4. Air Surveillance

Environmental Surveillance at Los Alamos during 2004

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A. Ambient Air Sampling *(Andrew Green and Craig Eberhart)*

1. Introduction

The radiological air-sampling network, referred to as AIRNET, measures environmental levels of airborne radionuclides, such as plutonium, americium, uranium, tritium, and activation products, that may be released from Los Alamos National Laboratory (LANL or the Laboratory) operations. Natural atmospheric and fallout radioactivity levels fluctuate and affect measurements made by LANL's air-sampling program. Most of the regional airborne radioactivity come from the following sources: (1) fallout from past atmospheric nuclear weapons tests conducted by several countries, (2) natural radioactive constituents in particulate matter (such as uranium and thorium), (3) terrestrial radon diffusion out of the earth and its subsequent decay products, and (4) material formation from interactions with cosmic radiation (for example, natural tritiated water vapor produced by interactions of cosmic radiation and common atmospheric gases). Table 4-1 summarizes regional levels of radioactivity in the atmosphere for the past 5 years, which can be useful in interpreting current air sampling data.

Particulate matter in the atmosphere is primarily caused by aerosolized soil. Windy, dry days can increase soil entrainment, but precipitation (rain or snow) can wash particulate matter out of the air. Consequently, changing meteorological conditions often cause large daily and seasonal fluctuations in airborne radioactivity concentrations. Natural events can also have major impacts: during 2000, the Cerro Grande fire dramatically increased short-term ambient concentrations of particulate matter (ESP 2001).

In the Environmental Stewardship Division, Meteorology and Air Quality Group (ENV-MAQ) personnel compare ambient air concentrations, as calculated from the AIRNET sample measurements, with environmental compliance standards for publicly accessible locations or with workplace exposure standards for on-site locations. The group usually compares annual concentrations in areas accessible to the public with the 10-mrem equivalent concentration established by the Environmental Protection Agency (EPA) (EPA 1989). Concentrations in controlled access areas are usually compared with Department of Energy (DOE) Derived Air Concentrations (DACs) for workplace exposure (DOE 1988a) because access to these areas is generally limited to workers with a need to be in the controlled area.

2. Air-Monitoring Network

During 2004, LANL operated 46 environmental air samplers to sample radionuclides by collecting water vapor and particulate matter. AIRNET sampling locations (Figures 4-1 through 4-3) are categorized as follows: regional, pueblo, perimeter, waste site [Technical Area (TA) -54], or other on-site locations.

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Table 4-1. Average Background Concentrations of Radioactivity in the Regional[a] Atmosphere

	Units	EPA Concentration Limit[b]	Annual Averages[c]				
			2000	2001	2002	2003	2004
Alpha	fCi/m^3	NA[d]	1.0	0.8	0.8	0.8	1.1
Beta	fCi/m^3	NA	13.0	13.9	13.3	13.7	18.3
Tritium[e]	pCi/m^3	1500	0.8	0.0	–0.1	–0.1	0.1
Pu-238	aCi/m^3	2100	0.0	0.0	0.0	–0.1	1.2
Pu-239	aCi/m^3	2000	0.0	0.1	0.3	–0.1	–0.1
Am-241	aCi/m^3	1900	0.4	–0.2	0.3	–0.7	–0.4
U-234	aCi/m^3	7700	17.1	17.9	21.7	20.9	14.9
U-235	aCi/m^3	7100	0.9	1.3	2.4	1.8	0.9
U-238	aCi/m^3	8300	15.9	17.7	21.8	20.1	14.1

[a] Data from LANL-operated regional air-sampling stations during the last 5 years. (Locations can vary by year.)

[b] Each EPA concentration limit is from 10 CFR 40 Part 61, Appendix E and corresponds to 10 mrem.

[c] Gross alpha and beta annual averages are calculated from gross air concentrations. All other annual averages are calculated from net air concentrations.

[d] Not available

[e] Tritium annual averages have been corrected for the tritium lost to bound water in the silica gel.

3. Sampling Procedures, Data Management, and Quality Assurance

a. Sampling Procedures. Generally, each AIRNET sampler continuously collects particulate matter and water-vapor samples for approximately 2 weeks per sample. Particulate matter is collected on 47-mm polypropylene filters at airflow rates of about 0.11 m^3 per minute. These filters are analyzed for various radionuclides.

Vertically mounted canisters that contain about 135 g of silica gel with an airflow rate of about 0.0002 m^3 per minute are used to collect water vapor samples. This silica gel is dried in a drying oven to remove most residual water before being used in the field. The gel is a desiccant that removes moisture from the sampled air. After use in the field, the gel is removed from the canister and shipped to the analytical laboratory where the moisture is distilled, condensed, and collected as a liquid. This liquid is then analyzed for the presence of tritium. The AIRNET quality assurance project plan (MAQ-AIRNET) and the numerous procedures through which the plan is implemented provide details about the sample collection, sample management, chemical analysis, and data management activities.

b. Data Management. In the field, MAQ personnel recorded on a palm-held microcomputer the sampling data, including timer readings, volumetric airflow rates at the start and stop of the sampling period, and comments pertaining to these data. These data are transferred to an electronic table format within the AIRNET database.

c. Analytical Chemistry. A commercial laboratory analyzed each particulate-matter filter for gross alpha and gross beta activities. These filters were also grouped across sites, designated as "clumps," and analyzed for gamma-emitting radionuclides. For 2004, clumps usually ranged from six to nine filters. To prepare a quarterly composite for isotopic analyses for each AIRNET station, half-filters from the six or seven sampling periods at each site are combined during the quarter. Analysts dissolved these composites, separated them chemically, and then analyzed them for isotopes of americium, plