci)	^{3}H (Ci)
TA-2	-	-	-	-	-	-	1.3	210	270	-
TA-3	7 300	310	640	0.14	13	4.2	-	-	-	-
TA-9	-	-	-	-	-	-	-	-	-	36
TA-21	1 400	910	-	-	0.001	-	-	-	-	4
TA-33	-	-	-	-	-	-	-	-	-	3 900
TA-35	2.4	-	-	-	-	-	-	-	-	1 200
TA-41	1.5	-	-	-	-	-	-	-	-	59
TA-43	0.5	-	-	-	-	-	-	-	-	-
TA-46	-	2.2	-	-	-	-	-	-	-	-
TA-48	20	2.0	-	-	1.0	-	-	-	-	-
TA-50	2.5	-	-	-	0.017	-	-	-	-	-
TA-15	-	-	-	-	-	-	-	-	-	930

[a]Depleted ^{238}U of varying isotopic compositions.

[b]Mixed fission products.

II. SUMMARY OF ENVIRONMENTAL MONITORING RESULTS

The results of the monitoring program for this reporting period confirm the generally low radiation levels previously noted[1] in the Los Alamos environs. Measurements of gross radioactivity in air and precipitation revealed concentrations similar to those measured at other locations in the northern hemisphere where activity is entirely attributable to the presence of worldwide fallout. Airborne plutonium and tritium measurements revealed that Laboratory activities have slightly elevated the levels of both materials above the concentrations expected from global fallout.

Radiation dose calculations were made for individuals susceptible to the maximum off-site contributions by the Laboratory, and for the general public in the vicinity of the Laboratory. The only contribution to whole body dose that could be attributed to the Laboratory was from airborne tritium (oxide). The maximum potential dose from tritium to an off-site person was 0.12 mrem/year; to the residents of Los Alamos County, the estimated annual dose was 0.007 mrem. These values represent 0.02% and 0.004% of the individual and population dose limits, respectively. A total population dose of 0.14 man-rem was calculated as the Laboratory's tritium contribution to total dose.

Maximum lung doses to off-site individuals, and average lung doses to Los Alamos residents, resulting from airborne actinides, were calculated to be 0.007% and 0.01% of the appropriate dose limits.

III. ENVIRONMENTAL MONITORING CONSIDERATIONS

A. Geographic Coordinate System and LASL Boundaries

All Los Alamos County (and vicinity) locations referenced in this report are identified by the LASL Cartesian coordinate system first shown in Fig. 2. Most internal LASL documentation, including maps and survey markers, is referenced to this coordinate system. Hence, we employ this system here because of its acceptance and convenience. The LASL coordinate system was established somewhat arbitrarily during the early years of the Laboratory and is completely independent of the U.S. Geological Survey and the New Mexico State Survey

coordinate systems. The major coordinate markers shown on the maps are at 10 000-ft (3.048-km) intervals, but for the purposes of this report, locations are identified to the nearest 1000 ft (0.30 km). For example, the air sampling station at TA-33 (see Figs. 2 and 3) has coordinates S250 E230 and is in the southeast quadrant approximately 25 000 ft (7.6 km) south and 23 000 ft (7.0 km) east of the coordinate center.

The LASL boundaries are shown on p. iv and on subsequent Los Alamos area maps in this report. Not all of this area is routinely controlled by LASL because some of the more remote and little used regions are accessible to the public. However, all area within the LASL perimeter, including public roads, is considered a controlled area. The Laboratory has the capability of strict control over these areas should the need arise. Much of the Laboratory area is, of course, restricted for reasons of security and/or safety.

B. Units of Measurement and Statistical Treatment of Data

As of 1974, all LASL scientific and technical documentation uses metric units, and conversion to the International System of Units (SI) is advised wherever practicable. We have attempted to comply with SI notation here, with certain exceptions. First, the non-SI units curie (Ci), liter (ℓ), gram (g), and roentgen equivalent man (rem) are used. Second, in accordance with AEC Manual Chapter 0513, values of radioactivity in air and water are reported in units of μCi/mℓ. For the benefit of readers who may not be familiar with SI, Appendix A gives conversion factors for units used in this report.

Most of the data in this report are annual averages of individual measurements of environmental conditions or concentrations. For many environmental measurements, particularly those from which a chemical or instrumental background must be subtracted, it is possible to obtain net values that are lower than the minimum detection limit (MDL) of the system; it is not uncommon for individual measurements to result in values of zero or negative numbers. In spite of the fact that a negative value for an environmental measurement does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small or negative values are included with the larger, positive values. For this reason, the primary value shown in each of the numerical tabulations in this report is the actual value obtained from an individual measurement or group of measurements. The primary values thus listed are those used in making subsequent statistical analyses and in evaluating the real environmental impact of Laboratory operations. However, to provide an indication of the validity of each numerical value in the tables, an additional value is included in parentheses immediately following each primary numerical value. The interpretation of the value in parentheses is designated by the sign preceding that value:

1. (±X) indicates that the primary value preceding the parentheses is greater than the MDL, and the parenthetical value indicates the range of the 95% confidence interval for the primary value.
2. (<Y) indicates that the primary value preceding the parentheses is lower than the MDL, and the parenthetical value represents the MDL for that particular measurement.

The statistical distribution of annual averages of environmental conditions or concentrations deserves attention. Most annual-average data are analyzed with respect to a Gaussian or normal distribution. This well known law describes the frequency distribution of many physical measurements. For example, the distribution of annual-average gross alpha radioactivity concentrations measured at our air sampling stations obeys such a probability law. The frequency P(c) of a concentration c is stated as:

$$P(c) = (1/\sigma_c\sqrt{2\pi})\exp[-(c-\bar{c})^2/2\sigma_c^2] \quad ,$$

where $\bar{c}$ is the arithmetic mean of the distribution, and σ_c is the standard deviation (std dev). This distribution has the symmetrical "bell" shape around the central value $\bar{c}$, and σ_c is the difference between the 84.13 percentile concentration and the 50 percentile concentration $\bar{c}$ (and, identically, the difference between $\bar{c}$ and the 15.87 percentile concentration).

Many environmental data, however, do not fit the normal distribution law; instead, the distributions are often asymmetrical or skewed toward the higher values. It has been observed that even though the data are not normally distributed, the logarithms of the data quite often obey the normal law. As an example, data for external penetration radiation dose x (determined from our passive-dosimeter array) can be described log-normally. The frequency distribution P(ln x) of the natural logarithms of dose ln x is described by

$$P(\ln x) = (1/n\sqrt{2\pi})\exp[-(\ln x - m)^2/2n^2] \quad ,$$

where m is the arithmetic mean of the values of ln x and is equal to the logarithm of the geometric mean, and n is the associated std dev of the arithmetic mean. The geometric mean $\bar{x}_g$ of the values of x is then given by $\bar{x}_g = \exp[m]$ and the geometric std dev $\sigma_g = \exp[n]$. The geometric mean of a log-normal distribution is closer to the median value than is the arithmetic mean. The multiplicative parameter σ_g is simply the ratio of the 84.13

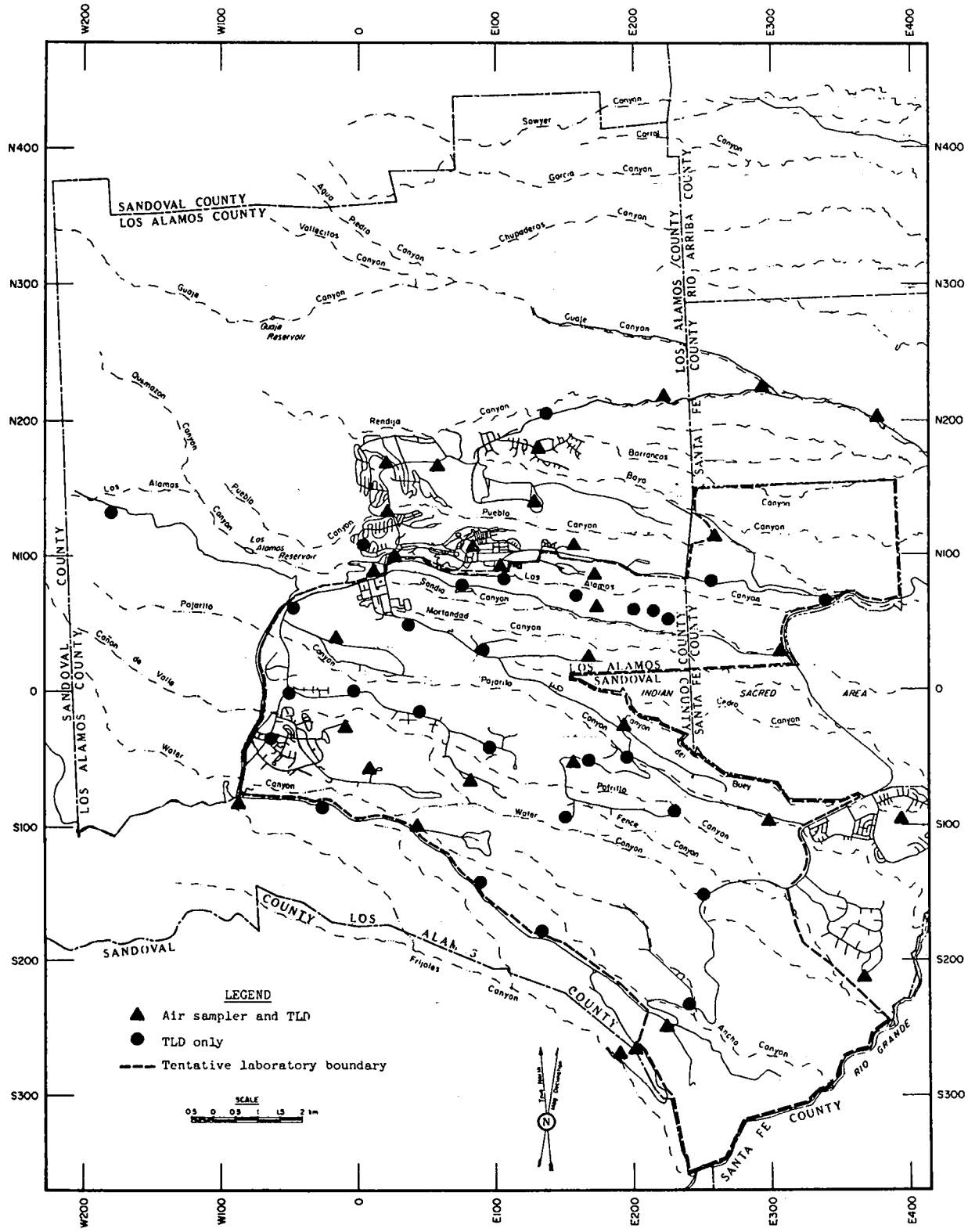

Fig. 3.
TLD and air sampler locations.

percentile value of x to the 50 percentile value $\bar{x}_g$ (and, identically, the ratio of $\bar{x}_g$ to the 15.87 percentile value). Hence, $\bar{x}_g$ and σ_g describe the log-normal distribution completely. The geometric values $\bar{x}_g$ and σ_g are related to the arithmetic mean and std dev $\bar{x}$ and σ_x by the following relationships:

$$\bar{x} = \exp[m + n^2/2]$$

$$\sigma_x = \bar{x}(\exp[n^2] - 1)^{1/2}$$

Inspection of a frequency histogram of the data gives an indication of the distribution characteristics. Probability graph paper is also useful in evaluating the statistical distribution both for Gaussian and log-normal data sets. We have used the log-normal probability distribution in describing some of the environmental data reported herein. It is intended that the use of the geometric parameters $\bar{x}_g$ and σ_g will tell more about the data set than would the conventional arithmetic mean and std dev.

C. Standards for Environmental Contaminants

The concentrations of radioactive and chemical contaminants in air, water, sediment, soil, plant, and animal samples collected throughout the environment are compared with the standards contained in regulations of several federal and state agencies to verify the compliance of the Laboratory with all pertinent standards. LASL operations, including environmental quality control, are conducted in accordance with the directives and procedures contained in the AEC Manual, particularly Part 0500: Health and Safety. The chapters most relevant to environmental control and monitoring are:

Chapter 0510, Prevention, Control and Abatement of Air and Water Pollution.
Chapter 0511, Radioactive Waste Management.
Chapter 0513, Effluent and Environmental Monitoring and Reporting.
Chapter 0524, Standards for Radiation Protection.
Chapter 0550, Operational Safety Standards. (Excerpts from this chapter, listing prescribed and recommended standards, can be found in Appendix B.)

In the case of radioactive materials in the environment, the standards contained in AECM 0514 (see Appendix D) take precedence over all other federal or state regulations. For other kinds of pollutants, e.g., biological or chemical, the controlling standards are those promulgated by either the Environmental Protection Agency or the appropriate state agencies.

Federal air pollution standards are contained in "EPA Regulations on Air Pollution from Federal Government Activities," 40 CFR76 (36 FR 22417, Nov. 25, 1971). The "New Mexico Environmental Improvement Board Ambient Air Quality Standards and Air Quality Control Regulations" (adopted Jan. 23, 1970; seven revisions through July 29, 1972) also define ambient air quality standards, but standards for emission controls are limited to combustion processes and special industries.

The basic standards for drinking water are contained in "PHS Regulations on Drinking Water Standards," 42 CFR 72. 201-207* (27 FR 2152, Mar. 6, 1962), which specifies bacteriological, physical, and chemical characteristics. Equivalent standards are contained in "New Mexico Water Quality Control Commission Regulations," Reg. 4, "Effluent Quality" (adopted March 4, 1968), and Reg. 6, "Discharge of Hazardous Substances" (adopted Aug. 27, 1971). Additional surface stream standards, primarily for protection of recreational resources, are contained in "Water Quality Standards for Intrastate Waters and Tributaries to Interstate Streams," New Mexico Water Quality Control Commission (adopted June 30, 1970).

D. Quality Control Program

The quality control program for 1973 dealt primarily with analytical chemistry procedures for plutonium in environmental samples. The retention of plutonium tracer added to air filters was investigated in conjunction with the atmospheric radioactivity monitoring program. Systematic procedural losses of plutonium from air filter samples during ashing and processing were quantified. Plutonium determinations of water samples were studied by conducting analyses of "spiked" samples, analyses of blank samples, and analyses of replicate samples. In general, the procedures for plutonium determination in water samples were found to be satisfactory. The quality control program for routine soil sample analyses consisted of plutonium analyses of spiked samples, blank samples, and replicate samples. The results of the blank and spiked sample analyses gave no indication of analytical inadequacies. The replicate determinations, however, had an incongruity of results, probably caused by sampling procedures and inhomogeneity of soil samples.

A general problem identified in the quality control program was that of laboratory plutonium contamination of environmental samples. The plutonium analytical laboratory is located in the basement of a plutonium liquid waste treatment facility, which is clearly an undesirable location for low-level radioactivity determinations. Many erratic and unrealistic plutonium results can probably be

*Also, PHS Publication 956 and EPA Bulletin 956.

explained by contamination of environmental samples in the analysis laboratory. As space becomes available, the environmental plutonium analysis laboratory is being relocated to an uncontaminated area.

IV. EXTERNAL PENETRATING RADIATION EXPOSURE

A. Procedures

Radiation exposure from external penetrating radiation (gamma and x rays) is monitored by 65 thermoluminescent dosimeters (TLDs), of which 20 are located beyond the Laboratory boundaries and 17 are located along the perimeter of the Laboratory site (within ≈1/2 km of the boundary). The remaining 28 are located on Laboratory property (Fig. 3). Each of the TLD monitors is composed of three Harshaw TDS-100 chips, 3.2 mm square by 0.9 mm thick, which are cut from single crystals of LiF containing the natural isotopic abundance of ^{6}Li and ^{7}Li. The chips are wrapped in aluminum foil and placed in an opaque 7-ml polyethylene vial for placement in the field. Most TLDs are exchanged quarterly, although a few are exchanged monthly to permit more detailed analysis of temporal variations at selected locations.

B. Results

The annual average dose rates determined from the TLD monitoring program are summarized in Table II according to off-site, perimeter, and on-site locations. The observed temporal variations from all stations are consistent and are of the same order of magnitude as the spatial variations of annual average dose rates. The numbers given parenthetically with the average dose rates are the 95% confidence level errors associated with the data. It should be noted that the average elevation of the 20 off-site stations is 2.06 km, compared with an average elevation of 2.15 km for the perimeter and on-site stations. Variations in cosmic radiation due to differences in elevation, combined with variations due to geological setting for the various monitoring stations, complicate the analysis of external exposure contributions from Laboratory operations. No attempt was made to normalize the data to correspond to a constant elevation, but efforts are being made to eliminate the anomalous effects caused by monitoring station environs.

C. Analysis

In determining the mean of station annual doses, the distribution of the annual doses must be considered. By determining the commonly used arithmetic mean and std dev, one presumes a normal, i.e., Gaussian, distribution. For the TLD annual dose data, the presumption of normal statistics is inappropriate. The data are not distributed in a characteristic "bell" shape, but are distributed asymmetrically toward the higher values. The physical reasons for this skewing include increased dose from geological setting and, in some cases, Laboratory operations. Data of this kind more closely resemble a log-normal distribution, where the distribution of the logarithms of the data is characteristically bell shaped. The geometric mean of such a distribution is closer to the median value than is the arithmetic mean. The geometric std dev σ_g is a unitless, multiplicative number that represents the ratio of the 84.13 percentile value to the 50 percentile value and, identically, the 50 percentile value to the 15.87 percentile value.

Table III shows a comparison of arithmetic and geometric statistical treatments for annual data from TLDs. Even after excluding the three stations exposed to known radiation from TA-18, the distributions for the three location groups are amenable to log-normal treatment. (Nuclear physics experiments at TA-18 use nuclear fission critical assemblies. These operations give bursts of gamma rays and neutrons which are observable in the immediate environs.) Figure 4 shows the log-normal analysis for each location group. Also shown in Fig. 4 is a typical 95% confidence level error associated with the mean annual dose for an on-site station. This error bar gives an indication of the inherent uncertainty in the annual dose data for the various stations. It is evident that the doses received at on-site locations are statistically indistinguishable from those for off-site and perimeter locations.

V. RADIOACTIVITY IN AIR

A. Sampling Procedures

Concentrations of atmospheric radioactivity were measured at 36 continuously operating air sampling stations in Los Alamos County and vicinity. Station locations are shown in Fig. 3, and map coordinates identify the locations in the data tabulations. Samples were

TABLE II

ANNUAL THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station Location	Coordinates	Elevation (km)	Exposure Period (weeks)	Average Dose Rate (mrad/day)
Off-site Stations:				
1 Guaje Booster 2	N220 E220	2.03	13	0.45(±0.10)
2 Guaje Booster 1	N270 E300	1.92	13	0.41(±0.08)
3 Sportsmans' Club	N200 E140	2.10	13	0.49(±0.10)
4 Well G-1	N200 E380	1.85	13	0.40(±0.08)
5 Barranca School	N180 E130	2.22	4	0.36(±0.07)
6 Arkansas Avenue	N170 E 20	2.26	4	0.32(±0.06)
7 Golf Course	N160 E 60	2.22	13	0.42(±0.08)
8 Well LA-3	N150 E490	1.73	4	0.33(±0.07)
9 Cumbres School	N140 E130	2.25	13	0.62(±0.13)
10 Pajarito Ski Area	N130 W180	2.80	13	0.40(±0.08)
11 Diamond Drive	N130 E 20	2.21	13	0.39(±0.08)
12 47th Street	N110 E 0	2.24	13	0.37(±0.07)
13 Fuller Lodge	N110 E 90	2.22	13	0.43(±0.09)
14 Totavi	N100 E440	1.77	13	0.39(±0.08)
15 White Rock STP	S 90 E390	1.92	4	0.33(±0.06)
16 Pajarito Acres	S210 E370	1.93	4	0.33(±0.07)
17 Bandelier HQ	S270 E190	1.85	4	0.53(±0.10)
18 Española		1.70	13	0.30(±0.06)
19 Pojoaque		1.78	13	0.32(±0.08)
20 Santa Fe		2.13	13	0.35(±0.07)
	Arith Mean:	2.06	Arith Mean:	0.40
Perimeter Stations:				
21 L. A. Airport	N110 E160	2.15	4	0.44(±0.08)
22 Bayo STP	N110 E260	1.99	13	0.55(±0.11)
23 TA-43	N100 E 20	2.22	13	0.43(±0.09)
24 Acorn Street	N100 E110	2.21	13	0.43(±0.09)
25 TA-3	N 80 E 10	2.25	13	0.46(±0.09)
26 Los Alamos Highway	N 80 E260	2.07	13	0.44(±0.09)
27 Highway 4	N 70 E350	1.92	13	0.73(±0.14)
28 W. Jemez Road	N 60 W 50	2.35	13	0.47(±0.10)
29 Well PM-1	N 30 E310	1.98	13	0.50(±0.10)
30 TA-16	S 40 W 60	2.33	13	0.43(±0.09)
31 W. Jemez Road	S 80 W 90	2.32	4	0.37(±0.07)
32 Highway 4	S 80 W 30	2.26	13	0.41(±0.08)
33 TA-49	S100 E 40	2.21	13	0.38(±0.08)
34 Pajarito Booster 1	S100 E300	2.00	13	0.47(±0.09)
35 Highway 4	S140 E 90	2.15	13	0.39(±0.08)
36 Highway 4	S180 E130	2.10	13	0.37(±0.09)
37 Bandelier Lookout	S270 E200	1.98	13	0.51(±0.10)
	Arith Mean:	2.15	Arith Mean:	0.46

TABLE II (cont.)

Station Location	Coordinates	Elevation (km)	Exposure Period (weeks)	Average Dose Rate (mrad/day)
On-site Stations:				
38 TA-2	N 90 E110	2.16	4	0.45(±0.09)
39 TA-21	N 90 E170	2.17	13	0.33(±0.07)
40 E. Jemez Road	N 30 E 80	2.22	13	0.45(±0.09)
41 TA-53	N 70 E160	2.16	13	0.38(±0.07)
42 TA-53	N 60 E180	2.16	4	0.39(±0.07)
43 TA-53	N 60 E200	2.13	13	0.50(±0.10)
44 TA-53	N 60 E220	2.12	13	0.65(±0.13)
45 TA-53	N 50 E230	2.10	13	0.53(±0.11)
46 TA-3	N 50 E 40	2.24	4	0.35(±0.07)
47 TA-6	N 40 E 20	2.29	13	0.39(±0.08)
48 TA-50	N 30 E 90	2.21	13	0.37(±0.08)
49 TA-52	N 20 E170	2.15	13	0.35(±0.07)
50 TA-9	N 0 W 50	2.30	13	0.47(±0.10)
51 TA-9	N 0 W 0	2.27	13	0.45(±0.10)
52 TA-9	S 20 E 40	2.24	13	0.43(±0.09)
53 TA-16	S 30 W 10	2.27	13	0.41(±0.08)
54 Pajarito Booster 2	S 30 E190	2.10	13	1.13(±0.24)
55 TA-15	S 40 E 90	2.20	13	0.43(±0.09)
56 TA-36	S 50 E160	2.11	13	0.53(±0.12)
57 TA-36	S 50 E170	2.11	4	0.90(±0.18)
58 TA-18	S 50 E200	2.06	4	1.73(±0.33)
59 TA-11	S 60 E 10	2.25	13	0.40(±0.08)
60 TA-15	S 70 E 80	2.19	4	0.48(±0.10)
61 TA-18	S 90 E150	2.10	13	0.45(±0.09)
62 TA-18	S 90 E230	2.04	13	0.47(±0.12)
63 Highway 4	S150 E250	1.98	13	0.46(±0.10)
64 Highway 4	S230 E240	1.98	13	0.55(±0.11)
65 TA-33	S250 E230	1.99	13	0.40(±0.08)
	Arith Mean:	2.15	Arith Mean[a]:	0.44

[a] Excluding stations 54, 57, and 58.

exchanged routinely every week. Two types of air pumps, with flow rates of approximately 1 and 3 ℓ/s, were used in the network. Atmospheric aerosol was collected on a 79-mm-diam polystyrene filter which was supported on a Welsh activated-charcoal respirator cartridge between the cartridge prefilter and the louvered polyethylene cover. A fraction of the total air flow (≈1 mℓ/s) was passed in parallel through a cartridge containing silica gel to adsorb atmospheric water vapor. Air flow rates through both sampling cartridges were monitored with variable-area flowmeters.

Appendix D contains a listing of concentration guides (CGs) for several radioactive species in air and water for uncontrolled and controlled areas. Referring to Fig. 3 and Table IV, monitoring stations 1 through 17, 20, 21, 23, and 26 are outside the LASL boundary, and concentrations for these locations are compared to CGs for uncontrolled areas. All other stations in Table IV, however, are within the LASL boundary where the CGs for controlled areas apply.

TABLE III

ANNUAL EXTERNAL DOSE ANALYSIS

Monitored Locations	No. of Stations	Avg Elev (km)	Annual Dose (mrad)					
					Arithmetic		Geometric	
			Min	Max	Mean	Std Dev	Mean	Std Dev[a]
Off-site, all	20	2.06	110	226	145	29	142	1.2
Off-site, all above 2 km	11	2.24	117	226	153	29	150	1.2
Off-site, all below 2 km	9	1.83	110	193	135	26	135	1.2
Perimeter, all	17	2.15	133	265	167	31	165	1.2
Perimeter, excluding #27[b]	16	2.16	133	201	161	19	161	1.1
On-site, all	28	2.15	120	632	193	105	178	1.4
On-site, excluding 3 highest[c]	25	2.16	120	238	162	26	160	1.2
Los Alamos Community[d]	11	2.22	117	226	155	28	153	1.2

[a] The geometric standard deviation σ_g is a unitless, multiplicative number.

[b] The perimeter location on Highway 4 (#27) represents a very localized area of abnormally high radiation intensity.

[c] The monitoring stations at Pajarito Booster 2 (#54), TA-36 (#57) and TA-18 (#58) are influenced by operations at TA-18.

[d] The eleven stations include 7 classified as off-site and 4 classified as perimeter along the northern boundary of the Laboratory.

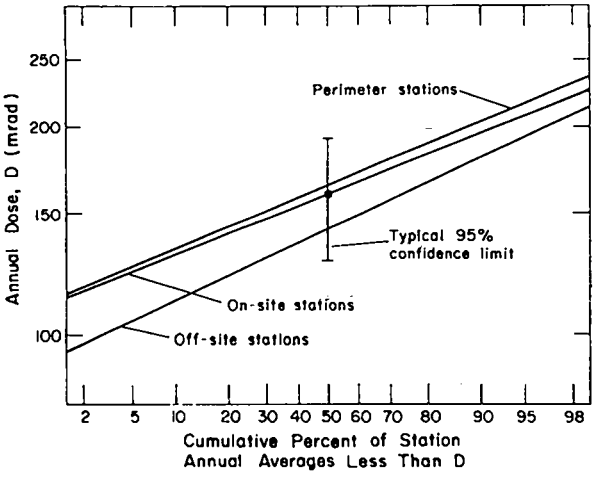

Fig. 4.
Log-normal probability distributions of TLD data.

B. Daily Radioactivity Sampling

Atmospheric radioactivity was measured daily at TA-50, N 30 E 90, with a particulate sampling system similar to those used in the weekly sampling. A daily deposition sample was collected simultaneously with a 0.4-m^2 precipitation sampler.

The daily particulate filter was counted for gross alpha and gross beta on the day of collection and again 7 to 10 days after collection. The first count would provide an early indication of any major unpredicted radioactivity release. The data from the second count were used to observe temporal variations in the long-lived radioactivity. The gross alpha and gross beta radioactivity measurements for the daily deposition sample were made on the same schedule as that of the daily particulate sample, but they were not routinely reported. The gross alpha activity data for the daily particulate samples are not presented because they did not generally exceed the MDL for this measurement.

Gross beta activity data from the second count of the daily particulate sample are shown in Fig. 5. The seasonal variations for 1973 are noteworthy and atypical of expected trends; the beta activity for 1973 was relatively low, and the characteristic spring maximum was absent. An increase in activity for December is also anomalous. However, the observed trends were confirmed by preliminary data reported for the Nevada Test Site, suggesting a

TABLE IV

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR AND URANIUM CONCENTRATIONS

		Tritiated Water Vapor ($10^{-12}\mu Ci/m\ell$)			Uranium Concentration (ng/m^3)		
Sampling Station	Coordinates	Maximum	Average	% CG	Maximum	Average	% CG
Off-site Stations:							
1 Guaje Booster 2	N220 E220	116	14(±16)[b]	0.01	0.2	0.1 (±0.1)[b]	0.001
2 Guaje Booster 1	N220 E300	42	10(±16)	0.01	0.1	0.03(±0.03)	0.0003
3 Well G-1	N200 E380	28	4(±16)	0.002	0.2	0.1 (±0.1)	0.001
4 Barranca School	N180 E130	48	12(±16)	0.01	0.2	0.1 (±0.1)	0.001
5 Arkansas Avenue	N170 E 20	46	11(±16)	0.01	0.2	0.1 (±0.1)	0.001
6 Golf Course	N160 E 60	49	13(±16)	0.01	0.2	0.1 (±0.1)	0.001
7 Well LA-3	N150 E490	30	9(±16)	0.01	0.2	0.1 (±0.1)	0.001
8 Cumbres School	N140 E130	58	14(±16)	0.01	0.2	0.1 (±0.1)	0.001
9 Diamond Drive	N130 E 20	190	14(±16)	0.01	0.2	0.1 (±0.1)	0.001
10 Fuller Lodge	N110 E 90	201	27(±18)	0.01	0.2	0.1 (±0.1)	0.001
11 White Rock STP	N 90 E390	124	18(±16)	0.01	0.3	0.2 (±0.1)	0.002
12 Pajarito Acres	S210 E370	116	16(±16)	0.01	0.2	0.1 (±0.1)	0.001
13 Bandelier HQ	S270 E190	45	12(±16)	0.01	0.2	0.2 (±0.1)	0.002
14 Española	-	219	13(±16)	0.01	0.3	0.1 (±0.1)	0.001
15 Pojoaque	-	34	6(±16)	0.003	0.3	0.1 (±0.1)	0.001
16 Santa Fe	-	135	4(±16)	0.002	0.1	0.04(±0.03)	0.0004
		Arith Mean: 12		0.01	Arith Mean: 0.11		0.001
Perimeter Stations:							
17 Airport	N110 E160	1 650	123(±40)	0.06	0.1	0.1 (±0.04)	0.001
18 Bayo STP	N110 E260	79	16(±16)	0.0003	0.3	0.1 (±0.1)	0.00005
19 TA-43	N100 E 20	70	14(±16)	0.0003	0.3	0.1 (±0.1)	0.00005
20 Acorn St.	N100 E110	169	37(±20)	0.02	0.3	0.2 (±0.1)	0.002
21 TA-3	N 80 E 10	371	35(±20)	0.02	0.2	0.1 (±0.1)	0.001
22 Well PM-1	N 30 E310	569	42(±20)	0.001	0.1	0.04(±0.03)	0.00002
23 W. Jemez Road	S 80 W 90	50	8(±16)	0.004	0.2	0.1 (±0.1)	0.001
24 TA-49	S100 E 40	1 120	32(±18)	0.001	0.1	0.1 (±0.04)	0.00005
25 Pajarito Booster 1	S100 E300	115	45(±20)	0.001	0.1	0.1 (±0.1)	0.00005
26 Bandelier Rim	S270 E200	113	22(±18)	0.01	0.1	0.1 (±0.1)	0.001
		Arith Mean: 37		0.02	Arith Mean: 0.11		0.001
On-site Stations:							
27 TA-21	N 90 E170	4 250	151(±48)	0.003	0.3	0.1 (±0.1)	0.00005
28 TA-53	N 60 E180	591	46(±22)	0.001	0.1	0.1 (±0.04)	0.00005
29 TA-6	N 40 E 20	78	17(±16)	0.0003	0.2	0.1 (±0.1)	0.00005
30 TA-52	N 20 E170	272	102(±34)	0.002	0.4	0.3 (±0.1)	0.0001
31 TA-16	S 30 W 10	68	16(±16)	0.0003	0.3	0.1 (±0.1)	0.00005
32 Pajarito Booster 2	S 30 E190	202	39(±20)	0.001	0.3	0.2 (±0.1)	0.0001
33 TA-36	S 50 E160	214	29(±18)	0.001	0.1	0.1 (±0.04)	0.00005
34 TA-11	S 60 E 10	113	13(±16)	0.0003	0.3	0.1 (±0.1)	0.00005
35 TA-15	S 70 E 80	90	21(±18)	0.0004	0.7	0.2 (±0.1)	0.0001
36 TA-33	S250 E230	280	60(±24)	0.001	0.3	0.2 (±0.1)	0.0001
		Arith Mean: 49		0.001	Arith Mean: 0.14		0.00007

[a] Converted from concentration in water vapor to total atmospheric concentration based on relative humidity.

[b] Values in parentheses indicate 95% confidence limits (± 2 S.D.).

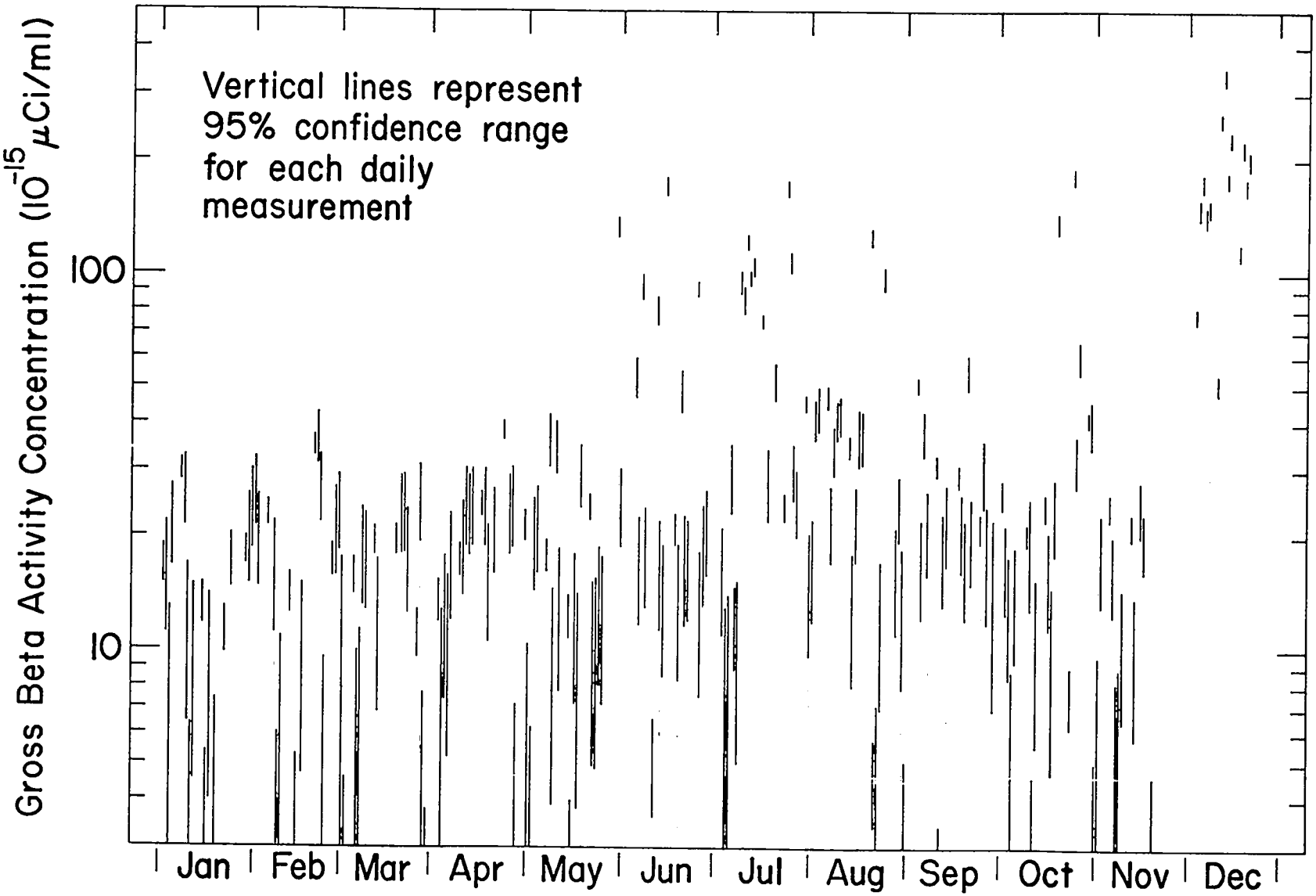

Fig. 5.
Gross beta activity concentrations in daily air samples.

more general meteorological pattern. Our atmospheric radioactivity data did not show evidence of foreign atmospheric nuclear tests.

C. Tritium

Thirty-six silica gel cartridges were analyzed each week for tritiated water. Water was distilled from each silica gel sample, and a standard aliquot of the distillate was analyzed for tritium by liquid scintillation counting. The resultant tritium activity concentration in water was then multiplied by the average absolute humidity (mass water/volume air) for the sample collection period to give the average tritiated water vapor activity concentration in air.

The weekly activity concentrations for each station were averaged for CY 73 and are presented in Table IV. Parenthetical values are the 95% confidence level errors associated with average annual concentrations. The data are grouped according to off-site, perimeter, and on-site sampling locations. The large uncertainties in concentration values at the off-site or "background" stations were due primarily to the fact that most of the values were near the MDL (Appendix C). Certain perimeter and on-site locations, e.g., Airport, TA-21, TA-52, and TA-33, were influenced by LASL tritium releases. The highest observed annual concentration for an off-site area (Airport) was 123×10^{-12} μCi/mℓ for the on-site locations, the highest value was 151×10^{-12} μCi/mℓ, measured at TA-21. These concentrations are, respectively, 0.06 and 0.08% of the CGs specified in AEC Manual Chapter 0524 for tritium in air. The tritium concentrations reported herein, as well as the CGs, are for atmospheric tritium oxide.

The distribution for the 36 annual tritium concentration averages (Fig. 6) is skewed in such a manner that it is amenable to a log-normal statistical treatment. The geometric mean for all stations is 20×10^{-12} μCi/mℓ and the geometric std dev (multiplicative) is $\sigma_g = 2.3$. By comparison, the arithmetic mean and std dev are $(30 \pm 33) \times 10^{-12}$ μCi/mℓ. Also shown in Fig. 6 is a typical uncertainty associated with the annual average concentration. The 95% confidence level uncertainty corresponds to about 80% of the measured value.

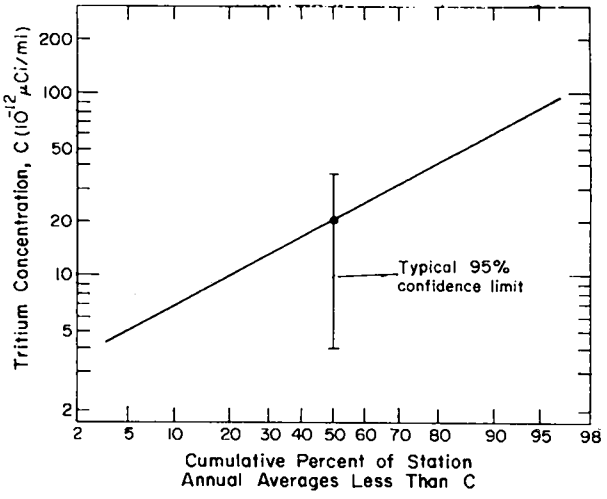

Fig. 6.
Log-normal probability distribution of atmospheric tritium concentrations.

D. Gross Radioactivity

On the first and tenth day after collection, gross alpha and gross beta activities in the weekly air filters were counted with a gas-flow proportional counter. The first count was used to screen the samples for inordinate levels of radioactivity. The second count, free from the activity of the radon and thoron daughters, provided a record of the long-lived atmospheric radioactivity. Generally, temporal variations in radioactivity for the weekly stations were similar to those for the daily station shown in Fig. 5. The average weekly gross alpha and gross beta activity concentrations for each station for CY 73 are presented in Table V. Parenthetical values are the 95% confidence level errors associated with average annual concentrations. The data are grouped according to off-site, perimeter, and on-site sampling locations. For the gross alpha activity, the 36 annual average concentrations are distributed randomly around an arithmetic mean of 1.0×10^{-15} μCi/mℓ and have a standard deviation of 0.2×10^{-15} μCi/mℓ. The spatial variation of the annual averages is not related to LASL operations. In fact, the annual average concentrations for off-site stations are typically higher than those for perimeter and on-site stations (see Table V). The highest gross alpha concentration, observed at Española, is 2.3% of the CG for an uncontrolled area (Appendix D). For the gross beta activity, the 36 annual average concentrations are also normally distributed with an arithmetic mean and standard deviation of $(38 \pm 3) \times 10^{-15}$ μCi/mℓ, and spatial variations are not related to LASL operations. The three location groups have essentially the same annual average concentration mean (see Table V). Each group had a highest observed annual concentration of 43×10^{-15} μCi/mℓ, which is only 0.14% of the CG for gross beta activity in an uncontrolled area and 0.004% of the CG for a controlled area (Appendix D).

TABLE V

ANNUAL ATMOSPHERIC GROSS ALPHA AND GROSS BETA ACTIVITY CONCENTRATIONS

Sampling Station		Gross Alpha Concentrations (10^{-15} μCi/mℓ)			Gross Beta Concentrations (10^{-15} μCi/mℓ)		
Location	Coordinates	Maximum	Average	%CG	Maximum	Average	%CG
Off-site Stations:							
1 Guaje Booster 2	N220 E220	2.6	1.3(±0.5)	2.2	111	39(±7)	0.13
2 Guaje Booster 1	N220 E300	1.1	0.7(±0.4)	1.2	74	32(±6)	0.11
3 Well G-1	N200 E380	2.3	1.3(±0.4)	2.2	127	39(±7)	0.13
4 Barranca School	N180 E130	1.9	1.0(±0.4)	1.7	127	39(±7)	0.13
5 Arkansas Ave.	N170 E 20	2.0	1.0(±0.4)	1.7	89	39(±7)	0.13
6 Golf Course	N160 E 60	2.6	1.2(±0.4)	2.0	91	40(±7)	0.13
7 Well LA-3	N150 E490	2.3	1.2(±0.4)	2.0	127	43(±8)	0.14
8 Cumbres School	N140 E130	3.4	1.3(±0.4)	2.2	116	41(±7)	0.14
9 Diamond Drive	N130 E 20	4.1	1.3(±0.4)	2.2	151	38(±7)	0.13
10 Fuller Lodge	N110 E 90	2.9	1.2(±0.4)	2.0	164	42(±8)	0.14
11 White Rock STP	S 90 E390	2.6	1.3(±0.4)	2.2	85	41(±7)	0.14
12 Pajarito Acres	S210 E370	2.9	1.0(±0.4)	1.7	85	38(±7)	0.13
13 Bandelier HQ	S270 E190	2.2	1.2(±0.4)	2.0	87	41(±7)	0.14
14 Española	-	3.1	1.4(±0.4)	2.3	85	41(±7)	0.14
15 Pojoaque	-	3.3	1.2(±0.4)	2.0	72	36(±6)	0.12
16 Santa Fe	-	2.4	0.9(±0.4)	1.5	163	34(±6)	0.11
		Arith Mean: 1.16		1.9	Arith Mean: 39		0.13
Perimeter Stations:							
17 L. A. Airport	N110 E160	1.7	0.8(±0.4)	1.3	80	32(±6)	0.11
18 Bayo STP	N110 E260	4.1	1.1(±0.4)	0.06	138	43(±8)	0.004
19 TA-43	N100 E 20	2.4	1.2(±0.4)	0.06	180	43(±8)	0.004
20 Acorn St.	N100 E110	1.8	0.9(±0.4)	1.5	99	38(±7)	0.13
21 TA-3	N 80 E 10	4.4	1.2(±0.4)	2.0	142	40(±7)	0.13
22 Well PM-1	N 30 E310	1.7	0.8(±0.4)	0.04	110	36(±6)	0.004
23 W. Jemez Road	S 80 W490	1.9	0.9(±0.4)	1.5	85	37(±7)	0.12
24 TA-49	S100 E 40	4.4	0.9(±0.4)	0.05	77	34(±6)	0.003
25 Paj. Booster 1	S100 E300	2.1	1.0(±0.4)	0.05	90	40(±7)	0.004
26 Bandelier Rim	S270 E200	2.0	1.0(±0.4)	1.7	86	39(±7)	0.13
		Arith Mean: 0.98		1.6	Arith Mean: 38		0.13
On-site Stations:							
27 TA-21	N 90 E170	1.8	0.8(±0.4)	0.04	77	36(±6)	0.004
28 TA-53	N 60 E180	1.5	0.9(±0.4)	0.05	95	35(±6)	0.004
29 TA-6	N 40 E 20	1.7	0.9(±0.4)	0.05	131	37(±7)	0.004
30 TA-52	N 20 E170	2.8	0.9(±0.4)	0.05	81	36(±6)	0.004
31 TA-16	S 30 W 10	4.0	1.1(±0.4)	0.06	134	42(±7)	0.004
32 Paj. Booster 2	S 30 E190	2.0	1.2(±0.4)	0.06	85	37(±7)	0.004
33 TA-36	S 50 E160	1.8	0.7(±0.4)	0.04	78	34(±6)	0.003
34 TA-11	S 60 E 10	2.0	1.1(±0.4)	0.06	128	43(±8)	0.004
35 TA-15	S 70 E 80	3.3	0.8(±0.4)	0.04	81	33(±6)	0.003
36 TA-33	S250 E230	2.3	1.1(±0.4)	0.06	88	42(±7)	0.004
		Arith Mean: 0.95		0.05	Arith Mean: 38		0.004

E. Plutonium and Americium

After being measured for gross alpha and gross beta activities, the weekly filters for each station were combined and dissolved to produce composite 4-wk samples for each station. An aliquot of each sample was saved for uranium analysis, and plutonium was separated by anion exchange from the remaining solution. For 12 selected stations, the eluent solutions from the plutonium separation were combined to represent 13-wk samples. Americium was then separated from these twelve 13-wk samples via cation exchange. The purified plutonium and americium were separately electrodeposited and counted for alpha-particle emission with a solid-state alpha-detection system. Alpha-particle energy groups associated with the decay of ^{238}Pu, ^{239}Pu, and ^{241}Am were then integrated, and the concentration of each radionuclide in its respective air sample was calculated.

The annual average 4-wk ^{238}Pu and ^{239}Pu concentrations for each station are listed in Table VI according to off-site, perimeter, and on-site sampling locations. Parenthetical values are the 95% confidence level errors associated with average annual concentrations. For both ^{238}Pu and ^{239}Pu, the asymmetric distributions of annual average concentrations can be described log-normally, as shown in Fig. 7. The range of values observed for the 36 stations, and typical uncertainties associated with the observed annual average ^{238}Pu and ^{239}Pu concentrations, are shown in Fig. 7. In both cases, the 95% confidence level uncertainties are about 20% of the observed values. For ^{238}Pu annual concentrations, the geometric mean for all stations is 9×10^{-18} μCi/mℓ and σ_g is 2.3. The geometric means (see Table VI) for each of the three location groups are comparable, suggesting no major spatial variation in ^{238}Pu concentration. However, increased concentrations at TA-3 and Fuller Lodge, for example, apparently result from LASL operations. The highest observed annual concentration, at TA-3, is 0.12% of the CG for an uncontrolled area (Appendix D). The trends observed for ^{239}Pu concentrations are similar to those observed for ^{238}Pu. The geometric mean of annual average ^{239}Pu concentrations for all stations is 17×10^{-18} μCi/mℓ and σ_g is 1.8. The geometric means for the location groups (Table VI) do not suggest significant spatial variation for ^{239}Pu concentration. The highest annual concentrations, observed at Arkansas Ave. and TA-3, are 0.09% of the CG for ^{239}Pu in an uncontrolled area (Appendix D).

The annual average 13-wk ^{241}Am concentrations for each of the 12 selected stations are shown in Table VI. Not only is there a wide variation in the data, but the 95% confidence level uncertainties associated with the concentrations are high. Therefore, no attempt was made to analyze the ^{241}Am data statistically as was done for ^{238}Pu and ^{239}Pu. The highest observed annual average concentration of ^{241}Am was 0.01% of the CG for an uncontrolled area (Appendix D).

F. Uranium

For each of the 36 stations, an air-filter sample was composited with aliquots from the plutonium-americium procedure to represent a 13-wk sampling period. The uranium content of the sample was determined by fluorometric techniques to obtain quarterly atmospheric uranium concentrations. The 13-wk annual averages for each station are listed in Table IV. The fluorometric analysis, of course, does not differentiate isotopes of uranium, and the annual average concentrations are given in ng/m^3. The concentration values in general do not exceed the MDL for the measurement and are not amenable to statistical analysis. The highest observed annual concentration of 0.3 ng/m^3, at TA-52, is 0.0001% of the CG for natural uranium in a controlled area (Appendix D). Although the isotopic composition of the uranium is unknown, the total uranium in LASL release is not drastically different from natural uranium in isotopic composition.

G. Summary

Table VII summarizes the results of the atmospheric radioactivity monitoring program for CY 73.

VI. RADIOACTIVITY IN SURFACE AND GROUND WATERS

A. Overview

The monitoring of radioactivity in surface and ground waters provides surveillance of LASL operations. Water samples were obtained from a network which includes (a) regional water sources within 75 km of LASL, (b) perimeter sources within 5 km of the LASL boundary, (c) Los Alamos water supply system, and (d) LASL on-site sources. The water samples were analyzed radiochemically for ^{238}Pu, ^{239}Pu, tritium (HTO), and ^{137}Cs activities as well as for gross alpha, beta, and gamma activities. A fluorometric technique was used to measure uranium concentrations. Americium-241 was determined radiochemically for selected samples from LASL effluent release areas.

TABLE VI

ANNUAL ATMOSPHERIC ^{238}Pu, ^{239}Pu, AND ^{241}Am CONCENTRATIONS

Sampling Station		^{238}Pu Concentration($10^{-18}\mu Ci/m\ell$)			^{239}Pu Concentration($10^{-18}\mu Ci/m\ell$)			^{241}Am Concentration($10^{-18}\mu Ci/m\ell$)		
Location	Coordinates	Maximum	Average	% CG	Maximum	Average	% CG	Maximum	Average	% CG
Off-site Stations:										
1 Guaje Booster 2	N220 E220	370	42(±10)	0.06	68	29(± 7)	0.05			
2 Guaje Booster 1	N220 E300	15	4(± 1)	0.01	27	10(± 2)	0.02			
3 Well G-1	N200 E380	36	13(± 4)	0.02	31	13(± 4)	0.02			
4 Barranca School	N180 E130	43	8(± 2)	0.01	482	54(±40)	0.09	139	26(± 5)	0.01
5 Arkansas Avenue	N170 E 20	32	9(± 2)	0.01	395	54(±10)	0.09	6	5(± 2)	0.002
6 Golf Course	N160 E 60	15	6(± 2)	0.01	40	14(± 3)	0.02			
7 Well LA-3	N150 E490	19	5(± 2)	0.01	36	11(± 3)	0.02			
8 Cumbres School	N140 E130	21	10(± 3)	0.01	264	46(± 9)	0.08	5	2(± 5)	0.001
9 Diamond Drive	N130 E 20	406	40(± 8)	0.06	55	17(± 4)	0.03			
10 Fuller Lodge	N110 E 90	719	68(±13)	0.10	48	20(± 4)	0.03			
11 White Rock STP	S 90 E390	30	8(± 2)	0.01	56	14(± 3)	0.02	7	5(± 4)	0.002
12 Pajarito Acres	S210 E370	11	6(± 2)	0.01	22	9(± 2)	0.02			
13 Bandelier HQ	S270 E190	24	7(± 2)	0.01	26	10(± 2)	0.02			
14 Española		49	10(± 2)	0.01	24	10(± 2)	0.02			
15 Pojoaque		7	4(± 1)	0.01	31	10(± 2)	0.02			
16 Santa Fe		7	2(± 1)	0.003	21	8(± 2)	0.01	4	4(± 1)	0.002
		Arith Mean: 15		0.02	Arith Mean: 21		0.04			
Perimeter Stations:										
17 L. A. Airport	N110 E160	177	19(± 3)	0.03	186	44(± 7)	0.07			
18 Bayo STP	N110 E260	31	9(± 3)	0.0005	68	28(± 5)	0.001	3	3(± 3)	0.00005
19 TA-43	N100 E 20	73	21(± 5)	0.001	135	31(± 6)	0.002			
20 Acorn St.	N100 E110	45	10(± 3)	0.02	118	28(± 5)	0.05	9	4(± 1)	0.002
21 TA-3	N 80 E 10	659	86(±16)	0.12	221	53(±10)	0.09	11	7(± 3)	0.004
22 Well PM-1	N 30 E310	22	5(± 1)	0.0003	57	13(± 3)	0.0007			
23 W. Jemez Road	S 80 W 90	13	5(± 2)	0.01	129	26(± 5)	0.04			
24 TA-49	S100 E 40	23	6(± 2)	0.0003	69	13(± 3)	0.0007			
25 Pajarito Booster 1	S100 E300	78	10(± 8)	0.0005	37	13(± 6)	0.0007			
26 Bandelier Rim	S270 E200	9	4(± 2)	0.01	37	10(± 2)	0.02			
		Arith Mean: 18		0.03	Arith Mean: 26		0.04			
On-site Stations:										
27 TA-21	N 90 E170	31	7(± 2)	0.0004	59	16(± 3)	0.0008			
28 TA-53	N 60 E180	10	3(± 1)	0.0002	18	8(± 2)	0.0004	2	2(± 1)	0.00003
29 TA-6	N 40 E 20	56	14(± 3)	0.0007	82	24(± 9)	0.001			
30 TA-52	N 20 E170	21	7(± 2)	0.0004	104	12(± 2)	0.0006			
31 TA-16	S 30 W 10	36	10(± 3)	0.0005	83	18(± 4)	0.0009	4	3(± 2)	0.00005
32 Pajarito Booster 2	S 30 E190	260	30(± 6)	0.002	77	20(± 4)	0.001	23	12(± 3)	0.0002
33 TA-36	S 50 E160	16	6(± 1)	0.0003	60	16(± 3)	0.0008			
34 TA-11	S 60 E 10	21	7(± 2)	0.0004	53	16(± 4)	0.0008			
35 TA-15	S 70 E 80	36	6(± 2)	0.0003	33	10(± 2)	0.0005	4	2(± 1)	0.00003
36 TA-33	S250 E230	13	6(± 2)	0.0003	27	11(± 3)	0.0006			
		Arith Mean: 10		0.0005	Arith Mean: 15		0.0008			

The plutonium analyses performed on these samples deserve special mention. Plutonium concentrations reported for many of the sampling stations are highly suspect because there exists a cross-contamination and/or effluent-contamination problem in the analytical laboratory. Plutonium concentrations are reported, however, even though they may not be representative of the actual contamination in the sampled waters. Efforts are being made to eliminate these analysis contaminations.

B. Regional Surface Waters

Streams and reservoirs within about 75 km of LASL were sampled routinely to ascertain normal levels of

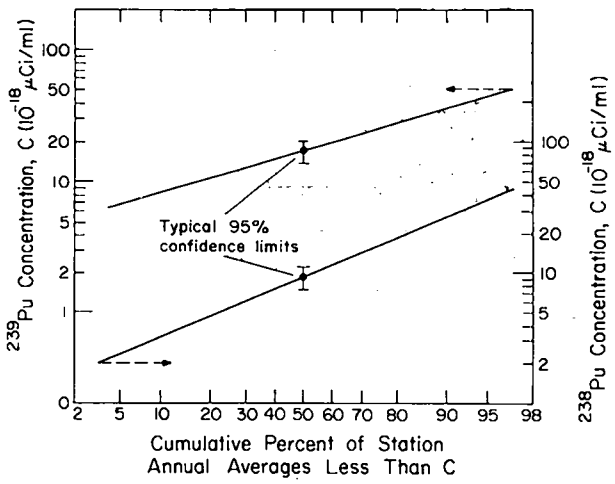

Fig. 7.
Log-normal probability distributions of airborne plutonium concentrations.

radioactivity in waters of the area. Locations of the regional sampling stations are given in Table VIII and Fig. 8. The radioactivity concentration ranges and averages determined for 19 samples are given in Table IX. Plutonium-238 concentrations for Embudo, 120 (±50), and Jemez Creek, 70 (±30) x 10^{-12} µCi/mℓ, as well as ^{239}Pu concentrations for Chamita, 210 (±70), Embudo, 690 (±120), Otowi, 820 (±140), Cochiti, 590 (±120), Fenton Lake 210 (±70), and Santa Cruz Reservoir, 190 (±80) x 10^{-12} µCi/mℓ were suspect. These levels exceed concentrations expected from global fallout, yet it is highly improbable that they resulted from LASL operations. Contamination of the samples during analysis is a more realistic explanation. All other data fall within expected ranges for background radioactivity concentrations, and all concentrations were well below the CGs given in Appendix D.

C. Perimeter Surface and Ground Waters

Samples were collected from perimeter surface and ground water sources located ≲5 km outside the LASL boundary. Six of these stations are located on the Pajarito Plateau and 24 are in White Rock Canyon (exact locations are given in Table VIII and Figs. 9 and 10). Radioactivity concentration data for 40 perimeter samples are presented in Table IX. Again, certain anomalous plutonium concentrations probably result from contamination in the analytical laboratory. In all cases, concentrations were well below CGs.

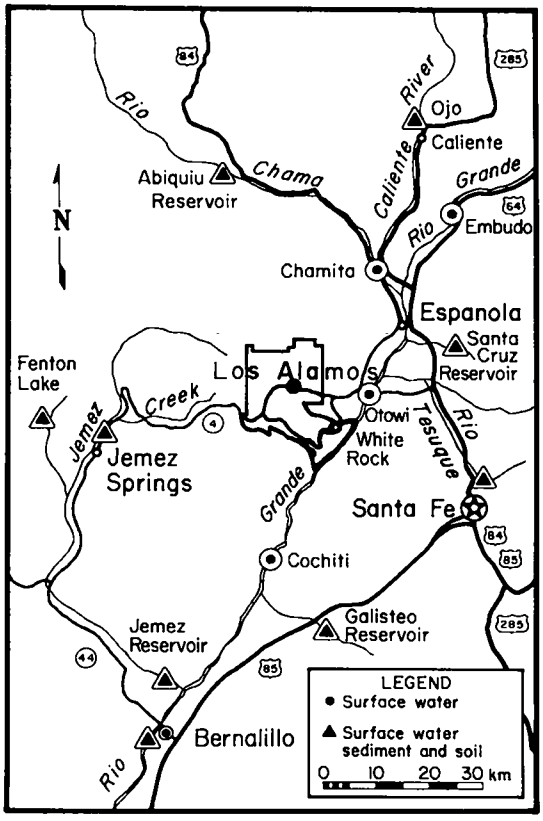

Fig. 8.
Regional surface water, sediment, and soil sampling locations.

D. Los Alamos Water Supply System

Radioactivity concentrations were determined for the 16 wells and 1 gallery of the Los Alamos water supply system. The locations of these stations are given in Table VIII and Fig. 10. Plutonium-239 was detected in the trace amounts, 120 (±70), 110 (±50), and 120 (±90) x 10^{-12} µCi/mℓ, in samples from wells LA-1B, LA-4, and PM-2, respectively. However, average plutonium concentrations are comparable to the minimum detection limits of the analyses. The radioactivity concentration data for 33 samples are presented in Table IX. In all cases, concentrations were well below CGs.

E. On-Site Surface and Ground Waters

Radioactivity concentrations were determined in water samples from five on-site locations that are not Laboratory effluent release areas. In addition, samples were

TABLE VII

SUMMARY OF ANNUAL ATOMSPHERIC RADIOACTIVITY MONITORING

Number and Type of Sampling Locations	Type of Analysis Performed	Time Period per Composite Sample[a]	Number of Samples Analyzed	Mean Radioactivity Concentration[b]	%CG
16 off-site	gross α	1 week	797	1.2 10^{-15} μCi/mℓ	1.9
10 perimeter			516	1.0 10^{-15} μCi/mℓ	1.6
10 on-site			514	1.0 10^{-15} μCi/mℓ	0.05
16 off-site	gross β	1 week	807	39 10^{-15} μCi/mℓ	0.13
10 perimeter			516	38 10^{-15} μCi/mℓ	0.13
10 on-site			511	38 10^{-15} μCi/mℓ	0.004
16 off-site	tritiated H_2O	1 week	719	12 10^{-12} μCi/mℓ	0.01
10 perimeter			494	37 10^{-12} μCi/mℓ	0.02
10 on-site			485	49 10^{-12} μCi/mℓ	0.001
16 off-site	^{238}Pu	1 month	189	15 10^{-18} μCi/mℓ	0.01
10 perimeter			119	18 10^{-18} μCi/mℓ	0.02
10 on-site			118	10 10^{-18} μCi/mℓ	0.0004
16 off-site	^{239}Pu	1 month	189	21 10^{-18} μCi/mℓ	0.03
10 perimeter			119	26 10^{-18} μCi/mℓ	0.04
10 on-site			118	15 10^{-18} μCi/mℓ	0.0007
5 off-site	^{241}Am	3 month	12	8 10^{-18} μCi/mℓ	0.004
3 perimeter			8	5 10^{-18} μCi/mℓ	0.002
4 on-site			12	5 10^{-18} μCi/mℓ	0.0001
16 off-site	uranium	3 month	64	0.11 ng/m³	0.001
10 perimeter			40	0.11 ng/m³	0.001
10 on-site			40	0.14 ng/m³	0.0001

[a]For each station, weekly air filters are composited to represent the tabulated sampling period.

[b]From the annual average radioactivity concentrations for each station, the mean is tabulated for each location group.

analyzed from 24 locations in past and present Laboratory effluent release areas. Effluent release area samples were obtained from Acid-Pueblo Canyon (formerly LASL, AEC property), Sandia Canyon, DP-Los Alamos Canyon, and Mortandad Canyon. Surface and ground waters in these canyons are not a source of domestic or municipal supply, nor do the streams in these canyons reach the Rio Grande. The on-site water sampling locations are given in Tables VIII and X and Fig. 10. Table X presents the radioactivity concentration data for each location according to non-disposal and effluent areas.

The radioactivity concentrations observed in Acid-Pueblo Canyon resulted from effluents released in the canyon before 1964. Observations indicated no significant change in radioactivity concentrations compared to previous reporting periods.[1] The concentrations in Sandia Canyon water were also similar to previous observations, except for one ^{238}Pu concentration of 220 (±60) x 10^{-12} μCi/mℓ at station SCS-2.

Surface water samples from DP-Los Alamos Canyon reflected the release of industrial effluents from the treatment plant at TA-21. Except for ^{137}Cs, all radioactivity in surface waters of DP Canyon was above background concentrations. Los Alamos Canyon observation holes LAO-2, LAO-3, and LAO-4.5, which are below the confluence with DP Canyon, showed observable radioactivity which decreased with downstream distance. The surface and ground waters of Mortandad Canyon gave evidence of

TABLE VIII

WATER SAMPLING STATIONS

Designation	Location
Regional Water Sources:	
Abiquiu Res.	44 km NNW of L. A.
Caliente River	55 km NNE of L. A.
Chamita	25 km NE of L. A.
Embudo	45 km NE of L. A.
Santa Cruz Res.	32 km ENE of L. A.
Otowi	16 km E of L. A.
Tesuque Creek	40 km SE of L. A.
Galisteo Res.	48 km SSE of L. A.
Cochiti	35 km S of L. A.
Bernalillo	73 km SSW of L. A.
Jemez Res.	60 km SSW of L. A.
Jemez Creek	38 km WSW of L. A.
Fenton Lake	50 km WSW of L. A.
LASL Perimeter Sources:	
Los Alamos Res.	N105 W 75
Guaje Canyon	N215 E315
Test Well 2	N115 E260
Basalt Spring	N 65 E395
Los Alamos Spring	N 60 E405
Frijoles Canyon	S280 E195
White Rock Canyon, Rio Grande River	(24 locations, see Fig. 9)

Designation	Location
Los Alamos Supply System:	
Well LA-1B	15 km E of L. A.
Well LA-2	15 km E of L. A.
Well LA-3	14 km E of L. A.
Well LA-4	12 km E of L. A.
Well LA-5	13 km E of L. A.
Well LA-6	13 km E of L. A.
Well G-1	N200 E375
Well G-1A	N205 E365
Well G-2	N210 E350
Well G-3	N220 E340
Well G-4	N210 E310
Well G-5	N235 E295
Well G-6	N215 E265
Well PM-1	N 35 E305
Well PM-2	S 65 E205
Well PM-33	S 45 E255
Water Canyon Gallery	S 50 W110
LASL On-site Sources:	
Non-effluent release areas:	
Test Well 3	N 80 E210
Cañada del Buey	N 5 E165
Pajarito Canyon	S 60 E225
Water Canyon	S 90 E 90
Test Well DT-5A	S110 E 90
Effluent release areas:	(24 locations, see Fig. 10 and Table X.)

the radioactive effluent released from the industrial waste treatment plant at TA-50. The concentrations of most radionuclides generally decreased with distance down the canyon. Tritium concentrations, however, varied erratically along the length of the canyon.

VII. RADIOACTIVITY IN LIQUID EFFLUENTS, SEDIMENTS, AND SOILS

A. Industrial Wastes

Industrial wastes are collected separately from domestic wastes and treated at one of two plants (TA-21-257 and TA-50-1). The treated wastes are retained in holding tanks until analyzed and are released only when the CGs for release to uncontrolled areas are not exceeded. A composite of each week's total effluents is later analyzed for radioisotopes of concern to determine the total activity of each discharged. The total activity of each isotope and the total volumes discharged were used to calculate the annual average concentrations shown in Table XI.

B. Domestic Wastes

The effluents from the technical area and municipal sewage plants (Fig. 10) were analyzed for radionuclides twice during 1973. The municipal plants were included to provide background data with which the technical area

TABLE IX

RADIOACTIVITY IN REGIONAL, PERIMETER, AND LOS ALAMOS WATER SOURCES

	Number of Samples	Type of Activity	Units	Min	Max	Avg	%CG
Regional Surface Water Sources:	19	^{3}H	10^{-6} μCi/mℓ	- 0.1 (< 0.3)[a]	1.3 (± 0.6)[a]	0.6 (± 0.6)[a]	0.02
	19	^{137}Cs	10^{-6} μCi/mℓ	- 0.02(< 0.03)	0.05(± 0.09)	0.02(± 0.07)	0.1
	19	^{238}Pu	10^{-12} μCi/mℓ	- 9 (< 4)	120 (± 50)	40 (±30)	0.0008
	19	^{239}Pu	10^{-12} μCi/mℓ	- 7 (< 5)	820 (±140)	140 (±40)	0.003
	19	U, total	ng/ℓ	< 13	780	76	0.0001
	19	Gross α	10^{-9} μCi/mℓ	- 0.2 (< 0.3)	3.8 (± 0.8)	1.0 (± 0.6)	0.02
	19	Gross β	10^{-9} μCi/mℓ	- 1.8 (< 0.5)	5 (± 1)	1 (± 1)	0.3
Perimeter Surface and Ground Water Sources:	40	^{3}H	10^{-6} μCi/mℓ	- 0.6 (< 0.3)	1.0 (± 1.0)	0.2 (± 0.6)	0.007
	39	^{137}Cs	10^{-6} μCi/mℓ	- 0.04(< 0.03)	0.09(± 0.10)	0.03(± 0.04)	0.2
	40	^{238}Pu	10^{-12} μCi/mℓ	- 8 (<144)	170 (± 60)	20 (±20)	0.0004
	40	^{239}Pu	10^{-12} μCi/mℓ	- 20 (< 30)	50 (± 60)	10 (±30)	0.0002
	40	U, total	ng/ℓ	< 13	1 300	78	0.0001
	40	Gross α	10^{-9} μCi/mℓ	- 0.04(< 0.13)	7.3 (± 0.8)	1.0 (± 0.6)	0.02
	40	Gross β	10^{-9} μCi/mℓ	- 0.11(< 0.5)	22 (± 1.4)	3.5 (± 1.0)	1.2
Los Alamos Water Supply Sources:	33	^{3}H	10^{-6} μCi/mℓ	- 0.3 (< 0.4)	0.7 (± 0.8)	0.1 (± 0.8)	0.003
	33	^{137}Cs	10^{-6} μCi/mℓ	- 0.02(< 0.07)	0.3 (± 0.1)	0.1 (± 0.1)	0.5
	33	^{238}Pu	10^{-12} μCi/mℓ	0 (< 6)	90 (± 40)	20 (±30)	0.0004
	33	^{239}Pu	10^{-12} μCi/mℓ	- 6 (< 10)	120 (± 90)	20 (±30)	0.0004
	33	U, total	ng/ℓ	< 13	1 300	80	0.0001
	33	Gross α	10^{-9} μCi/mℓ	- 0.6 (< 0.3)	8 (± 2)	2 (± 1)	0.04
	33	Gross β	10^{-9} μCi/mℓ	0.1 (< 3)	7 (± 1)	3 (± 1)	1.0

[a] Values in brackets represent either (< MDL) or (± 2 S.D.)

plants' concentrations could be compared. Concentrations in the municipal plant effluents (Table XII) were lower than for the previous year. No previous data are available for the technical area plants.

The plants' influents and effluents were also sampled routinely to detect any accidental release of radioactive wastes to the domestic waste collection system. Samples were collected twice a week and analyzed for gross alpha and gross beta concentrations. No detectable releases occurred during 1973.

Septic tanks at isolated TAs were not sampled, but recently installed sampling boxes will permit sampling of these tanks.

C. Soil and Sediment Sampling Procedures

Soil samples were collected by taking five plugs, 75-mm diam and 50 mm deep, at the center and corners of a 10-m-square area. The five plugs were combined to form a composite sample for radiochemical analysis.

Sediment samples were collected from dune build-up behind boulders in the main channels of perennially flowing streams. Samples from the beds of intermittently flowing streams were collected across the main channel to a depth of 20 mm with a 75-mm-wide scoop.

The soil and sediment samples were analyzed for gross alpha and beta activities, cesium, and plutonium. Moisture distilled from the soil samples was analyzed for tritium.

TABLE X

RADIOACTIVITY IN ON-SITE SURFACE AND GROUND WATER SOURCES

Sampling Locations		No. & Type[a]	Average Radioactivity Concentrations[b]							
			^{3}H	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am	Gross α	Gross β	U[c]
Name and Coordinates			$10^{-6}\mu Ci/ml$	$10^{-6}\mu Ci/ml$	$10^{-9}\mu Ci/ml$	$10^{-9}\mu Ci/ml$	$10^{-9}\mu Ci/ml$	$10^{-9}\mu Ci/ml$	$10^{-9}\mu Ci/ml$	(μg/ℓ)
Non-disposal areas:										
Test Well 3	N 80 E210	1-G	0.3 (<0.3)	-0.02(<0.3)	0.02(<0.05)	0.01(<0.05)	-	0.1 (<0.3)	-1(< 3)	<0.01
Cañada del Buey	N 5 E165	1-S	2.5 (±0.6)	0.07(<0.3)	0.01(<0.05)	0 (<0.05)	-	0.5 (±0.6)	7(± 2)	<0.01
Pajarito Canyon	S 60 E225	1-S	2.3 (±0.6)	0.1 (<0.3)	0.06(<0.06)	0.03(<0.05)	-	0.2 (<0.3)	4(± 2)	0.02
Water Canyon	S 90 E 90	1-S	1.3 (±0.6)	0.3 (<0.3)	0.04(<0.05)	0 (<0.05)	-	0.3 (<0.3)	1(< 3)	0.05
Test Well DT-5A	S110 E 90	1-G	-	0.05(<0.3)	0.02(<0.05)	0.02(<0.05)	-	-0.1 (<0.3)	11(± 1)	<0.01
Acid-Pueblo Canyon (formerly AEC-LASL property):										
Acid Weir	N130 E 60	2-S	1.4 (±0.6)	0.01(<0.3)	0.05(±0.03)	0.2 (±0.2)	-	4.6 (±1.2)	86(± 3)	0.07
Pueblo 1	N130 E 65	2-S	0.3 (<0.3)	0.0 (<0.3)	0.09(±0.02)	0.33(±0.06)	-	0.9 (±0.8)	21(± 1)	0.06
Pueblo 2	N120 E160	2-S	-0.1 (<0.3)	0.02(<0.3)	0.1 (±0.07)	0.7 (±0.2)	-	1.1 (±0.6)	14(± 2)	0.02
Obs. Hole PO-3B	N110 E245	1-G	13 (±1)	-0.01(<0.3)	0.05(±0.04)	1.5 (±0.4)	-	1.8 (±1.0)	10(± 2)	0.07
Hamilton Bend Spring	N110 E250	2-G	0.7 (±0.6)	0.01(<0.3)	0.16(±0.02)	0.01(<0.05)	-	4.3 (±1.0)	14(± 2)	<0.01
Pueblo 3	N 85 E315	2-S	0.7 (±0.6)	0.01(<0.3)	6.8 (±0.1)	0.21(±0.06)	-	0.6 (±0.6)	14(± 2)	0.02
Sandia Canyon:										
SCS-1	N 80 E 40	4-S	2.5 (±0.8)	0.05(<0.2)	0.02(±0.03)	0.01(±0.05)	0.59(±0.03)	1.2 (±0.8)	12(± 1)	0.17
SCS-2	N 55 E 60	3-S	3.6 (±0.8)	0.03(<0.2)	0.10(±0.04)	0.04(±0.02)	0.03(±0.03)	1.8 (±0.8)	32(± 1)	0.28
DP-Los Alamos Canyon:										
DPS-1	N 95 E160	3-S	88 (±3)	0.05(<0.2)	2.9 (±0.3)	10.1 (±0.8)	9 (±2)	18 (±2)	462(± 6)	0.04
DPS-4	N 80 E205	4-S	49 (±1)	0.01(<0.2)	0.03(±0.03)	0.09(±0.04)	0.14(±0.05)	1.6 (±0.7)	294(± 6)	0.2
Obs. Hole LAO-C	N 90 E 70	3-G	1.3 (±0.8)	0.04(<0.2)	0.05(±0.04)	0.01(<0.02)	0.2 (<0.3)	1.1 (±0.8)	3(± 1)	0.05
Obs. Hole LAO-1	N 85 E130	5-G	12 (±1)	-0.01(<0.2)	0.02(±0.02)	0.04(±0.03)	0.17(±0.06)	1.6 (±0.9)	140(± 2)	<0.01
Obs. Hole LAO-2	N 75 E205	4-G	38 (±2)	0.02(<0.2)	0.05(±0.04)	0.05(±0.04)	0.08(±0.06)	6 (±1)	294(± 2)	0.02
Obs. Hole LAO-3	N 80 E215	5-G	32 (±2)	0.05(<0.2)	0.06(±0.04)	0.05(±0.03)	0.2 (±0.2)	2 (±1)	47(± 2)	0.05
Obs. Hole LAO-4.5	N 65 E270	4-G	22 (±1)	0.02(<0.2)	0.05(±0.04)	0.03(±0.03)	0.8 (±0.04)	1 (±1)	8(± 1)	0.04
Mortandad Canyon:										
Gaging Station 1	N 50 E 95	3-S	24 (±1)	1.9 (±0.1)	8.2 (±0.7)	0.58(±0.09)	65.6 (±0.2)	63 (±13)	2 320(±20)	0.36
MCS-3.9	N 45 E125	3-S	58 (±2)	0.04(<0.2)	5.5 (±0.5)	0.25(±0.02)	4.5 (±0.6)	17 (±2)	308(± 6)	0.85
Obs. Hole MCO-3	N 45 E105	3-G	99 (±2)	0.01(<0.2)	7.9 (±0.7)	0.46(±0.09)	-	29 (±2)	343(± 5)	0.50
Obs. Hole MCO-4	N 45 E135	3-G	65 (±2)	0.05(<0.2)	2.5 (±0.2)	0.38(±0.07)	2.4 (±0.4)	7 (±1)	18(± 3)	1.04
Obs. Hole MCO-5	N 45 E145	3-G	51 (±2)	0.03(<0.2)	2.3 (±0.2)	0.17(±0.04)	6.2 (±0.7)	6 (±1)	50(± 2)	0.26
Obs. Hole MCO-6	N 40 E155	3-G	48 (±2)	0.01(<0.2)	0.8 (±0.1)	0.3 (±0.1)	4 (±1)	5 (±1)	47(± 2)	0.58
Obs. Hole MCO-7	N 35 E170	4-G	53 (±2)	0.08(<0.2)	0.13(±0.04)	0.01(<0.02)	0.80(±0.07)	2.6 (±0.9)	43(± 2)	0.55
Obs. Hole MCO-7.5	N 30 E190	3-G	61 (±3)	0.05(<0.2)	0.10(±0.04)	0.05(±0.04)	0.44(±0.06)	3 (±1)	46(± 2)	0.81
Obs. Hole MCO-8	N 30 E205	3-G	84 (±3)	0.05(<0.2)	0.93(±0.04)	0.01(<0.02)	0.66(±0.09)	0.8 (±0.6)	33(± 2)	0.15

[a] Number of samples collected during the year and type of source: G = ground water; S = surface water.

[b] Values preceding the brackets are the actual data obtained; values within the brackets indicate either (±2 S.D.) or (<MDL).

[c] Confidence limits were not determined for uranium determinations because of the small numbers of samples and the different type of statistics involved.

D. Regional Soils and Sediments

Soil and sediment samples, collected in the same general locations as the regional water samples shown in Fig. 8, were analyzed to provide data on the normal concentrations of radioactive materials in the environment beyond the range of possible influence by LASL operations (Table XIII).

E. Los Alamos Soils and Sediments

Soil and sediment samples were collected in the general vicinity of the Laboratory and Los Alamos County, as shown in Fig. 10, and data from these samples are listed in Table XIV. The radioactivity concentrations measured in soil at off-site locations were within the expected range for contamination from global fallout. Two on-site soil

TABLE XI

RADIOACTIVITY IN EFFLUENTS FROM INDUSTRIAL WASTE TREATMENT FACILITIES

Facility (Location):		TA-50-1 (N 30 E 93)		TA-21-257 (N 82 E169)	
Total Volume Discharged (Receiving Canyon):		53.7 Mℓ (Mortandad)		5.4 Mℓ (DP-Los Alamos)	
Type of Activity	MDL[a]	Total Annual Release	Avg. Annual Concentration	Total Annual Release	Avg. Annual Concentration
^{3}H	0.5×10^{-6} μCi/mℓ	17.5 Ci	325×10^{-6} μCi/mℓ	1.5 Ci	260×10^{-6} μCi/mℓ
^{89}Sr	5×10^{-9} μCi/mℓ	4.6 mCi	85×10^{-9} μCi/mℓ	0.3 mCi	45×10^{-9} μCi/mℓ
^{90}Sr	2×10^{-9} μCi/mℓ	7.1 mCi	130×10^{-9} μCi/mℓ	0.4 mCi	70×10^{-9} μCi/mℓ
^{137}Cs	50×10^{-9} μCi/mℓ	292.7 mCi	5×10^{-6} μCi/mℓ	1.1 mCi	202×10^{-9} μCi/mℓ
^{238}Pu	0.5×10^{-9} μCi/mℓ	8.4 mCi	160×10^{-9} μCi/mℓ	0.2 mCi	40×10^{-9} μCi/mℓ
^{239}Pu	0.5×10^{-9} μCi/mℓ	0.6 mCi	11×10^{-9} μCi/mℓ	0.2 mCi	30×10^{-9} μCi/mℓ
^{241}Am	0.5×10^{-9} μCi/mℓ	1.4 mCi	25×10^{-9} μCi/mℓ	0.1 mCi	20×10^{-9} μCi/mℓ
U, total	0.01 μg/ℓ	1.4 kg	26 μg/ℓ	0.1 kg	23 μg/ℓ
Gross α	20×10^{-9} μCi/mℓ	14.6 mCi	270×10^{-9} μCi/mℓ	0.9 mCi	150×10^{-9} μCi/mℓ
Gross β	3×10^{-9} μCi/mℓ	970 mCi	18×10^{-6} μCi/mℓ	29 mCi	5×10^{-6} μCi/mℓ

[a] The MDLs in this table are different from those shown elsewhere because the analyses were made in a different laboratory.

TABLE XII

RADIOACTIVITY IN SANITARY SEWAGE EFFLUENTS

Areas served:		Technical			Municipal		
No. of samples:		11 Samples			8 Samples		
Type of Activity	MDL[a] (10^{-9} μCi/mℓ)[b]	Radioactivity Concentrations (10^{-9} μCi/mℓ)[b] Minimum[c]	Maximum[c]	Average[c]	Radioactivity Concentrations (10^{-9} μCi/mℓ)[b] Minimum[c]	Maximum[c]	Average[c]
^{3}H	300	0	20 600	4 700	0	1 600	800
		(<300)	(±1 200)	(±13 600)	(<300)	(±600)	(±1 000)
^{137}Cs	65	-37	35	9	-5	67	27
		(±66)	(±80)	(±46)	(±35)	(±94)	(±58)
^{238}Pu	0.05	0.01	0.24	0.08	0.006	0.13	0.046
		(±0.04)	(±0.012)	(±0.08)	(±0.012)	(±0.04)	(±0.008)
^{239}Pu	0.05	0.002	0.41	0.09	0.001	0.15	0.03
		(±0.03)	(±0.08)	(±0.26)	(±0.016)	(±0.06)	(±0.10)
U, Total	0.004	<0.004	0.096	<0.019	<0.004	0.033	0.016
		(±0.003)	(±0.06)	(±0.05)	(±0.003)	(±0.016)	(±0.023)
Gross α	0.3	0	2.6	1.6	0.1	2.6	0.9
		(<0.3)	(±0.6)	(±1.6)	(<0.3)	(±0.6)	(±1.6)
Gross β	3	3.8	15.2	9.0	1.5	19.7	10.9
		(±1.0)	(±1.4)	(±7.6)	(±1.2)	(±1.6)	(±10.0)

[a] MDL = Nominal minimum detection limit at the 95% confidence level.

[b] 1 pCi/ℓ = 10^{-9} μCi/mℓ = 37 (disintegrations)/s·m³.

[c] The actual analytical data are shown even though numerically they may be less than the MDL; values in parentheses indicate 2 standard deviations of the mean value.

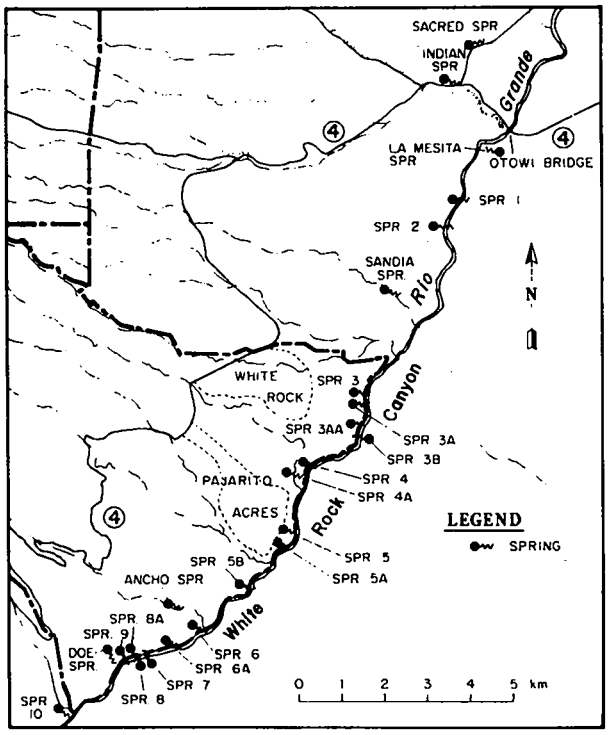

Fig. 9.
Water sampling locations in White Rock Canyon of the Rio Grande.

samples exhibited plutonium concentrations above normal background, possibly as a result of airborne contamination in the analytical laboratory.

Sediment samples collected near the lower ends of Pueblo (N 70 E350) and Los Alamos Canyons (N 65 E355) contained ^{239}Pu in concentrations above normal background. Pueblo Canyon received radioactive liquid effluents until 1964, and some wastes are still being released to Los Alamos Canyon. The sediments in the canyons have adsorbed radionuclides and have been transported down the canyons by storm run-off.

Sediment samples from two other on-site locations (N 35 E165 and S 70 E160) also contained plutonium in amounts above normal background concentrations. These locations are in areas that receive effluents from industrial waste treatment plants.

Radioactivity concentrations in all other soil and sediment samples approximated those reported in previous years.[1]

TABLE XIII

RADIOACTIVITY IN REGIONAL SOIL AND SEDIMENT

Analysis	Units	Min	Max	Avg
Soil Analyses from 7 Locations[a]				
^{3}H[b]	$10^{-6}\mu Ci/m\ell$	1.0(±0.6)	6.9(± 0.8)	2.7(±0.6)
^{137}Cs	pCi/g	0.2(<0.2)	2.3(± 0.3)	1.3(±0.2)
^{238}Pu	fCi/g	6 (±2)	14 (± 6)	8 (±6)
^{239}Pu	fCi/g	3 (±2)	41 (±10)	10 (±4)
Gross α	pCi/g	0.7(±0.2)	5.6(± 0.6)	2.3(±0.4)
Gross β	pCi/g	14 (±1)	28 (± 1)	21 (±1)
Sediment Analyses from 9 Locations				
^{137}Cs	pCi/g	0.7(±0.2)	1.3(± 0.2)	0.9(±0.2)
^{238}Pu	fCi/g	1 (<2)	100 (±10)	15 (±2)
^{239}Pu	fCi/g	1 (<2)	36 (± 6)	17 (±4)
Gross α	pCi/g	0.9(±0.3)	2.8(± 0.4)	1.7(±0.4)
Gross β	pCi/g	10.8(±0.8)	35 (± 1)	24 (±1)

Sampling Locations

Name	Distance from Los Alamos
Abiquiu Reservoir	44 km NNW
Caliente River	55 km NNE
Santa Cruz Reservoir[a]	33 km ENE
Tesuque Creek	40 km SE
Galisteo Reservoir	48 km SSE
Bernalillo	73 km SSW
Jemez Reservoir	60 km SSW
Jemez Creek	38 km WSW
Fenton Lake[a]	50 km WSW

[a] Soil samples not collected at Santa Cruz Reservoir and Fenton Lake.

[b] Tritium in moisture extracted from soil.

VIII. ECOLOGICAL INVESTIGATIONS

A. Overview

The Ecology Section of the Environmental Studies Group is engaged in a variety of research directed toward specific ecological problems. Much of the information obtained in the course of specialized ecological studies is also broadly applicable to environmental monitoring. It not only supplements the direct monitoring program, but

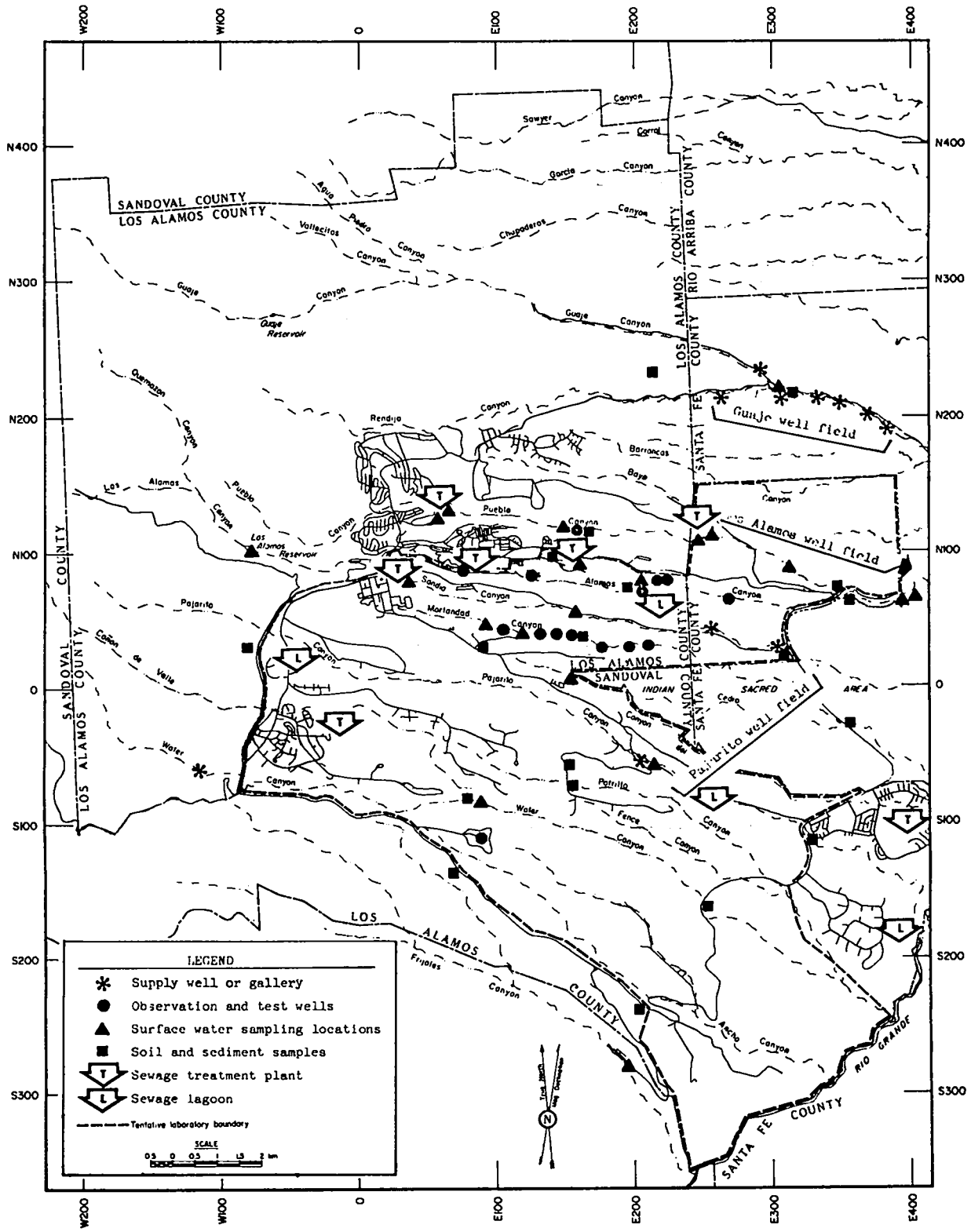

Fig. 10.
Water, sediment, and soil sampling locations on or near the LASL site.

TABLE XIV

RADIOACTIVITY IN SOIL AND SEDIMENT IN LOS ALAMOS COUNTY

Sampling Locations	Radioactivity Concentrations					
	^{3}H[a] (nCi/ℓ)	^{137}Cs (pCi/g)	^{238}Pu (fCi/g)	^{239}Pu (fCi/g)	Gross α (pCi/g)	Gross β (pCi/g)
Off-site soils:						
N230 E215	4(±1)	2.8(±0.3)	14(<16)	60(± 40)	2.2(±0.4)	31(±1)
N 30 W 80	2(±1)	1.1(±0.2)	7(<32)	6(± 3)	8.9(±0.8)	40(±1)
S135 E205	2(±1)	2.1(±0.2)	5(<20)	27(± 4)	4.6(±0.6)	32(±2)
S240 E205	4(±1)	2.1(±0.3)	-	-	1.4(±0.4)	25(±1)
On-site soils:						
N 95 E145	12(±1)	1.8(±0.2)	16(± 3)	1 200(± 80)	3.0(±0.4)	29(±1)
N 30 E100	13(±1)	1.2(±0.2)	7(± 3)	15(± 4)	2.2(±0.4)	27(±1)
N 20 E310	5(±1)	2.7(±0.3)	120(±10)	58(± 8)	2.8(±0.4)	32(±1)
S 55 E 55	6(±1)	1.1(±0.2)	8(± 3)	57(± 8)	2.6(±0.4)	29(±1)
Off-site sediments:						
N210 E320	-	0.9(±0.2)	-	-	0.9(±0.3)	19(±1)
N120 E 65	-	0.9(±0.2)	5(± 3)	5(± 3)	2.0(±0.4)	27(±1)
N 70 E350	-	1.6(±0.2)	25(±10)	560(± 80)	1.7(±0.4)	29(±1)
N 65 E355	-	3.2(±0.3)	14(± 4)	130(± 10)	0.5(<0.6)	33(±1)
S 30 E360	-	0.8(±0.2)	-	-	1.8(±0.4)	27(±1)
S105 E330	-	3.4(±0.3)	8(± 3)	20(± 4)	1.4(±0.4)	25(±1)
On-site sediments:						
N 75 E205	-	1.7(±0.2)	8(± 4)	100(± 20)	0.9(±0.4)	18(±1)
N 35 E165	-	140 (±4)	75(± 6)	1 300(±100)	2.6(±0.4)	89(±2)
S 70 E160	-	0.7(±0.2)	11(± 3)	210(± 20)	-	-
S 85 E 95	-	-	-	-	4.4(±0.6)	39(±1)
S160 E255	-	0.9(±0.2)	6(± 6)	13(± 6)	1.3(±0.4)	21(±1)

[a] Tritium in moisture extracted from soil.

provides insight into the proper interpretation of environmental monitoring data. Duplication of effort is avoided by incorporating the results of ecological studies into the environmental monitoring program.

The following sections summarize some current ecological studies that are especially relevant to the environmental monitoring program. Although these studies have been initiated only recently and cannot yet provide the complete evaluations desired, they are already beginning to have an impact on the environmental monitoring program and on planning for more effective environmental controls.

B. Environmental Inventory

The variety of Laboratory activities and research programs dictates the need for a thorough environmental resources inventory of the Los Alamos area. For example, hazard assessments and radionuclide inventories arising from the Laboratory's waste disposal practices, recommendations for plutonium standards for soils, and the establishment of the Laboratory property as a National Environmental Research Park are all current efforts that require or could benefit from information on the environmental resources of the Los Alamos area.

Specific to environmental monitoring activities, information on the flora of the area would provide input for the prediction of atmospheric effluent behavior because the types, longevity, and gross morphology of the plant species may be important factors determining the removal of radionuclides from air. In addition, the types of vegetative cover are expected to have an important bearing on the radionuclide content of soils surrounding the Laboratory. Information on the types and characteristics of the soils will be vital to assessing long-term build-up and behavior of the various radioactive effluents in the abiotic and biotic environment.

Most TAs that release radionuclides to the air are located in the middle of the Transition Life Zone at an elevation of about 2.1-2.2 km above sea level. Ponderosa pine (*Pinus ponderosa*) is the major overstory plant in the mid-Transition Zone and covers about 75% of the nondisturbed landscape. This species is long-lived, and at Los Alamos the present stand is 10-30 m in height and is estimated to be 30-300 years old. The wide range in height and age of the stand can be attributed to past logging activities. In the lower Transition Zone, which occurs to the east and downwind side of most of the TAs, the dominant tree cover is a mixture of pinon pine (*Pinus edulis*) and one-seeded juniper (*Juniperus monosperma*). Both species are evergreens and have longevity and morphological characteristics similar to ponderosa pine.

The relatively dense cover formed by the tree canopy may reduce the importance of wind transport of resuspended particles as a mechanism in the redistribution of ground-deposited radionuclides. On the other hand, soils exposed by mechanical disturbance are readily transported by wind, hence proper planning of construction activities and final restoration of a protective vegetation covering is important.

The biotic resources inventory already includes a listing and library of plant and animal species (including several rare and endangered or game species) occurring in Los Alamos County. Quantitative work on the vegetation of the area and an inventory of local soils will be continued in 1974.

C. The Honeybee as a Potential Indicator Organism

Relatively high tritium concentrations (up to 9.6×10^{-3} μCi/mℓ) were found in bees from four LASL areas during 1972.[2] Subsequent experiments showed that caged bees do not concentrate tritium above the levels in a supplied food; consequently, the high concentrations observed in unconfined bees (200-400 times the concentrations found in liquid effluents) could not have been attained solely by ingestion of effluents.

Nectar from flowering vegetation is probably the major tritium source to all honeybee colonies because the tritium concentrations in flower moisture were equal to or exceeded the levels in bees. Tritium sources in vegetation include atmospheric effluents and buried solid waste.

Tritium concentrations in bees cannot be compared with those from stack effluents because data are lacking on the chemical form of the tritium in the effluents. However, preliminary studies indicate that most of the tritium released at TA-33 (the major source of airborne tritium in the vicinity of the honeybee study areas) is in the oxide form.

Routine measurements of tritium in atmospheric moisture at locations near the honeybee study areas did not correlate well with concentrations in the bees. In Mortandad Canyon and S-Site the correlation coefficients r were 0.50 (n = 16) and 0.42 (n = 17), respectively, which were significant at $\alpha < 0.05$; in Acid-Pueblo and DP Canyons, the correlation coefficients were not significant ($\alpha < 0.05$). Regression analyses for all four locations indicated that the tritium in honeybees averaged 2-200 times that in air moisture samples. There were significant correlations ($\alpha = 0.05$) between tritium concentrations in bees and in vegetation from Mortandad and DP Canyons but not for Acid-Pueblo Canyon and S-Site.

It is difficult to assess the utility of honeybees as bio-indicators of tritium entering the environment from a specific source. The bees used three sources of tritium during at least part of the 17-month study period. During the spring of 1973, bee colonies in Mortandad and DP Canyons used the effluent water and ingested ^{137}Cs, ^{238}Pu, and ^{239}Pu, as well as tritium. During the summer, large areas of vegetation contaminated by airborne tritium were a potential source to bees. In the fall, a late blooming stand of white clover (*Melilotus albus*) growing over an old solid waste burial ground was the probable source of unexpectedly high tritium levels in the Mortandad Canyon bee colony.

At present, we can draw two conclusions relating to the honeybee studies. First, honeybees in the LASL environment can accumulate tritium from the environment and, in the process, can encounter concentrations that may not be measured during corresponding time periods by the Laboratory's air monitoring network. Second, honeybees are useful in identifying sources of tritium to biota. Vegetation over relatively large areas is a potential source of tritium to nectivorous as well as herbivorous animals. In addition, moisture in vegetation growing over an old solid waste burial site has been identified as a potential source of fairly intense tritium concentrations ($\approx$1 μCi/mℓ).

D. Radionuclides in Canyon Ecosystems

A detailed study of radionuclide behavior in three canyon areas was begun in 1972:

(1) Acid-Pueblo Canyon received untreated liquid radioactive wastes from 1943 to 1951, and received effluent from the TA-45 treatment plant from 1951 to 1964. The facility was subsequently decommissioned and dismantled, and Acid-Pueblo Canyon has received no liquid wastes for about 10 years.

(2) DP-Los Alamos Canyon has been receiving the effluent from the treatment plant at TA-21 since 1952. However, this facility will probably be decommissioned within the next few years.

(3) Mortandad Canyon has received the effluent from the TA-50 treatment plant since 1963. This plant is scheduled to handle larger quantities of plutonium-contaminated wastes when a new plutonium research facility is completed.

These three canyon areas provide a unique opportunity for investigating the behavior of plutonium in environments that are in three different stages of temporal impact: (1) an area that has not received plutonium waste for a decade, (2) an area that has received plutonium waste for two decades and that soon will not receive any more, and (3) an area that has received plutonium waste for a decade and that will continue to receive it.

The relationship of the canyon radioecology studies to the routine environmental surveillance program can be appreciated more fully when one realizes that these canyons also represent three different situations as far as control of released radioactivity is concerned. During its time of active use, that part of Acid-Pueblo Canyon from the waste treatment plant to ≈9 km below the plant outfall was owned by the AEC. The upper 5 km of this drainage area has subsequently been transferred to public and private ownership and is no longer part of the LASL site. Thus, radioactivity that was once on site is now off site as a result of administrative actions rather than environmental transport.

The DP-Los Alamos Canyon is located entirely on the LASL site until its confluence with Acid-Pueblo Canyon, about 6 km below the outfall from the TA-21 plant. Mortandad Canyon is within the LASL boundary for a distance of 5 km below the TA-50 outfall, at which point it becomes Indian land.

A geometric progression of sampling stations was selected and permanently marked in each of the three canyons. These stations are located at the waste outfalls, and at 20, 40, 80, 160, 320, 640, 1 280, 2 560, 5 120, and 10 240 m below the release points. Two stations at 100 and 200 m above the outfalls were selected as background reference locations in each canyon. At each station, measurements have been made of the external radiation exposure rates and of the concentrations of tritium, ^{137}Cs, and total plutonium in environmental media. Data on tritium and ^{137}Cs concentrations in sediments, vegetation, and various fauna, as well as further details on the design of these studies, have been reported elsewhere.[2] A summary of the external exposure rate measurements and of the plutonium concentrations found in environmental samples is presented here as an adjunct to other environmental monitoring data.

(1) External exposure rates were measured with a scintillation survey meter and a pressurized ionization chamber. Because of the energy dependence of the NaI(Tl) crystal, the scintillation survey meter overresponded to the low-energy gamma rays in the environment by about a factor of 2, compared with the response to the gamma rays from ^{60}Co used in its calibration. The scintillation survey meter, because of its sensitivity and rapid response, was particularly useful for assessing the variability of exposure rates. The ionization chamber provided the most accurate measurements because of its uniform response over a wide range of gamma-ray energies (0.1-10 MeV).

External exposure rates are given in Table XV. The highest exposure rates were observed a few hundred meters below the effluent outfall in each canyon, corresponding to areas of highest ^{137}Cs concentrations. The scintillation survey meter measurements correlated well with the data for ^{137}Cs in the top 75 mm of sediment in DP-Los Alamos and Mortandad Canyons, but not in Acid-Pueblo Canyon. Correlation coefficients of 0.81 and 0.80 ($n = 11$) for DP-Los Alamos and Mortandad Canyons, respectively, were significant at $\alpha = 0.01$.

(2) Radionuclides in alluvial soils. Maximum concentrations of plutonium in alluvial sediments occurred within 320 m of the respective effluent outfalls (Table XVI). Over 300 pCi $^{239}Pu/g$ (dry) was measured in Mortandad Canyon sediments, whereas 82 pCi $^{239}Pu/g$ and 54 pCi $^{239}Pu/g$ were the maxima for Acid-Pueblo and DP-Los Alamos Canyons. Concentrations generally decreased with increasing distance beyond the outfall.

There was considerable heterogeneity of plutonium concentrations in replicate sediment samples. The coefficients of variation (CV = 100 x std dev/mean) among triplicate samples were typically about 80%. Inter-sample variability yielded CVs of 10-15% compared to CVs of less than 7% from analytical methods.

A distributional relationship apparently exists between the ^{137}Cs and plutonium concentrations in post-outfall stream channel sediments. Linear regressions on the sediment concentrations of ^{137}Cs vs ^{238}Pu and ^{137}Cs vs ^{239}Pu in

TABLE XV

EXTERNAL RADIATION EXPOSURE RATES IN LIQUID WASTE RECEIVING CANYONS

Distance from Waste Outfall	External Exposure Rates (μR/h)								
	Acid-Pueblo Canyon			DP-Los Alamos Canyon			Mortandad Canyon		
	Scint.[a]		Ion Ch.[b]	Scint.[a]		Ion Ch.[b]	Scint.[a]		Ion Ch.[b]
	h = 0	h = 1 m	h = 0.5 m	h = 0	h = 1 m	h = 0.5m	h = 0	h = 1 m	h = 0.5 m
- 200 m[c]	22	28	8	30	42	16	26	28	16
0	30	40	21	750	600	>150	750	425	>150
20 m	40	50	25	800	800	>150	700	400	>150
40 m	40	35	21	300	160	87	1 500	700	>150
80 m	85	50	29	220	160	76	1 100	550	>150
160 m	40	50	23	50	45	26	1 400	700	>150
320 m	40	50	18	140	160	54	1 300	800	>150
640 m	-	-	-	110	110	-	600	450	>150
1.28 km	50	60	21	-	-	-	300	250	91
2.56 km	30	35	18	110	80	-	160	150	71
5.12 km	26	20	15	35	40	21	30	30	17
10.24 km	-	-	-	-	-	-	26	28	16

[a] Portable scintillation survey meter (Ludlum Model 12 S) with NaI (Tl) crystal.

[b] Pressurized ionization chamber (Reuter-Stokes Model RSS-111); maximum range = 150 μR/h.

[c] Background location upstream from outfalls.

TABLE XVI

PLUTONIUM IN SEDIMENTS IN LIQUID WASTE RECEIVING CANYONS

Distance from Waste Outfall	Plutonium Concentrations (pCi/g dry)								
	Acid-Pueblo Canyon			DP-Los Alamos Canyon			Mortandad Canyon		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
- 200 m[a]	0.4	9	3 (± 5)[b]	0.01	0.07	0.04(± 0.02)[b]	0.4	16	5 (± 8)[b]
- 100 m[a]	0.1	0.1	0.1(± 0.02)	0.01	0.1	0.05(± 0.04)	0.3	0.8	0.5 (± 0.1)
0	0.7	5.7	2.5(± 2.8)	22	54	38 (±23)	140	290	220 (± 70)
20 m	1	3	2 (± 1)	4	47	9.4 (±24)	3	310	180 (±160)
40 m	0.4	14	6.9(± 6.8)	0.2	2	0.6 (± 0.8)	18	190	91 (± 90)
80 m	0.4	82	50 (± 43)	0.3	6	3 (± 3)	19	77	48 (± 28)
160 m	10	15	13 (± 3.5)	0.4	1	0.8 (± 0.3)	22	250	120 (±120)
320 m	9	13	12 (± 2.7)	0.3	54	19 (±31)	5	47	24 (± 21)
640 m	7	13	10 (± 3)	0.5	1	1 (± 0.5)	19	24	21 (± 2)
1.28 km	2	3	2 (± 1)	-	-	- -	5	13	9 (± 4)
2.56 km	0.03	0.6	0.4(± 0.3)	0.04	0.3	0.2 (± 0.1)	3	26	11 (± 13)
5.12 km	0.6	2	1 (± 0.7)	0.1	0.8	0.4 (± 0.3)	0.1	0.2	0.1 (± 0.1)
10.24 km	0.1	0.3	0.2(± 0.02)	-	-	- -	0.01	0.1	0.03(± 0.02)

[a] Negative distances represent background locations upstream from the outfalls.

[b] Values in parentheses represent one standard deviation (± 1 S.D.).

Mortandad Canyon yielded a correlation coefficient r of 0.64 and 0.45, respectively, for 33 samples. The ^{137}Cs vs ^{238}Pu and ^{137}Cs vs ^{239}Pu regressions for DP-Los Alamos Canyon yielded an r of 0.57 and 0.62 (n = 25). The Acid-Pueblo regressions resulted in a calculated r of 0.43 (^{137}Cs vs ^{238}Pu) for 26 samples. A correlation coefficient of 0.65 and 0.21 (n = 83) was obtained when the post-outfall ^{137}Cs vs ^{238}Pu and ^{137}Cs vs ^{239}Pu concentrations from all the canyons were compared.

Most correlation coefficients were significant at the 5% level; however, the largest variation r^2 accounted for by regression analysis was about 42%, indicating that there were other sources of variability.

A positive relationship between ^{137}Cs and plutonium may provide information on the mechanisms of radionuclide distribution in each of the canyons.

(3) Radionuclides in vegetation. Plutonium concentrations in vegetation from the three canyons (Table XVII) were 100-1 000 times greater than those observed in Northern New Mexico vegetation,[3] and about 0.001-1 times the concentrations per gram of sediment upon which the plants were growing.

Plutonium concentrations in vegetation varied considerably among growth forms, such as grasses, forbs, and trees, from the same collection location. Coefficients of variation were consistently near 1.0. Algae, crustose lichens, and mosses--none of which is included in Table XVII--had the highest plutonium concentrations of any plant species, with maxima of 3, 0.15, and 0.03 μCi/g (dry), respectively.

(4) Radionuclides in animal tissues. Plutonium concentrations in rodent tissues (Table XVIII) varied considerably within the same species from the same collection location. In general, the lungs and pelt contained the highest concentrations.

The $^{238}Pu/^{239}Pu$ activity ratios in the plant and animal sample types were generally indicative of plutonium concentrations in the canyons from which the samples were obtained. Mortandad Canyon sediments, vegetation, and rodent samples contained activity ratios of 3.6±1.8, 3.9±3.5, and 4.6±4.3, respectively. Respective ratios for Acid-Pueblo Canyon samples averaged 0.06±1.6, 0.32±0.55, 2.0±3.0; and for DP Canyon, 0.19±0.12, 0.77±1.5, 0.58±1.2.

The waste disposal histories of the three canyons are quite different. Acid-Pueblo Canyon, during a 20-year period from 1943-1964, received ^{239}Pu-contaminated effluent exclusively, while DP-Los Alamos Canyon, during a 20-year period (1952-present), received a combination of ^{238}Pu-^{239}Pu-contaminated effluents which currently

TABLE XVII

PLUTONIUM IN VEGETATION[a] IN LIQUID WASTE RECEIVING CANYONS

Distance from	Plutonium Concentrations (pCi/g wet)											
	Acid-Pueblo Canyon			DP-Los Alamos Canyon			Mortandad Canyon		
Waste Outfall	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
- 200 m[b]	2	8	5(± 3)[c]	17	180	75(± 94)[c]	0	7	4(± 3)[c]
- 100 m[b]	16	30	25(± 8)	16	330	120(± 150)	0	10	4(± 4)
0	-	-	-	5	6 300	2 100(±3 600)	26	2 100	1 000(±1 100)
20 m	230	3 900	2 100(±1 800)	0	44	22(± 31)	27	5 200	1 100(±2 200)
40 m	-	-	-	3	59	26(± 29)	7	150	57(± 64)
80 m	20	2 600	1 000(±1 400)	24	151	80(± 65)	37	2 300	710(±1 100)
160 m	13	150	96(± 74)	8	65	28(± 27)	19	11 000	5 400(±7 700)
320 m	50	130	91(± 58)	3	149	47(± 69)	-	-	-
640 m	24	500	200(± 270)	7	26	13(± 8)	9	170	52(± 80)
1.28 km	3	96	18(± 34)	-	-	-	2	24	9(± 10)
2.56 km	0	3	2(± 2)	2	17	7(± 6)	7	2	4(± 2)
5.12 km	1	200	38(± 83)	1	134	26(± 48)	5	20	10(± 9)
10.24 km	1	9	5(± 4)	-	-	-	0	4	2(± 1)

[a] Sampled vegetation included grasses, forbs, shrubs and trees, but excluded mosses, lichens and algae; collected during October 1972 but analyzed during 1973.

[b] Negative distances represent background locations upstream from the outfalls.

[c] Values in parentheses represent one standard deviation (± 1 S.D.).

TABLE XVIII

PLUTONIUM IN RODENTS IN LIQUID WASTE RECEIVING CANYONS

Canyon and Distance from Waste Outfall	Total Plutonium Concentration in Soft Tissues (fCi/g wet)											
	Liver			Lungs			Hide			Carcass		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Acid-Pueblo												
- 0.2 km[a]	2	10	7(± 4)[b]	0	35	12(± 20)[b]	2	7	5(± 2)[b]	0	11	4(± 5)[b]
0	4	91	27(±43)	0	41	25(± 18)	67	226	144(± 80)	0.4	55	20(±24)
2.6 km	0	200	24(±47)	0	619	67(± 150)	11	215	32(± 50)	0	14	4(± 4)
10.2 km	1	16	4(± 5)	3	38	25(± 18)	4	82	32(± 29)	0.4	3	1(± 1)
DP-Los Alamos												
- 0.2 km[a]	0	17	7(± 6)	0	97	22(± 34)	95	970	480(± 340)	0.2	34	13(±13)
0	2	110	27(±32)	0	110	24(± 27)	72	680	310(± 200)	0	310	51(±75)
2.6 km	0	20	9(±10)	0	86	30(± 38)	2	44	19(± 16)	0	15	6(± 7)
Mortandad												
- 0.2 km[a]	-	3	3 -	8	13	11(± 4)	4	15	10(± 8)	0	1	1(± 1)
0	9	66	33(±24)	19	1 500	460(± 710)	66	1 500	790(± 520)	0.2	100	39(±44)
2.6 km	0	26	10(± 9)	18	6 000	840(± 2 100)	4	710	100(± 240)	0	15	3(± 5)
10.2 km	0	210	33(±68)	0	7 800	1 100(± 2 500)	4	6 300	500(±1 700)	0.1	92	10(±25)

[a]Negative distances represent background locations upstream from the outfalls.

[b]Values in parentheses represent one standard deviation (±1 S.D.).

averages about 80% ^{239}Pu of total activity. Mortandad Canyon, during a 10-year period (1963-present), received a mixture of ^{238}Pu-^{239}Pu which for the last 5 years has been at least 80% ^{238}Pu.

Several studies should provide information useful to LASL's environmental monitoring activities. For example, studies on the rates and mechanisms of plutonium movement down canyons during high precipitation run-off periods are essential in assessing potential as well as actual off-site losses of the radionuclide. There is evidence that an important mechanism in plutonium movement is the flushing of sediments down the canyon.

Refined studies on the distribution of plutonium in the canyons' biota should provide input for the assessment of plutonium release standards for liquid effluents at LASL. Similar studies will be initiated in areas where the principal source of environmental plutonium is the effluent released to the atmosphere. Questions regarding long-term buildup and availability of chronic, low-level releases of plutonium to the environment require consideration.

E. Characterization of Soils

Much of the alluvial soil in the waste discharge areas is in deep canyons which have formed in the Bandelier tuff since Pleistocene times. The original ash-flow tuff deposits, consisting of rhyolite ash and pumice with small amounts of quartz and sanidine crystals, have weathered to form the alluvial soils in the study areas. Ten core samples were taken of the alluvium at each of 11 stations in Mortandad, DP-Los Alamos, and Acid-Pueblo Canyons during 1973. The core samples were frozen, cut into four segments (0-25, 25-75, 75-125, and 125-300 mm), oven dried, and characterized as to their physical and chemical properties.

More than 500 of these soil samples were mechanically separated into 6 size fractions:

Size Description	Particle Diameter
Silt and clay	<53 μm
Very fine sand	53-105 μm
Medium and fine sand	105-500 μm
Coarse sand	500-1000 μm
Very coarse sand	1-2 mm
Coarse fragments	2-23 mm

Soil profiles of severely and moderately eroded soil from all canyons showed <1-2% silt and clay in the top 25 mm of soil and <3-4% silt and clay in the remainder. Severely eroded soils contained up to 70% coarse fragments, whereas the dominant size fraction (up to 46% by weight) in most moderately eroded soils was very coarse sand. Only 4 of the 33 stations had soils with minimal water erosion; these soils contained up to 54% silt and clay, with increasingly smaller amounts of larger size fractions. They usually contained < 10% coarse fragments (2-23-mm-diam).

The cation exchange capacity of about 150 alluvial soil samples was determined. In general, increases in the cation exchange capacities of soil samples correlated with increases in the smaller size fractions, especially soil particles smaller than 53-μm diam. Thus, profiles of severely eroded, moderately eroded, and minimally eroded soils usually demonstrated cation exchange capacities of 20-40, 40-100, and 110-210 meq per kilogram of soil, respectively. Cation exchange capacity generally increased with soil depth, reflecting increased percentages of silt and clay beneath the 0-25-mm level.

Organic matter in soil is known to react specifically with several heavy metals, and also contributes to the cation exchange capacity of soil. Severely eroded and moderately eroded soil in the canyons contained 0.10-0.20% organic carbon, except in upper Mortandad Canyon (0-160 m post-outfall) soils which had organic carbon contents of 0.20-0.45%. Soils exhibiting minimal water erosion had as much as 50 times more organic carbon than more severely water-worked soils. A soil from the 0-25-mm depth of Mortandad Canyon (100 m pre-outfall) had an organic carbon content of 5.2%, whereas a severely eroded soil from the pre-outfall station contained 0.10% organic carbon.

The pH and levels of carbonates in soils fluctuated as a function of distance above and below the waste outfall areas, partially due to alkaline liquid effluents. For example, pH values in Mortandad Canyon increased from about 5.7 at the pre-outfall station to a maximum value of 9.2 at 320 m below the outfall, and then decreased to near the pre-outfall values at post-outfall stations. The pH changed very little with soil depth. Although soils may contain carbonates of calcium, magnesium, and sodium, carbonate concentrations are expressed as a percentage of calcium carbonate equivalents. Since there are very low carbonate levels in Bandelier tuff, the alluvial soils in the canyons also have low percentages of calcium carbonate equivalent values, e.g., 0.07-0.20%. However, certain soils receiving alkaline wastes in Mortandad Canyon (0-1280 m post-outfall) and in DP Canyon (0-80 m post-outfall) have calcium carbonate levels as high as 3.7%.

A formal soil survey of the LASL environs to be completed by USDA Soil Conservation Service scientists during early 1974 should provide a detailed data base for future radiation ecology studies and for engineering and waste management operations.

IX. RADIATION DOSE CALCULATIONS

A. Assumptions

The dose assessments presented in this section are based on actual environmental monitoring data, as opposed to theoretical calculations of dispersions of radioactive materials. However, uncertainties associated with many of the data require that certain assumptions be made:

1. **Critical locations.** For making the dose assessments, consideration was given to all of the normally occupied off-site locations. Calculations were made for doses to the general population at locations of maximum exposure in the Los Alamos area and to the total population within 80 km of the Laboratory. Calculations were not made for the locations of highest potential doses at unoccupied locations along the LASL perimeter (the "fence post" dose), because such calculations would not be meaningful.

2. **Affected populations.** Every effort was made to use the most realistic data available (including the subtraction of contributions from background radiation) with respect to potential exposure rates and activity concentrations, while still applying very conservative (pessimistic) assumptions regarding exposed populations. No environmental concentrations of radionuclides attributable to LASL operations were detected beyond the immediate vicinity of the Laboratory. Consequently, it was not considered necessary to extend the dose assessments beyond Los Alamos County; for the purposes of these calculations the total dose to the population within a radius of 80 km is considered equal to the dose to the population of Los Alamos. The population distributions for Los Alamos County used in the dose assessments were based upon 1970 census data and growth factors obtained from the Los Alamos County Planning and Zoning Commission.

3. **Calculational methods.** The data and methods recommended by the International Commission on Radiological Protection (ICRP) were used for all dose assessments. For the materials of concern at LASL, the results of these calculations are essentially the same as would be obtained if one assumed that the ratio of actual doses to the dose limits given in AECM 0524 were the same as the ratios of measured concentrations to the CGs given in AECM 0524.

B. External, Penetrating Radiation

The analysis of external radiation exposures is complicated by the large area and variable topography encompassed by the LASL site and the off-site areas. TLD stations range from 1.7 to 2.8 km in elevation; some are located on mesas, others are in canyons. Each major grouping of stations (off-site, perimeter, and on-site) and each functional subgroup (e.g., the Los Alamos community) exhibits a significant range of dose rates as a result of the variability of local conditions.

The highest annual average dose recorded by TLDs at an occupied off-site location was at Cumbres Junior High School (N140 E130). This dose was 226 mrem, or 73 mrem above the average background of 153 mrem for all off-site stations situated above 2 km. There are two reasons, however, for rejecting this dose measurement as either a valid average for the school or as representing a LASL contribution to an off-site dose. First, the other TLDs in the Los Alamos community, including several near the LASL boundary (Fig. 3), did not register abnormal doses; and second, the TLD at Cumbres School was located near a brick wall which apparently contains a higher-than-normal concentration of natural radioactivity. To obtain a more valid dose measurement at Cumbres School during 1974, the TLD has been moved from the brick wall to a more representative position.

The most reasonable population dose estimate that can be derived from the TLD data is based on a comparison of the average annual dose in the Los Alamos community with the average annual dose recorded by all off-site stations situated at elevations above 2 km (see Table III). An annual average dose of 2 mrem above background was detected in the Los Alamos community. This net increase would represent approximately 1% of the annual population dose limit (170 mrem) if statistically significant. It can be seen from Table III, however, that the uncertainty involved in the external radiation exposure measurements is much greater than the 2 mrem per year difference. Consequently, a calculated population dose is not considered statistically significant.

C. Airborne Tritium

The dose resulting from continuous inhalation of tritiated water vapor was calculated using the following equation:

$$D(t) = 51\, C I_a f_a E t/\lambda m \quad ,$$

where:

$D(t)$ = dose equivalent delivered during continuous exposure time t(days), in rem

$$51 = \frac{(1.6 \times 10^{-6}\ \text{erg/MeV})\,(8.64 \times 10^{4}\ \text{s/dav})\,(3.7 \times 10^{4}\ \text{dis/s-}\mu\text{Ci})}{100\ \text{erg/g-rad}}$$

C = average airborne concentration, in μCi/mℓ

I_a = average air intake rate
= 2×10^7 mℓ/day (Ref. 4)

f_a = fraction of inhaled material reaching organ of interest
= 1 for tritium (oxide) (Ref. 4)

E = effective energy deposition per disintegration, including the quality factor for dose equivalent conversion
= 0.010 MeV-rem/dis-rad (Refs. 4, 5, and 6)

t = duration of exposure, in days

λ = effective elimination rate, in day^{-1}
= 0.069 day^{-1} (Ref. 6)

m = mass of organ of interest, in g
= 4.3×10^4 g for body water (Ref. 4)

Therefore:

$$D(t) = 1.2 \times 10^{6} C.$$

The average annual concentration of airborne tritiated water vapor for all off-site locations was $(12 \pm 6) \times 10^{-12}$ μCi/mℓ. The highest average concentration of tritiated water vapor measured at an occupied off-site location was $(113 \pm 40) \times 10^{-12}$ μCi/mℓ at the Los Alamos Airport. The background concentration of tritium would result in a whole body dose of approximately 0.014 mrem per year, and the additional 100×10^{-12} μCi/mℓ observed at the airport would contribute an additional 0.12 mrem per year. This represents less than 0.03% of the annual dose limit for an individual member of the public and less than 0.1% of the dose limit for a population group. For the 200 people estimated to reside in the immediate vicinity of the Los Alamos Airport, the calculated population dose contribution would be 0.02 man-rem.

The most reasonable estimate of the dose contribution to the Los Alamos community from airborne tritiated water vapor was obtained by averaging the annual concentrations measured at eight locations in the Los Alamos community (station nos. 4, 5, 6, 8, 9, 10, 19, and 20). This average concentration was 18×10^{-12} μCi/mℓ. For White Rock and Pajarito Acres area (station nos. 11 and 12) the average concentration was 17×10^{-12} μCi/mℓ. The net increase of 6×10^{-12} μCi/mℓ above the average background concentration resulted in additional dose of 0.007 mrem for the year. For the 17 000 residents of Los Alamos County the resulting population dose was calculated to be 0.12 man-rem.

D. Airborne Uranium

Although uranium analyses were performed routinely on a large number of the air sample filters, the majority of the results were less than or equal to the minimum detection limit of 1×10^{-10} μg/mℓ. No effort was made to determine the solubility of the uranium collected on air filters because the quantities were so small. The recommended concentration limits (by the ICRP) for individual members of the public are 3×10^{-12} μCi/mℓ for soluble uranium and 2×10^{-12} μCi/mℓ for insoluble uranium particles.[4,5] Based upon the isotopic composition of natural uranium, which is very similar to uranium that might be released by LASL, the conversion to a mass concentration is 0.33 μCi/g. This conversion results in mass CGs of 9×10^{-6} and 6×10^{-6} μg/mℓ, for soluble and insoluble forms of uranium, respectively. Because the CGs for natural uranium (and uranium of similar isotopic composition) are based on chemical toxicity rather than radiotoxicity, and because the measured concentrations were lower than 0.003% of the CGs, dose calculations were not made for contributions from airborne uranium.

E. Airborne Plutonium and Americium

Measurements were made of ^{238}Pu and ^{239}Pu on monthly composites of all filters from each air sampling station. Measurements of ^{241}Am were made on filters from only a few selected locations. The annual average concentration of ^{239}Pu for all off-site stations combined was 21×10^{-18} μCi/mℓ. This average value is in good agreement with data reported from the Radiation Alert Network of the Environmental Protection Agency.[7] For ^{238}Pu, the annual average concentration for all off-site locations was calculated to be 15×10^{-18} μCi/mℓ; this value is approximately a factor of 8 larger than that reported by EPA from the Radiation Alert Network. For ^{241}Am, the annual average concentration for 5 off-site locations was found to be 8×10^{-18} μCi/mℓ, compared to 5×10^{-18} μCi/mℓ for 7 perimeter and on-site stations. The EPA Radiation Alert Network does not report ^{241}Am concentrations.

Because of the large variations exhibited in our ^{238}Pu and ^{241}Am data, and because our analytical sensitivities are apparently not as low as those obtained by the EPA Radiation Alert Network, the dose calculations for inhaled actinides were made using the following estimates of global fallout concentrations: 15×10^{-18} μCi/mℓ for ^{239}Pu and 2×10^{-18} μCi/mℓ for both ^{238}Pu and ^{241}Am. The use of these values, in lieu of our own data, results in somewhat higher calculated net concentrations and correspondingly larger calculated doses.

Lung dose calculations were made for potential inhalation of the actinides, and were based upon the following assumptions:

1. All of the airborne plutonium and americium was highly insoluble and therefore behaved according to the model for Class Y materials, as defined by the ICRP Task Group on Lung Dynamics.[8]
2. All of the airborne plutonium and americium particles were in the size range of 0.01- to 0.1-μm diam, for which deposition in the pulmonary region is maximum.[8]

The following equation was used to calculate lung doses resulting from inhalation of plutonium or americium:

$$D(t) = 51\ CI_a f_a f_r E t/\lambda m \left(1 - \frac{1-e^{-\lambda t}}{\lambda t}\right)$$

where:

f_a = 0.7 (max) for the pulmonary region (Ref. 8)

f_r = fraction of pulmonary deposition undergoing long-term retention

= 0.6 for actinides (Class Y) (Ref. 8)

E = 53 MeV-rem/dis-rad for ^{239}Pu

= 57 MeV-rem/dis-rad for ^{238}Pu

= 57 MeV-rem/dis-rad for ^{241}Am (Ref. 4)

λ = mean clearance rate, in day^{-1}

= 0.0014 day^{-1} for actinides (Class Y) from the pulmonary region (Ref. 9)

m = 1000 g for the lungs (Ref. 4).

All other quantities are as defined previously for the airborne tritium calculation.

Therefore:

$$D\ (365\ days) = 2.4 \times 10^{10}\ CE$$
$$= 1.3 \times 10^{12}\ C \text{ for } ^{239}Pu$$
$$= 1.4 \times 10^{12}\ C \text{ for } ^{238}Pu$$
$$= 1.4 \times 10^{12}\ C \text{ for } ^{241}Am$$

Because many of the factors involved in the above equation and the measurements of airborne concentrations are valid to only one significant figure, the following dose calculations have been rounded off accordingly.

Only five locations in the Los Alamos community exhibited concentrations of airborne actinides significantly in excess of those expected from global fallout. Since the combined concentrations of actinides did not vary by more than a factor of 2 among these five locations, a separate calculation was not made for the highest dose at an occupied off-site location. The combined annual average net concentration of the actinide elements, and the calculated annual lung dose resulting from continuous inhalation of these concentrations, were:

Location	Combined Avg Net C (μCi/mℓ)	Calculated Annual Lung Dose (rem)
4 Barranca School	70×10^{-18}	9×10^{-5}
5 Arkansas Avenue	50×10^{-18}	5×10^{-5}
8 Cumbres School	40×10^{-18}	4×10^{-5}
9 Diamond Drive	40×10^{-18}	5×10^{-5}
10 Fuller Lodge	70×10^{-18}	10×10^{-5}

The dose limit to the lungs for any individual in the population is 1.5 rem/year (AECM 0524); the maximum dose calculated above was approximately 0.007% of that limit. The average dose limit to the lungs in a population group is 0.5 rem/year (AECM 0524); for the population represented by the five locations listed above, the average calculated dose was approximately 0.01% of the population dose limit.

F. Other Nuclides and Pathways

Tritium, uranium, and transuranic nuclides are the only significant radioactive materials released from LASL facilities. Although some short-lived radionuclides are rountinely measured in Laboratory effluents, they are not detectable in environmental media. The potential doses from these other nuclides are orders of magnitude smaller than the doses from the nuclides evaluated in the preceding sections, and consequently are not considered in the overall dose assessment.

Liquid effluents *per se* do not flow beyond the LASL boundary but are absorbed in the alluvium of the receiving canyons; excess moisture is lost primarily by evapotranspiration. These effluents are monitored at the points of discharge and in the alluvium of the canyons below the outfalls. Small quantities of radioactive contaminants have been measured in canyon sediments beyond the LASL boundary, probably transported there during periods of heavy run-off. However, no pathways from the sediments to humans have been identified.

No radioactivity in excess of normal background concentrations was detected in drinking water, surface water, or ground water at any off-site location. There are no significant aquatic pathways or food chains to humans in the local area. Consequently, no potential dose contributions beyond those already discussed could be identified or evaluated.

G. Dose Assessment Summary

The whole-body dose consists of the contributions from external, penetrating radiation and inhaled tritiated water vapor. The whole-body dose must be added to internal dose to obtain the total dose to a critical organ.

As was pointed out earlier, although the TLD data indicated an average external radiation exposure rate of 2 mrem per year in the Los Alamos community above the background measured at other off-site locations, this value was not statistically significant. The only whole-body dose assessment considered to be realistic is that resulting from inhaled tritiated water vapor; the estimated dose contribution from this source was approximately 0.012 mrem per year to a population of 200 people and 0.007 mrem per year to the remaining 17 000 residents of Los Alamos County. The total population dose from tritiated water vapor was calculated to be 0.02 plus 0.12 = 0.14 man-rem.

Concentrations of actinides in excess of those expected from global fallout were detected at only five occupied off-site locations. The calculated dose to the lungs of any individual continuously exposed in these locations ranged from (4 to 10) $\times 10^{-5}$ rem per year. Since the location of the highest concentration of tritiated water vapor was not the same as any of the locations exhibiting excess concentrations of plutonium or americium, these maximum doses were not additive.

The largest calculated dose that could have been received by any individual beyond the LASL boundary as a result of LASL operations was less than 0.03% of the annual dose limit; this would have been due to airborne tritium in the vicinity of the Los Alamos Airport. The average dose to all Los Alamos residents resulting from LASL operations was less than 0.002% of the individual dose limit, or 0.005% of the population dose limit.

X. CHEMICAL AND BIOLOGICAL QUALITY OF LIQUID EFFLUENTS

A. Industrial Wastes

Because the TA-50-1 and TA-21-257 operations are directed primarily toward removing radioactivity from industrial wastes, the overall chemical quality of the effluents frequently fails to meet drinking water standards. The data in Table XIX, reflecting the quality of effluents from the two plants, show that as the list of "toxic pollutants" pertinent to Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972) is expanded, measures may be required to improve the quality of the effluents.

B. Domestic Wastes

The effluent from each major technical area sewage treatment facility is analyzed twice a month by Zia Company* personnel to evaluate the performance of the plant. The results are shown in Table XX, along with the appropriate standards established by the Environmental Protection Agency (EPA). In general the plants are performing very satisfactorily, but fecal coliform standards are not

*The Zia Company is the primary service contractor to the AEC at Los Alamos.

TABLE XIX

CHEMICAL QUALITY OF MAJOR INDUSTRIAL LIQUID EFFLUENTS

Facility(Location):			TA-50 (N 30 E 93)			TA-21-257 (N 82 E169)		
Total Volume Discharged(Receiving Canyon):			53.7 Mℓ (Mortandad)			5.7 Mℓ(DP-Los Alamos)		
Analyses[a]	Units	MDL	Min	Max	Av(±2 S.D.)	Min	Max	Av(±2 S.D.)
Sodium	mg/ℓ	1	95	1 125	310 (±412)	250	645	436 (±186)
Calcium	mg/ℓ	2	4	116	33 (± 70)	4	112	24 (± 33)
Magnesium	mg/ℓ	1	1	18	5 (± 7)	1	19	5 (± 6)
Fluoride	mg/ℓ	0.1	0.2	5.5	1.5(± 1.9)	3	149	28 (± 54)
Chloride	mg/ℓ	1	20	125	60 (± 54)	20	163	75 (± 74)
Ammonia	mg/ℓ	0.1	0.7	189	15 (± 83)	1.2	18	7 (± 10)
Nitrate	mg/ℓ	0.4	27	2 093	310 (±818)	31	1 087	411 (±442)
Phenolphthalein Alkalinity	mg/ℓ	3	0	280	52 (±144)	0	230	73 (±118)
Total Alkalinity	mg/ℓ	3	60	860	331 (±316)	347	1 020	695 (±320)
Phosphate	mg/ℓ	0.03	0.1	0.9	0.3(± 0.4)	0.1	34	2.1(± 11.8)
Total Hardness	mg/ℓ	-	30	300	105 (±170)	16	300	83 (± 86)
Total Solids	mg/ℓ	-	578	4 034	1 148 (±1 394)	1 260	2 670	1 790 (±646)
Conductance	mS/m	-	68	580	163 (± 184)	157	337	225 (± 39)
Chemical Oxygen Demand	mg/ℓ	8	8	97	38 (± 32)	10	128	57 (± 58)
pH	-	-	7.1	11.7	-	7.1	10.6	-
Cadmium	µg/ℓ	1	<1	560	36 (±120)[b]	1	500	28 (± 94)[b]
Hexavalent Chromium	µg/ℓ	4	<4	65	<13 (± 26)	<4	7	<5 (± 1)
Total Chromium	µg/ℓ	4	<4	220	<27 (± 70)	<4	380	<34 (±140)
Copper	µg/ℓ	2	<2	5 280	<320 (±1 460)	<2	1 500	<150 (±400)
Mercury[c]	µg/ℓ	0.02	1	149	16 (± 72)	<0.02	25	1.7(± 9.8)
Lead	µg/ℓ	0.1	<0.1	2 600	<415 (±1 360)	<0.1	1 300	<510 (±1 680)
Zinc	µg/ℓ	2	<2	260	<34 (±100)	<2	1 120	<270 (±460)

[a] Fifty-two samples, each a composite of one week's effluent, were analyzed.

[b] The average does not include the maximum value because the value is probably erroneous. No concentration of such magnitude was detected in the plant influent.

[c] Twenty-six samples only; July through December.

TABLE XX

BIOLOGICAL QUALITY OF SEWAGE EFFLUENTS

		BOD (mg/ℓ)			Suspended Solids (mg/ℓ)			pH		Fecal Coliform (No./100 mℓ)		
Plant	Location	Min	Max	Arith Mean	Min	Max	Arith Mean	Min	Max	Min	Max	Geom Mean
TA-3	N 70 E 35	5	19	11(± 9)[a]	4	18	8(± 7)[a]	7.0	8.0	100	80 000	42 700
TA-8	N 15 W 40			10(±12)			29(±31)	8.0	8.5	-	-	-
TA-16	S 40 W 20	2	40	7(±16)	3	20	6(± 7)	7.0	9.0	100	4 900	940
TA-18	S 90 E240	5	50	19(±24)	10	60	16(±22)	8.6	10.0	-	-	-
TA-21	N 80 E170	6	64	31(±32)	10	60	22(±23)	6.8	8.0	600	10 000	2 050
TA-41	N 85 E 90	7	31	20(±15)	5	25	11(±24)	6.9	8.5	0	0	0
TA-53	N 50 E225	9	210	29(±67)	5	120	23(±40)	8.0	10.5	8	43 000	1 900
EPA Standards[b](Monthly Mean):		-	30		-	-	30	6.0	9.0	-	-	200

[a] Values in parentheses represents 2 standard deviations of the mean.

[b] 40 CFR Part 133, Secondary Treatment Information.

being met because the effluents, with the exception of those from TA-3 and TA-41, are not chlorinated. Efforts are being made to provide this chlorination.

The pH of effluents from the TA-18 and TA-53 lagoon systems is often higher than the EPA upper limit of 9.0, but may actually be lower than indicated because most of the measurements were made with a color comparator. Future data should be more accurate. Although effluents from lagoons typically have a higher pH than effluents from treatment plants, an investigation will be conducted to determine whether unknown industrial wastes are magnifying the problem.

The unusually high pH of the TA-53 effluent occurred in June when the system was not functioning properly because the east lagoon had become anaerobic for some reason. The system soon regained its normal condition.

Effluents from the sewage treatment facilities were also analyzed for chemical quality to verify that significant amounts of chemicals were not escaping from LASL facilities through the sanitary sewage systems. The data in Table XXI indicate that the chemical quality of the municipal plants is typical of domestic sewage and, as would be expected with a more dilute influent than that of municipal sewage, the average concentrations for the technical area effluents are lower. Nitrate concentrations are the only exception. However, the maximum value of 173 mg/ℓ, observed at the TA-18 lagoon, is not atypical for a grab sample from a lagoon.

TABLE XXI

CHEMICAL QUALITY OF EFFLUENTS FROM SEWAGE TREATMENT PLANTS

Areas Served(No. of Samples):		Municipal (8 samples)			Technical Areas (11 samples)		
Analyses	Units	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Calcium	mg/ℓ[a]	11	26	17(± 9)[c]	6	9	14(± 8)[c]
Magnesium	mg/ℓ	1	18	8(± 11)	0	5	2(± 4)
Sodium	mg/ℓ	63	105	81(± 28)	13	101	47(± 60)
Carbonate Alkalinity	mg/ℓ	0	0	0	0	12	2(± 10)
Bicarbonate Alkalinity	mg/ℓ	108	232	162(± 96)	48	160	88(± 66)
Chloride	mg/ℓ	32	40	37(± 6)	10	44	24(± 20)
Fluoride	mg/ℓ	1.9	5.2	3(± 2)	0.5	5	3(± 2)
Nitrate	mg/ℓ	2.2	52	27(± 39)	0	173	44(±118)
Total Solids	mg/ℓ	432	638	495(±142)	176	470	308(±188)
Total Hardness	mg/ℓ	40	120	74(± 60)	16	64	44(± 27)
Conductance	mS/m[b]	42	60	50(± 13)	16	58	31(± 26)

[a] 1 mg/ℓ = 1 µg/mℓ = 1 ppm.

[b] 1 mS/m (*millisiemens per metre*) = 10 µmho/cm.

[c] Value in parentheses represents 2 standard deviations of the mean.

C. Individual Outfalls

In the early days of LASL, many Laboratory effluents were simply routed to a canyon edge and discharged. The practice was stopped long ago, but many of the effluent residues still exist. None is known to contain radioactivity, but the chemical quality is generally unknown. In late 1973 a plan was initiated to locate, sample, and analyze these effluents to identify needs for waste treatment. Although data are incomplete, early indications are that these effluents will not present major problems.

Problems will be encountered at TA-16, where several effluent streams containing barium and explosives residues are discharged to the environment with sedimentation used as the only treatment process. Studies have indicated that these pollutants migrate very slowly, that residuals in soils near the outfalls pose no health or safety threat, and that the contaminants are contained well within the LASL site. TA-16 is the non-radioactive waste area needing the most attention.

Other waste management problems may exist (or develop as a consequence of Public Law 92-500) at the 20-odd cooling water towers scattered throughout the technical areas. The release of corrosion inhibitors and algaecides may require attention. Investigation of these problems also began during 1973 and is continuing.

XI. CHEMICAL QUALITY OF SURFACE AND GROUND WATERS

A. Regional Surface Waters

Regional rivers and reservoirs within 75 km of LASL (Fig. 8) were sampled to provide data on the chemical quality of water in the area. The average concentrations listed in Table XXII represent one sample each from Abiquiu, Caliente River, Santa Cruz Reservoir, Tesuque Creek, Galisteo Reservoir, Bernalillo, Jemez Reservoir, Jemez Creek, and Fenton Lake; two samples each from Chamita and Embudo; and three samples each from Otowi and Cochiti.

The mineral concentrations in water samples from Jemez and Galisteo Reservoirs were slightly lower than those observed in CY 72 because of dilution by greater volumes of run-off. There were no significant changes in the quality of waters from the remaining stations.

B. Perimeter Surface and Ground Waters

Perimeter surface and ground water samples were collected at six locations on the Pajarito Plateau (Table XXIII and Fig. 10) and at 27 locations in White Rock Canyon (Fig. 9). The chemical quality of these waters has not changed from previous reporting periods. These waters are of good enough quality to be used for domestic or municipal supplies, but are not so used. The one exception was obtained from the mouth of Mortandad Canyon, where effluent from the Los Alamos County White Rock Sewage Treatment Plant is discharged and the fluoride concentration is 8.1 mg/ℓ.

TABLE XXII

CHEMICAL QUALITY OF REGIONAL SURFACE WATERS

	Concentrations (mg/ℓ)			
Analysis	Min	Max	Avg[a]	% Std[b]
Bicarbonate	40	328	116	—
Calcium	14	205	49	—
Carbonate	0	0	0	—
Chloride	2	158	20	—
Fluoride	<0.1	1.1	0.4	~40
Magnesium	3	52	10	—
Nitrate	<0.4	2.6	0.9	2
Sodium	7	168	35	—
TDS	110	1 536	387	35
Hardness	48	724	176	—
pH	7.3	8.8		—
Conductance (mS/m)[c]	9	164	43	—

[a] Average of 19 samples.

[b] Percent of drinking water standards (EPA and PHS).

[c] 1 mS/m = 10 μmho/cm.

C. Los Alamos Water Supply System

The chemical quality of water in the Los Alamos water supply system varies slightly from periods of light production (winter) to periods of heavy pumpage (summer). The quality of samples from the 16 wells shown in Fig. 10 is presented in Table XXIV. These routine analyses indicate no significant changes in the quality of water. Maximum concentrations were well below the limits defined by the U.S. Public Health Standards for drinking water (see Appendix E), except for fluoride concentrations in water from two of the wells.

TABLE XXIII

CHEMICALS IN PERIMETER SURFACE AND GROUND WATERS

Sampling Locations	No.& Type of Sample	Chemical Concentrations (mg/ℓ)										pH	Cond. (mS/m)
		Ca^{+2}	Mg^{+2}	Na^{+2}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	F^{-1}	NO_3^{-1}	TDS	Hard		
Guaje Canyon N215 E315	1-S	11	4	10	0	52	2	0.3	0.4	138	44	7.5	11.0
Test Well 2 N115 E260	1-G	11	1	8	0	52	4	0.7	<0.4	112	32	7.8	9.5
Los Alamos Res. N105 W 75	1-S	10	6	6	0	32	2	0.1	0.4	98	48	7.0	8.5
Basalt Springs N 65 E395	2-S	27	7	15	0	88	14	0.9	9.3	263	96	7.7	31.0
Los Alamos Springs N 60 E405	2-S	35	10	19	0	92	22	1.2	11	290	128	7.6	32.0
Frijoles Canyon S280 E195	1-S	10	3	8	0	60	4	<0.1	0.9	126	36	7.6	11.0
White Rock Canyon of the Rio Grande (27 locations, see Fig. 9)	32												
	Min:	10	<1	8	0	56	2	<0.1	<0.4	130	28	7.4	11.0
	Max:	42	9	126	0	384	32	8.1	11	506	238	8.6	22.0
	Avg:	22	4	25	0	114	8	0.8	2.6	226	73	-	15.0

Selenium and arsenic concentrations in each of the 16 wells were studied because these elements were reported in well water in 1972. The study was made over a 10-h pumping period, with samples collected at intervals of 0.5, 1, 2, 3, 4, 6, 8, and 10 h after pumping began. The pumping period was preceded by a shutdown period of at least 24 h. Tests were made not only to determine concentration levels in the wells but also to determine whether these concentrations changed with pumpage. The Environmental Studies Group collected and analyzed 128 samples. To ensure quality control, duplicate samples were analyzed by a commercial laboratory.* Results were comparable with limits of analytical accuracy.

All selenium concentrations shown in Table XXV were below the 10-μg/ℓ U.S. Public Health Standard for drinking water, although a few were above the 1 μg/ℓ limit of detection. Selenium concentrations did not change with increased pumpage.

The maximum arsenic concentrations (Table XXV) in water from wells LA-6 and G-2 exceed the U.S. Public Health Service standard of 50 μg/ℓ, violation of which constitutes ground for rejection of the water supply. The arsenic concentration in water from well LA-6 averaged about 130 μg/ℓ during the 10-h test. The arsenic concentration in water from well G-2 increased from 8 μg/ℓ at 0.5 h after onset of pumping to 52 μg/ℓ at 10 h after the test began. Arsenic concentrations in the other wells varied slightly but were within permissible limits. Mixing of water in the distribution system dilutes the arsenic concentrations from wells LA-6 and G-2 to levels acceptable for domestic use. The arsenic reported in the analyses occurs naturally and is not the result of Laboratory contamination.

An evaluation of various ions was made in the water distribution system at stations on the main lines above the well fields. The samples represent a mixture of water from the wells in the fields. A commercial laboratory* made analyses for arsenic, barium, cyanide, selenium, silver, copper, iron, zinc, aluminum, nickel, and chromium. The results, shown in Table XXVI, were within acceptable limits for domestic use, with the exception of the selenium concentration reported from Los Alamos Booster. A reanalysis of water from this station indicated selenium concentrations of less than 1 μg/ℓ. The initial analysis was probably erroneous, as water from wells in the Los Alamos well field contain no significant amounts of selenium.

*Controls for Environmental Pollution, Inc., Santa Fe, NM.

TABLE XXIV

CHEMICALS IN LOS ALAMOS WATER SUPPLIES

Analyses	Concentrations (mg/ℓ) Min	Max	Avg[a]	% Std[b]
Arsenic	<0.001	0.133	0.027	54
Bicarbonate	40	280	108	—
Calcium	5	27	13	—
Carbonate	0	0	0	—
Chloride	1	18	6	—
Fluoride	0.5	2.9	1.0	~100
Magnesium	<1	11	3	—
Nitrate	<0.4	2.6	1.3	3
Selenium	<0.001	0.001	0.001	10
Sodium	4	134	35	—
TDS	104	456	210	42
Hardness	12	108	45	—
pH	7.5	8.7	--	—
Conductance (mS/m)[c]	7	54	20	—

[a]Average of 20 samples each for As and Se, and 33 samples for all others.

[b]Percent of drinking water standard (EPA and PHS).

[c]1 mS/m = 10 μmho/cm.

TABLE XXV

ARSENIC AND SELENIUM IN LOS ALAMOS SUPPLY WELLS

Field and Well	As (μg/ℓ) Min	Max	Av[a]	Se (μg/ℓ) Min	Max	Av[a]
Los Alamos Field						
LA-1B	38	47	41	<1	3	1
LA-2	18	23	20	<1	1	1
LA-3	<7	10	8	<1	<1	<1
LA-4	10	13	12	<1	<1	<1
LA-5	12	29	22	<1	<1	<1
LA-6	122	135	130	<1	<1	<1
Guaje Field						
G-1	10	21	14	<1	<1	<1
G-1A	8	12	10	<1	<1	<1
G-2	8	52	39	<1	1	1
G-3	<7	18	13	<1	6	2
G-4	<7	9	7	<1	2	1
G-5	<7	10	9	<1	2	1
G-6	8	31	12	<1	1	1
Pajarito Field						
PM-1	9	11	10	<1	<1	<1
PM-2	8	9	9	<1	<1	<1
PM-3	8	10	9	<1	<1	<1

[a]Average of 8 samples collected from each well during a 10-h pumping test.

D. On-Site Surface and Ground Waters

1. **Non-Effluent Release Areas.** Monitoring of on-site, non-effluent waters consisted of analyzing one sample each from Cañada del Buey, Pajarito Canyon, Water Canyon, and Test Well DT-5A, and two samples from Test Well 3 (see Fig. 10). Chemical analyses of these samples (Table XXVII) indicate no significant change from previous reporting periods. Although these water sources do not serve as municipal or domestic supplies, they do meet current drinking water standards (Appendix E).

2. **Effluent Release Areas.** Chemical quality was determined for samples of the alluvium in canyons receiving industrial effluents from TAs. Data for each canyon are presented separately in Table XXVII and can be compared to effluent release data in Table XIX.

Acid-Pueblo Canyon was formerly AEC-LASL property and received industrial wastes from 1943 to 1964. The chemical quality of samples from this area has not changed noticeably from other post-1964 analyses. The high fluoride and total dissolved solids concentrations result from the Pueblo municipal sewage treatment plant effluent.

Chemical analyses from two surface water stations in Sandia Canyon give indication of effluents from the TA-3 sewage treatment plant and cooling water effluents from the TA-3 steam plant. The higher concentrations of chemicals for Sandia Canyon are not unexpected since (except for storm or spring run-off) these effluents constitute the total canyon stream.

The chemical quality of surface and ground waters in DP-Los Alamos Canyon reflects the release of industrial sewage and cooling tower effluents from TA-21 and TA-2. In general, the quality of water improves down-gradient from the confluence of DP and Los Alamos Canyons. The concentrations observed for this reporting period were slightly decreased and probably resulted from the unusually large spring run-off which diluted effluents and recharged the shallow aquifer in the alluvium.

TABLE XXVI

TRACE MATERIALS IN WATER SOURCES

	Concentrations (μg/ℓ)										
	Ag	Al	As	Ba	CN	Cr[c]	Cu	Fe	Ni	Se	Zn
Drinking Water Standard[a]	50[b]		50[b]	1 000[b]	200[b]	50[c]	1 000[d]	300[d]	(100)[e]	10[b]	5 000[d]
Los Alamos Distribution System											
Guaje Booster	<80	40	<10	<100	<10	<10	5	<50	<100	<1	40
Los Alamos Booster	<80	<20	20	200	<10	<10	5	<50	<100	85	40
White Rock Booster	<80	90	<10	100	<10	<10	5	<50	<100	5	10
Pajarito Booster	<80	110	<10	<100	<10	<10	14	<50	<100	9	40
S-Site Booster	<80	120	30	<100	<10	<10	5	60	<100	9	60
Selected Stations in Effluent Release Areas											
DPS-4 N 80 E205	<80	970	<10	100	<10	< 10	10	440	<100	<1	50
LAO-1 N 85 E130	<80	68	<10	100	10	450	26	300	<100	<1	80
LAO-3 N 80 E215	<80	2 940	<10	200	20	<10	21	650	<100	25	20
SCS-1 N 80 E 40	<80	420	<10	<100	<10	100	267	1 670	<100	<1	290
MCO-7 N 55 E 60	<80	1 100	<10	200	<10	<10	67	450	<100	5	100

[a]EPA Bulletin 956; PHS Publ. 956; 42 CFR 72.

[b]Mandatory standard

[c]Standard shown is for hexavalent chromium; measured values represent total chromium.

[d]Recommended standard

[e]Recommended by NMWQCC.

Surface and ground waters of Mortandad Canyon are clearly influenced by the chemical discharges from the industrial waste treatment plant at TA-50 (see Sec. X-A).

Analyses for various trace ions were made on one sample each from selected stations in DP-Los Alamos, Sandia, and Mortandad Canyons (see Table XXVI). The selenium concentration reported for the observation hole LAO-3 sample exceeded the USPHS "grounds for rejection" limit for drinking water. However, samples obtained upstream at stations LAO-1 (ground water) and DPS-4 (surface water) contained no detectable selenium, and it is unlikely that the reported selenium concentration was representative of this sampling station. The chromium concentration reported for LAO-1 exceeded the "grounds for rejection" limit for a drinking water supply, and was caused by cooling tower effluents from an up-gradient TA. The waters from DP-Los Alamos, Sandia, and Mortandad Canyons are not sources of municipal or domestic supply; nevertheless, the trace ion concentrations observed in these canyons are reported in Table XXVI along with concentrations observed in the Los Alamos supply system. The concentrations can thus be compared to the drinking water standards given in the same table.

XII. METEOROLOGY AND CLIMATOLOGY

A. Objectives

Meteorological monitoring supports many Laboratory activities, including environmental surveillance, health and safety management, engineering design and operations, and engineering development. The data are important in environmental monitoring, where they serve many purposes, including:

(1) documentation of general environmental conditions including, but not limited to, contributions to physical stress in the working environment (extreme heat, cold, wind, precipitation, etc.),

(2) establishment of a base line for evaluation of climatic modifications caused by Laboratory activities,

(3) providing data for investigating the transport and fate of material released to the atmosphere as a result of routine Laboratory activities,

(4) maintenance of a readiness posture in the event of accidental releases of contaminants to the atmosphere, and

(5) generating a data base for estimating occurrence probabilities of relatively rare atmospheric phenomena

TABLE XXVII

CHEMICAL QUALITY OF ON-SITE SURFACE AND GROUND WATER SOURCES

Sources Sampled Name and Location		No. & Type[a] of Sample	Average Concentrations (mg/ℓ) Ca^{+2}	Mg^{+2}	Na^{+1}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	F^{-1}	NO_3^{-1}	TDS	Hard.	pH	Conductance (mS/m)[b]
Non-disposal areas:														
Test Well 3	N 80 E210	2-G	18	6	12	0	90	6	0.4	0.4	178	70	7.8	17.0
Cañada del Buey	N 5 E165	1-S	14	5	16	0	60	6	0.6	1.3	210	56	7.0	14.0
Pajarito Canyon	S 60 E225	1-S	16	7	14	0	60	10	0.9	< 0.4	150	68	7.5	16.5
Water Canyon	S 90 E 90	1-S	18	4	20	0	72	12	0.2	0.4	176	60	7.2	19.2
Test Well DT-5A	S110 E 90	1-G	11	3	10	0	60	4	0.2	0.9	150	40	7.7	10.5
Acid-Pueblo Canyon (formerly AEC-LASL property):														
Acid Weir	N130 E 60	2-S	12	2	68	0	122	41	0.9	4.9	326	38	7.4	36.0
Pueblo 1	N130 E 65	2-S	16	4	75	0	176	33	6.0	16	430	56	7.3	50.0
Pueblo 2	N120 E160	2-S	15	5	59	0	110	36	4.8	18	344	56	7.6	38.0
Obs. Hole PO-3B	N110 E245	1-G	30	8	23	0	92	32	0.6	0.4	318	108	7.0	30.0
Hamilton Bend Spring	N110 E250	2-G	16	5	66	0	104	52	4.2	18	370	60	7.5	40.0
Pueblo 3	N 85 E315	2-S	16	4	78	0	110	35	5.7	66	453	56	7.1	49.0
Sandia Canyon:														
SCS-1	N 80 E 40	4-S	43	16	198	0	96	127	6.4	22	1 394	174	6.1	209.0
SCS-2	N 55 E 60	3-S	34	14	121	0	177	85	4.6	8.8	726	141	7.7	78.0
DP-Los Alamos Canyon:														
DPS-1	N 95 E160	3-S	26	6	179	8	418	46	8.9	200	1 090	87	7.9	126.0
DPS-4	N 80 E205	4-S	22	4	115	5	204	75	4.2	34	540	72	7.8	71.0
Obs. Hole LAO-C	N 90 E 70	3-G	15	5	26	0	57	31	0.2	0.9	207	57	7.4	20.0
Obs. Hole LAO-1	N 85 E130	4-G	17	5	57	0	77	53	1.2	2.6	331	62	7.3	36.0
Obs. Hole LAO-2	N 75 E205	3-G	25	6	69	0	136	65	2.3	19	419	85	7.4	51.0
Obs. Hole LAO-3	N 80 E215	4-G	18	4	80	0	129	68	4.4	13	408	61	7.4	51.0
Obs. Hole LAO-4.5	N 65 E270	3-G	18	8	38	0	88	33	0.3	0.9	231	77	7.2	27.0
Mortandad Canyon:														
Gaging Station 1	N 50 E 95	3-S	24	4	165	0	193	23	1.1	234	397	73	8.0	88.0
MCS-3.9	N 45 E125	3-S	28	4	186	0	251	29	1.5	176	832	84	8.0	102.0
Obs. Hole MCO-3	N 45 E105	3-G	28	2	136	0	200	22	1.5	177	670	79	7.9	78.0
Obs. Hole MCO-4	N 45 E135	3-G	27	5	193	0	259	29	1.7	230	856	87	7.8	103.0
Obs. Hole MCO-5	N 45 E145	3-G	21	8	167	0	215	29	1.1	155	671	84	8.0	79.0
Obs. Hole MCO-6	N 40 E155	3-G	23	8	169	0	247	33	1.3	177	771	88	7.7	94.0
Obs. Hole MCO-7	N 35 E170	4-G	34	9	172	0	225	34	0.6	208	816	120	7.5	92.0
Obs. Hole MCO-7.5	N 30 E190	3-G	39	11	176	0	229	39	0.3	248	891	141	7.5	99.0
Obs. Hole MCO-8	N 30 E205	3-G	57	12	138	0	175	51	0.6	234	833	191	7.8	95.0

[a] Number of samples analyzed during 1973; G = ground water; S = surface water.

[b] 1 mS/m = 10 μmho/cm.

that might affect present or planned facilities and operations.

Data sources exploited for the first time during 1973 were:

(1) wind and temperature profiles measured on a 91-m tower providing the variation of transport wind with height and also indications of the dispersal capacity of the atmosphere,

(2) a network of rain gauges, providing the distribution of daily and monthly precipitation--a valuable input to the hydrology of the canyon-mesa topography of the LASL site, and

(3) a continuously recording pyrheliometer, measuring solar energy flux, valuable in heat transfer estimates for materials handling and engineering design.

Future requirements of the meteorological monitoring system include:

(1) evaporation rates from selected sites, e.g., waste disposal areas,

(2) time and space variation of the transport wind fields and the associated turbulence parameters affecting dispersion rates of contaminants, and

(3) resuspension of contaminants from the ground surface by various mechanisms and in a variety of chemical and physical configurations.

Proceeding concurrently with the evolution of an empirical observation system is the development of physical models to allow the interpretation and generalization of the data collected at a particular location under one set of conditions. The bases for such model development are often available in the literature but must be amended and tailored to the specific application. In other cases, extensive research is required to achieve even a minimal modeling foundation. Interpretive efforts have been initiated in all relevant areas of application and will be discussed briefly in the following sections.

B. Climatological Records

Tables XXVIII and XXIX show means and extremes of temperature and precipitation for the entire period of record and for 1973, respectively. The first half of 1973 was cooler than normal, the greatest deviation from average occurring in April when temperatures were 3.6°C below normal. Temperatures from August through December were above normal.

Precipitation in 1973, was below average in seven months, near the average in three months, and exceeded the long-term average in March and May. A record was set

TABLE XXVIII

CLIMATOLOGICAL SUMMARY 1910 - 1973

Latitude 35° 32' North
Longitude 106° 19' West
Elevation 2 260 m

Los Alamos, New Mexico

	Temperature (°C)							Precipitation Totals (mm)										Mean No. of Days		
	Means			Extremes				Rain					Snow and Frozen Precipitation							
	Daily Values		Mo						Daily		Mo			Daily		Mo		Precip	Max Temp	Min Temp
Mo	Max	Min	Mean	High	Yr	Low	Yr	Mean	Max	Yr	Max	Yr	Mean	Max	Yr	Max	Yr	≥2.5mm	≥26.7°C[a]	≤-9.4°C[a]
Jan	3.9	-7.9	-2.0	17.8	1963	-27.8	1963	20.83	62.23	1916	171.45	1916	240.7	381.0	1913	989.2	1949	2	0	8
Feb	6.1	-5.8	0.1	18.9	1936	-25.6	1951	17.52	26.67	1915	61.89	1948	206.6	330.2	1915	604.5	1948	2	0	6
Mar	9.4	-3.4	3.1	21.7	1971	-19.4	1948	25.42	57.15	1916	104.4	1973	262.6	457.2	1916	939.8	1973	3	0	3
Apr	14.6	1.0	7.8	26.7	1950	-15.0	1925	24.90	36.83	1969	117.86	1916	104.1	304.8	1958	853.4	1958	3	0	0
May	19.9	6.0	12.9	31.7	1935	-4.4	1938	32.63	45.72	1929	113.54	1929	20.0	228.6	1917	431.8	1917	3	1	0
Jun	25.3	10.9	18.1	33.9	1954	-2.2	1919	34.99	34.80	1931	141.49	1913	0	0	--	0	--	3	14	0
Jul	26.9	12.9	19.9	35.0	1935	2.8	1924	86.06	70.61	1968	202.69	1919	0	0	—	0	--	8	19	0
Aug	25.4	12.3	18.9	33.3	1937	4.4	1947	94.45	57.40	1951	283.97	1952	0	0	—	0	--	8	12	0
Sep	22.4	8.9	15.7	34.4	1934	-5.0	1936	50.13	56.13	1929	147.07	1941	5.0	152.4	1913	152.4	1914	5	5	0
Oct	16.7	3.2	9.9	27.8	1930	-8.9	1970	40.41	88.39	1919	171.96	1957	37.5	228.6	1972	228.6	1959 1972	3	0	0
Nov	9.4	-3.1	3.2	20.6	1937	-20.0	1957	17.86	37.08	1931	83.82	1957	128.1	355.6	1931	876.3	1957	2	0	2
Dec	4.9	-6.8	-1.0	16.7	1933	-23.3	1924	23.02	34.29	1965	72.39	1965	270.4	457.2	1915	1049.0	1967	3	0	6
Year	15.4	2.3	8.9	35.0	1935	-27.8	1963	464.97	88.39	1919	283.97	1952	1274.8	457.2	1915 1916	1049.0	1967	45	51	25

[a] 26.7°C = 80°F; -9.4°C = 15°F

TABLE XXIX

CLIMATOLOGICAL SUMMARY FOR 1973

	Temperature (°C)					Precipitation Total (mm)						
	Means			Extremes		Rain		Snow or Frozen Precipitation		Number of Days		
Month	Daily Max	Daily Min	Monthly	High	Low	Total	Daily Max	Total	Daily Max	Precip ≥2.5 mm	Max Temp ≥26.7°C[a]	Min Temp ≤-9.4°C[a]
Jan	2.1	-8.7	-3.3	10.0	-13.3	5.8	2.3	50.8	-	0	0	14
Feb	4.1	-6.2	-1.1	12.8	-13.3	17.5	5.6	101.6	50.8	3	0	6
Mar	5.9	-4.2	0.8	12.8	-8.3	104.4	41.7	939.8	355.6	6	0	0
Apr	10.6	-2.1	4.2	19.4	-11.7	10.2	4.6	101.6	76.2	2	0	2
May	18.4	5.4	11.9	25.6	-1.1	40.1	19.6	0	0	3	0	0
Jun	24.8	10.5	17.6	32.2	3.9	11.9	6.6	0	0	2	12	0
Jul	25.9	13.2	19.6	32.8	9.5	83.3	19.8	0	0	8	14	0
Aug	26.9	13.2	20.0	30.6	8.9	30.5	7.6	0	0	4	22	0
Sep	22.0	8.8	15.3	27.2	2.3	56.1	47.2	0	0	2	1	0
Oct	16.8	4.2	10.6	22.8	-2.2	11.4	7.9	0	0	1	0	0
Nov	11.2	-0.5	5.3	18.3	-9.4	7.6	5.3	38.1	25.4	1	0	1
Dec	4.5	-6.3	-0.4	12.2	-11.1	1.5	1.3	25	-	0	0	7
Year	14.4	2.3	8.4	32.8	-13.3	360.3	47.2	1256.9	355.6	32	49	30

[a]26.7°C = 80°F; -9.4°C = 15°F

during March with 104.4 mm, 4 times normal. Precipitation for the year was 85 mm less than normal. The distribution of annual precipitation totals for Los Alamos is approximately Gaussian, with a mean of 465 mm and a standard deviation of 120 mm. The calendar year 1973 is at the 25th percentile.

C. Rainfall Distributions

Distributions of hourly and daily rainfall accumulations observed by a recording rain/snow gauge are shown in Fig. 11. The distributions are highly skewed toward low rates, with a median hourly accumulation of 0.75 mm and a range of 0.25 to 13.5 mm. Daily accumulations ranged from 0.25 to 50 mm, with a median value of 1.75 mm. There were 80 days (289 h) with measurable precipitation.

To determine patterns of rainfall, and to aid in estimation of surface run-off and soil moisture movement in the drainage basins around Los Alamos, 72 rain gauges were distributed as widely as possible throughout the county. A record of daily observations at each site was compiled from June through October. Table XXX lists some gross

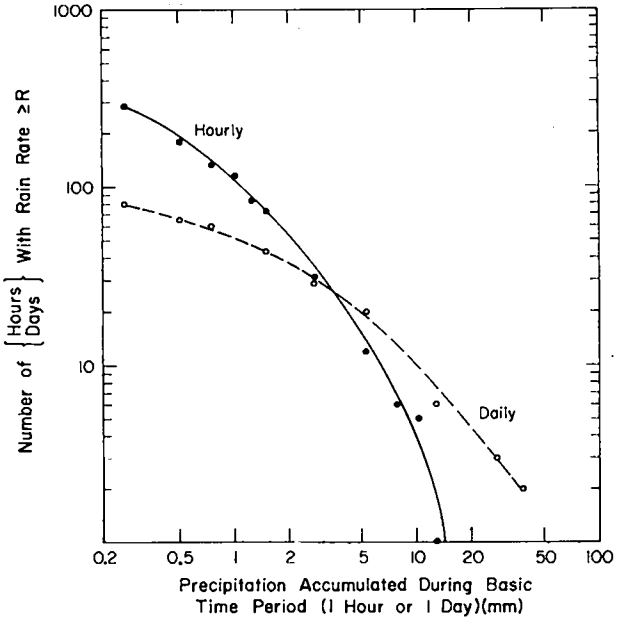

Fig. 11.
Distribution of hourly and daily rainfall rates during 1973.

TABLE XXX

RAIN-GAUGE NETWORK STATISTICS FOR 1973

Month	LASL Total[a] (mm)	No. of Stations Reporting	Network Mean (mm)	Std Dev (mm)	Coeff of Var
June	11.9	57	13.7	5.9	0.42
July	83.3	63	68.7	20.5	0.30
Aug	30.5	59	41.8	8.3	0.20
Sept	56.1	64	55.9	9.9	0.18
Oct	11.4	54	12.2	4.4	0.36

[a]Data collected at the LASL meteorological tower.

statistics for the monthly totals of the 72-station network, giving some indications of the spatial variability of monthly precipitation totals.

Precipitation totals from the LASL meteorological tower are fairly representative of the spatial means. However, the variation of rainfall across the network is quite large. The coefficient of variation (the ratio of the standard deviation to the mean) is between 0.18 and 0.42. The largest variations were in June and October when much of the rainfall came from a few major thunderstorms.

It is also pertinent to identify consistent aspects of the precipitation patterns. Figure 12 shows the isohyets of the June-through-October rain. The net gradient parallel to the terrain slope is 2-3 mm/km, and one or more tongues of precipitation maxima are oriented along the terrain gradient. Two primary thunderstorm tracks help to explain the patterns of Fig. 12. The more common track was the west-to-east movement of convective cells originating in the Jemez Mountains. A most probable site of cell formation, such as 3460-ft-high Redondo Peak, could explain a west-to-east oriented rainfall maximum. Such convective cells diminished as they traveled eastward. The second track led up the Rio Grande valley from the south, occurred far less frequently, but often accounted for very heavy rains. Precipitation diminished as these latter storms moved westward. The rain-gauge network is evidently situated near the edge of these storms. It must be stressed that the conclusions drawn from one season's rainfall data are tentative and only suggestive of possible mechanisms.

D. Windfield Patterns

Figure 13 shows the wind roses calculated from the anemometer at the Administration Building (TA-3). The wind roses are stratified into three categories by time of day to reflect the role of low-level buoyancy effects. The nocturnal period, from 2000 to 0800 MST, is representative of stable thermal stratification. During the period of insolation, 0800 to 1600 MST, the air is generally unstable, and 1600 to 2000 MST is a transition period during which the statistics are strongly affected by transient processes associated with sunset. The nighttime winds show the greatest incidence of calm conditions, 8.2% of the total hours of record. For all speeds, the winds at TA-3 are dominated by northwest flow (flow from the northwest). This suggests a downslope drainage to account for the light winds. The high incidence of strong northwest winds is also representative of other sites in Los Alamos and reflects a vertical confluence of the free stream flow on the lee of the Jemez Mountains. This effect may account for the majority of record surface winds in the 30-45 m/s range observed at Los Alamos over the last 30 years.

Daytime winds at TA-3 are more uniformly distributed in direction than those at night, and have a weak NW-SE axis and secondary maxima in the southerly and northeasterly directions. Again, winds greater than 9 m/s are predominantly from the northwest. The transition period also reflected the westerly dominance with a northwesterly maximum occurrence. Previous studies have shown that the weak west-to-northwest drainage flow has the lowest levels of turbulence and therefore results in the poorest dispersion of stack emissions. The terrain configuration at Los Alamos makes it inadvisable to extrapolate the wind rose from a single site or to assume that transport follows straight paths in the proportions indicated in Fig. 13. Several sources of data show that transport winds vary significantly over the area. Wind roses calculated for other years at sites near the ends of mesas show a distinct southerly maximum. One-year records of simultaneous hourly winds at three sites, TA-3, TA-53, and TA-55, covering the period May 1971 to April 1972, have been processed to determine spatial differences in the wind field. One statistic of interest is the fraction of the hours when the wind direction difference between the three sites exceeded 90 degrees. This occurred 20% of the time, primarily with wind speeds of less than 2 m/s. These data suggest that the drainage flow, which is quite well organized in the western portion of the Laboratory, closer to the Jemez Mountains, weakens and gives way to a southerly flow created by air channeling through the Rio Grande depression at the eastern end of the Laboratory site. A significant modeling effort will be required to quantify these concepts.

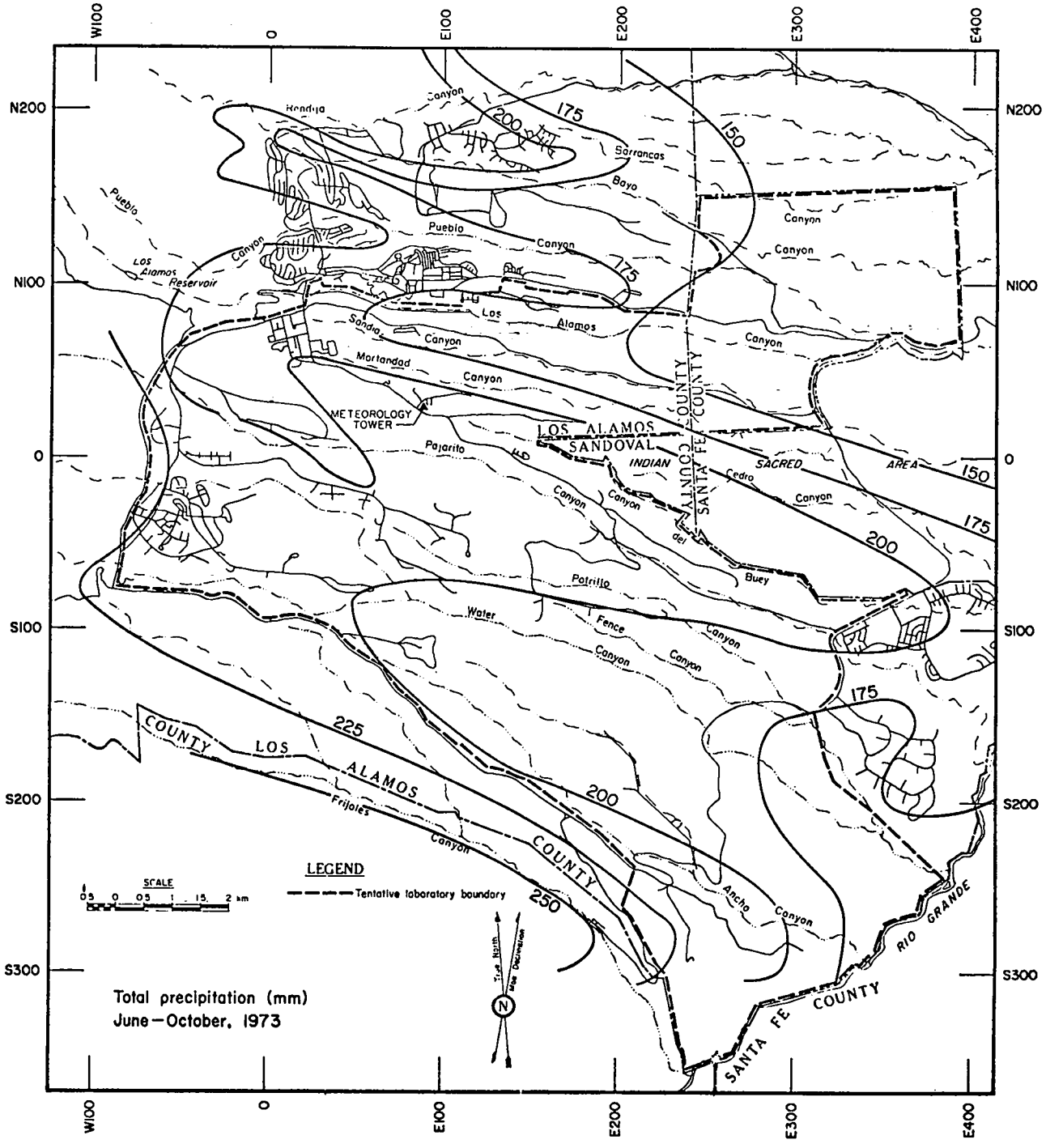

Fig. 12.
Total precipitation isohyets for June through October 1973.

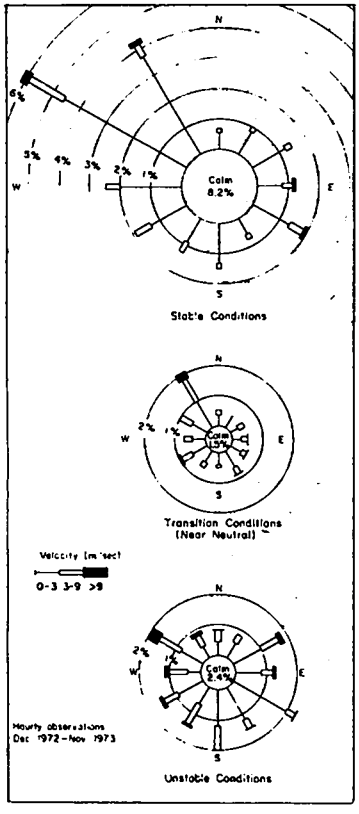

Fig. 13.
Wind roses for Los Alamos, 1973.

XIII. GEOLOGY AND HYDROLOGY

A. Application to Waste Management

Geo-hydrological studies of the LASL area indicate that buried wastes have been successfully isolated from the hydrologic environment.[10] Liquid effluents, on the other hand, tend to be retained in stream-connected aquifers in the alluvium of the receiving canyons. The stream flow in these canyons does not usually extend beyond the LASL boundaries because the water is lost by evapo-transpiration from the alluvium. During periods of heavy storm run-off, however, contaminated sediments are transported down the canyons. Any attempt to control the movement of contaminated sediments beyond the LASL boundaries, as well as to design an efficient monitoring program, requires an understanding of the potential scouring action of storm run-off.

B. Flood Frequencies and Maximum Discharges

There are no surface water data with which to evaluate the flood frequencies and maximum discharges in the canyons of the Los Alamos area. However, there are theoretical projections based on generalized rainfall data and nomographs devised by Scott.[11] The method uses empirical relationships between existing flood data at gauged sites and the physical and climatic conditions of the corresponding drainage basin. The nomographs are then used to estimate flood frequencies for areas where no direct flood data exist.

Although 16 drainage areas were identified within the LASL boundaries (Fig. 14), only 10 contained the well defined channels necessary for theoretical flood frequency and maximum discharge analyses. Drainage areas were determined from topographic maps; channel slopes were computed on the basis of two points: 15 and 90% of the distance from the drainage divide to the discharge point at the LASL boundary.

The calculated maxima and frequencies of discharges are shown in Table XXXI; the frequency, or "recurrence interval," is the average time between occurrences of discharges of a given magnitude.

The study of canyon discharge dynamics has just begun, and will be continued in an attempt to develop quantitative models for the transport of sediments through canyons.

XIV. ENVIRONMENTAL CONTROLS

A. Relevance to Surveillance

Continued surveillance of environmental contaminants would be of little value if the data were not used to improve environmental protection practices. Conversely, some environmental control activities provide source data that can be used in planning future surveillance programs.

A recent example from LASL operations illustrates the need for close coordination of control and surveillance functions. Three TAs decommissioned over a decade ago were subsequently demolished and decontaminated; the real property was then disposed of to private or public ownership. The small quantities of radioactive contaminants remaining at these locations therefore abruptly became "off-site" by administrative action. Recent requests for more detailed evaluations of these sites indicate the value of thorough and quantitative documentation of

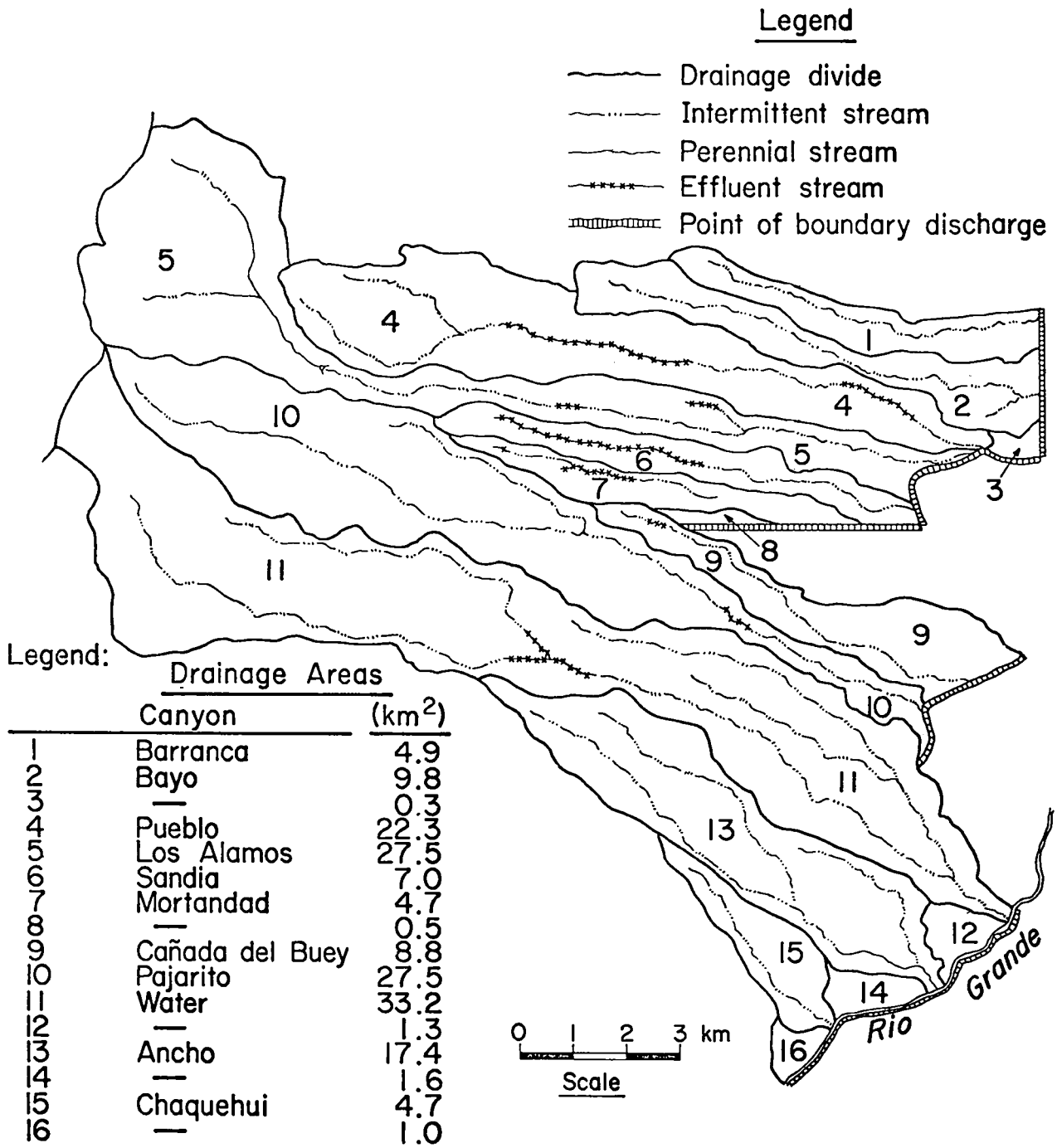

Fig. 14.
Surface water drainage areas.

TABLE XXXI

FLOOD FREQUENCY AND MAXIMUM DISCHARGE ESTIMATES

Drainage Area Designation	Area Drained (km^2)	Average Channel Slope[a]	Maximum Discharge (m^3/s) by Frequency				
			2 yr	5 yr	10 yr	25 yr	50 yr
1. Barranca Canyon	4.9	-0.039	1.5	4.1	6.7	12	14
2. Bayo Canyon	9.8	-0.028	2.4	6.1	8.5	17	19
3. Unnamed[b]	0.3	—	—	—	—	—	—
4. Pueblo Canyon	22.3	-0.033	3.1	7.1	10	17	21
5. Los Alamos Canyon	27.5	-0.040	3.0	6.8	11	16	20
6. Sandia Canyon	7.0	-0.028	2.0	5.4	8.5	16	18
7. Mortandad Canyon[c]	4.7	-0.029	—	—	—	—	—
8. Unnamed[b]	0.5	—	—	—	—	—	—
9. Cañada del Buey	8.8	-0.021	2.6	6.2	9.4	19	21
10. Pajarito Canyon	27.4	-0.039	3.0	7.1	10	16	20
11. Water Canyon	33.2	-0.050	2.8	6.8	9.6	14	18
12. Unnamed[b]	1.3	—	—	—	—	—	—
13. Ancho Canyon	17.4	-0.045	2.3	5.4	8.2	14	17
14. Unnamed[b]	1.6	—	—	—	—	—	—
15. Chaquehui Canyon	4.7	-0.078	1.1	3.0	4.5	8	10
16. Unnamed[b]	1.0	—	—	—	—	—	—

[a]Channel slopes are presented as dimensionless ratios of average vertical distance change (negative to horizontal distance traversed).

[b]Drainage area without well defined channel.

[c]Mortandad Canyon is the only major canyon for which no run-off at boundary is predicted owing to the lack of a main channel in the lower portions.

current decommissioning activities. This turn of events also emphasizes the artificiality of distinguishing between on-site and off-site contamination.

B. Decommissioning Surveillance

Before any demolition takes place, a preliminary survey is conducted in the immediate vicinity of each decommissioned structure. The survey includes measurements of external radiation intensity and the collection and analysis of soil samples or other appropriate environmental media. Results of the survey are used to determine the extent of required decontamination and concomitant costs.

During demolition, special air samplers in the immediate vicinity and daily meteorological forecasts for the local area are used to assess actual and probable releases of pollutants to the environment. A representative of the Environmental Studies Group is authorized to postpone or curtail the operations if weather conditions or decommissioning methods threaten to release excessive quantities of pollutants.

After demolition and decontamination, the site is thoroughly resurveyed for any residual contamination. Members of the Ecology Section are consulted on matters such as soil stabilization, revegetation, and the desirability of ecological studies at the site.

The above procedure was applied to one decommissioned facility during 1973 and will be used for other facilities. It is an important adjunct to the routine environmental surveillance program.

C. Construction Quality Assurance Program

As part of the quality assurance (QA) review for every proposed facility, environmental aspects of the design are reviewed by the Environmental Studies Group. Such factors as site selection and preparation, soil control and drainage, control of gaseous and liquid effluents, and stress on flora and fauna are included in the QA review. The concepts of environmental protection and evaluation are therefore used in the planning stage of a facility, in operational surveillance during the lifetime of the facility, and in the ultimate demolition and disposal of the property.

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8. ICRP Task Group on Lung Dynamics, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract," Health Physics 12, 173 (1966).

9. International Commission on Radiological Protection (ICRP), "The Metabolism of Compounds of Plutonium and Other Actinides," ICRP Publ. 19, Pergamon Press, New York (1972).

10. W. D. Purtymun and W. R. Kennedy, "Geology and Hydrology of Mesita del Buey," Los Alamos Scientific Laboratory report LA-4660 (1971).

11. A. G. Scott, "Preliminary Flood-Frequency Relations and Summary of Maximum Discharges in New Mexico," US Geological Survey Open-file Report (1971).

APPENDIX A

UNITS OF MEASUREMENT CONVERSIONS

Quantity	This Report	AECM 0524	International (SI)	Common Usage
Radioactivity Concentration				
Airborne	-	= 10^{-12} µCi/mℓ	= 0.037 $\delta^{-1}m^{-3}$	= 1 pCi/m³
	-	= 10^{-15} µCi/mℓ	= 3.7 x 10^{-5} $\delta^{-1}m^{-3}$	= 10^{-3} pCi/m³
	-	= 10^{-18} µCi/mℓ	= 3.7 x 10^{-8} $\delta^{-1}m^{-3}$	= 10^{-6} pCi/m³
In Liquids	-	= 10^{-9} µCi/mℓ	= 37 $\delta^{-1}m^{-3}$	= 1 pCi/ℓ
	-	= 10^{-12} µCi/mℓ	= 0.037 $\delta^{-1}m^{-3}$	= 10^{-3} pCi/ℓ
In Solids	1 pCi/g	-	= 37 $\delta^{-1}kg^{-1}$	= 1 pCi/g
	1 µCi/g	-	= 0.037 $\delta^{-1}kg^{-1}$	= 10^{-3} pCi/g
Chemical Properties				
Concentrations in Liquids	1 mg/ℓ	-	= 1 g/m³	= 1 ppm
	1 µg/ℓ	-	= 1 mg/m³	= 1 ppb
	1 ng/ℓ	-	= 1 µg/m³	= 10^{-3} ppb
Exchange Capacity	1 eq/kg	-	= 1(equivalent)/kg	= 10^{2} meq/100g
Electrical Conductance	1 mS/m	-	= 1 mS/m	= 10 µmho/cm
Fluid Flow Rates	1 m³/δ	-	= 1 m³/δ	= 6 x 10^{4} ℓpm
				= 2120 cfm
	1 ℓ/δ	-	= 1 dm³/δ	= 60 ℓpm
				= 2.12 cfm
Meteorological Data				
Temperature	°C	-	K = °C + 273.15	°F = 1.8(°C) + 32
Precipitation	1 mm	-	= 1 mm	= 0.039 inch
Wind Speed	1 m/δ	-	= 1 m/δ	= 0.447 mph
Air Pressure	1 mPa	-	= 1 mPa	= 9.87 x 10^{-3} atmos.
				= 10 mbar
				= 0.145 psi
				= 0.295 in. Hg
Geological Data				
Water Volume	1 m³	-	= 1 m³	= 8.11 x 10^{-4} ac.ft
	1 ℓ/δ	-	= 1 dm³/δ	0.0353 cfs
				= 15.9 gpm
				= 2.28 x 10^{4} gpd
Stream Flow Rate	1 m³/δ	-	= 1 m³/δ	= 35.3 cfs
				= 1.59 x 10^{5} gpm
				= 2.28 x 10^{7} gpd

APPENDIX B

STANDARDS PERTAINING TO EFFLUENT AND ENVIRONMENTAL MONITORING
(Excerpts from AEC Manual Chapter 0550, Appendix, March 26, 1973)

Part II. Environmental Protection

Prescribed:

Prevention, Control, and Abatement of Air and Water Pollution, AECM 0510.

Air and Water Pollution Control Standards Promulgated Pursuant to the Clean Air Act (42 U.S.C. 1857 et seq.) and the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.).

Intrastate or Interstate Regulations of Air and Water Pollution Control Authorities.

Effluent and Environmental Monitoring and Reporting, AECM 0513.

Recommended:

Standard Methods for the Examination of Water, Sewage, and Industrial Wastes (AWWA).

Manual of Septic-Tank Practice, Pub. No. 526 (USPHS).

Sanitary Landfill Facts, Pub. No. 1792 (USPHS).

Interim Guide of Good Practice for Incineration at Federal Facilities, Pub. No. AP-46 (USPHS).

Incinerator Guidelines, Pub. No. 2012 (USPHS).

Air Pollution Engineering Manual, Pub. No. AP-40 (USPHS).

Part IV. A. Radiation Protection

Prescribed:

Standards for Radiation Protection, AECM 0524

Recommended:

Applicable (FRC) Reports (#1-1960, #2-1962, #5-1964, #7-1965, #8 (Revised).

Handbooks, NCRP Recommendations (NBS).

Guide to Sampling Airborne Radioactive Materials in Nuclear Facility N13.1-1969 (ANSI).

Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents, N13 Series (ANSI) in Draft Status.

Part IV. D. Public Health and Sanitation

Prescribed:

Drinking Water Standards, Bulletin 956 (EPA).

Manual of Recommended Water-Sanitation Practice, Bulletin 525 (EPA).

Manual of Water Quality and Treatment (AWWA).

Sanitation Manual for Public Ground Water Supplies, Reports 59:137-177, Reprint 2539 (EPA).

Standards and Specifications for Water Supply, Treatment, Distribution System, and Storage Equipment, Materials, and Procedures (AWWA).

Part VII. F. Radioactive Waste Management

Prescribed:

Radioactive Waste Management, AECM 0511. (Manual chapter in preparation.)

Plan for the Management of AEC-Generated Radioactive Wastes, WASH-1202 (GPO).

Sources of Supply for Standards

(ANSI) American National Standards Institute
1403 Broadway
New York, New York 10018

(AWWA) American Water Works Association
2 Park Avenue
New York, New York 12603

(EPA) Environmental Protection Agency
401 M Street S.W.
Washington, D.C. 20024

(FRC) Federal Radiation Council
Washington, D.C. 20449

(GPO) Superintendent of Documents
United States Government Printing Office
Washington, D.C. 20402

(NBS) National Bureau of Standards
Department of Commerce
Washington, D.C. 20234

(USPHS) United States Public Health Service
Department of Health, Education, and Welfare
Washington, D.C. 20203

APPENDIX C

MINIMUM DETECTION LIMITS (MDLs) FOR ROUTINE ANALYSES OF RADIOACTIVITY IN TYPICAL ENVIRONMENTAL SAMPLES

Analysis	Airborne			Liquids			Solids[a]	
	Conc.		(%CG)	Conc.		(%CG)	Conc.	
^{3}H (oxide)	20	$10^{-12}\mu Ci/ml$[b]	(0.01)	0.3	$10^{-6}\mu Ci/ml$	(0.01)	3	nCi/ℓ[c]
^{137}Cs	20	$10^{-12}\mu Ci/ml$	(1)	0.3	$10^{-6}\mu Ci/ml$	(1.5)	0.1	pCi/g
^{238}Pu	10	$10^{-18}\mu Ci/ml$	(0.01)	50	$10^{-12}\mu Ci/ml$	(0.001)	5	fCi/g
^{239}Pu	10	$10^{-18}\mu Ci/ml$	(0.02)	50	$10^{-12}\mu Ci/ml$	(0.001)	5	fCi/g
^{241}Am	2	$10^{-18}\mu Ci/ml$	(0.001)	50	$10^{-12}\mu Ci/ml$	(0.001)	5	fCi/g
Gross α	0.4	$10^{-15}\mu Ci/ml$	(0.7)	0.3	$10^{-9}\mu Ci/ml$	(0.006)	3	pCi/g
Gross β	3	$10^{-15}\mu Ci/ml$	(0.01)	3	$10^{-9}\mu Ci/ml$	(1)	1	pCi/g
U (total)	0.1	ng/m^3	(0.001)	10	ng/ℓ[d]	(0.0001)	10	ng/g[d]

[a] MDLs as percent of CGs cannot be stated for solids such as soils and sediments since there are no published CGs for these materials.

[b] The tritium concentration is measured in atmospheric water vapor and converted to a concentration in air on the basis of the relative humidity during the collection period. The listed value is considered typical for this region.

[c] Only the tritium contained in the unbound water of the sample is analyzed.

[d] Total mass concentrations of uranium are determined fluorometrically; conversion to activity depends on the isotopic composition of the material.

APPENDIX D

CONCENTRATION GUIDES (CGs) FOR UNCONTROLLED AREAS[a]

CONCENTRATION GUIDES FOR UNCONTROLLED AREAS[a]

Nuclide	CG for Air		CG for Water	
	(μCi/mℓ)	(pCi/m³)[b]	(μCi/mℓ)	(nCi/ℓ)[b]
^{3}H	2×10^{-7}	2×10^{5}	3×10^{-3}	3 000
^{89}Sr	3×10^{-10}	300	3×10^{-6}	3
^{90}Sr[d]	3×10^{-11}	30	3×10^{-7}	0.3
^{131}I	1×10^{-10}	100	3×10^{-7}	0.3
^{137}Cs	2×10^{-9}	2 000	2×10^{-5}	20
^{238}Pu	7×10^{-14}	0.07	5×10^{-6}	5
^{239}Pu[d]	6×10^{-14}	0.06	5×10^{-6}	5
^{241}Am	2×10^{-13}	0.2	4×10^{-6}	4
		(μg/m³)[c]		(mg/ℓ)[c]
U, natural	3×10^{-12}	9	2×10^{-5}	60

CONCENTRATION GUIDES FOR CONTROLLED AREAS

Nuclide	CG for Air		CG for Water	
	(μCi/mℓ)	(pCi/m³)[b]	(μCi/mℓ)	(nCi/ℓ)[b]
^{3}H	5×10^{-6}	5×10^{6}	1×10^{-1}	1×10^{5}
^{89}Sr	3×10^{-8}	3×10^{4}	3×10^{-4}	300
^{90}Sr[d]	1×10^{-9}	1 000	1×10^{-5}	10
^{131}I	9×10^{-9}	9 000	6×10^{-5}	60
^{137}Cs	6×10^{-8}	6×10^{4}	4×10^{-4}	400
^{238}Pu	2×10^{-12}	2	1×10^{-4}	100
^{239}Pu[d]	2×10^{-12}	2	1×10^{-4}	100
^{241}Am	6×10^{-12}	6	1×10^{-4}	100
		(μg/m³)[c]		(mg/ℓ)[c]
U, natural	7×10^{-11}	210	5×10^{-4}	1 500

[a] This table contains the most restrictive CGs for nuclides of major interest at LASL (AEC Manual Ch.0524, Annex A).

[b] Although units of μCi/mℓ are used for all CGs in AECM 0524, units of m^3 for air volumes and ℓ for liquid volumes are given in this report because of their convenience and wide acceptance; these units are combined with standard metric prefixes as appropriate for the range of values reported.

[c] Fluorometric measurements of U mass concentrations may be converted to activity concentrations using the factor 0.33 μCi/g.

[d] Of the possible radionuclides released at LASL, ^{90}Sr and ^{239}Pu are the most restrictive. The CGs for these species are used for the gross beta and gross alpha CGs, respectively.

APPENDIX E

WATER STANDARDS

"DRINKING WATER STANDARDS" FOR CHEMICALS

Constituent	Symbol	Concentration Limit (mg/ℓ) PHS and EPA[a] Mandatory	PHS and EPA[a] Recommended	NMWQCC[b]
Alkyl benzene sulfonate	ABS	-	0.5	-
Arsenic	As	0.05	0.01	0.05
Barium	Ba	1.0	-	1.0
Boron	B	-	-	0.75
Cadmium	Cd	0.01	-	0.01
Carbon chloroform extract	CCE	-	0.2	-
Chlorine	Cl	-	250.	-
Chromium hexavalent	Cr^{+6}	0.05	-	-
total	Cr	-	-	0.01
Copper	Cu	-	1.0	0.05(0.1)[c]
Cyanide	CN	0.2	0.01	-
Fluoride	F	~1[d]	-	-
Iron	Fe	-	0.3	-
Lead	Pb	0.05	-	0.05
Manganese	Mn	-	0.05	0.1
Mercury	Hg	-	-	0.001
Molybdenum	Mo	-	-	0.01
Nickel	Ni	-	-	0.1
Nitrate	NO_3	-	45.	-
Phenols		-	0.001	-
Selenium	Se	0.01	-	0.01
Silver	Ag	0.05	-	0.05
Total dissolved solids	TDS	-	500.	-
Zinc	Zn	-	5.0	0.1(0.5)[c]

[a] PHS Regulations on Drinking Water Standards, 42 CFR 72, 201-207, Fed. Reg. 27:2152, Mar.6,1962. Also in PHS Publ. 956 and EPA Bulletin 956.

[b] New Mexico Water Quality Control Commission Regulations (see text).

[c] Concentrations shown in parentheses are permitted in community sewer systems.

[d] The concentration standard for fluoride varies depending upon temperature, but is centered around 1 mg/ℓ.

MISCELLANEOUS WATER STANDARDS

Radioactivity in drinking water (PHS):

Gross beta activity: (if strontium-90 and alpha emitters are not present) 1 000 pCi/ℓ

Strontium-90: 10 pCi/ℓ

Radium-226: 3 pCi/ℓ

Biological quality for drinking water (NMWQCC):

	Single Sample	Composite of 5 daily samples
Biological oxygen demand, BOD:	160mg/ℓ	30 mg/ℓ
Chemical oxygen demand, COD:	150mg/ℓ	125 mg/ℓ
Settleable solids:	1.0mℓ/ℓ	0.5 mℓ/ℓ
Fecal coliform organisms:	500/100mℓ	-
pH:	6.6 - 8.6	-

Quality factors for fisheries[a] and recreational waters (NMWQCC):

Maximum temperature: 70° F

Maximum temperature increase: 2° F

Dissolved oxygen DO (and BOD): not to drop to less than 50% of saturation or 6.0 mg/ℓ, whichever is greater.

Coliform organisms:
for fisheries: 2 000/100 mℓ, 5-day Arith Avg
for contact sports: 200/100 mℓ, 5-day Geom Mean

[a] All streams above 5 000 ft in elevation are considered to be trout producing.

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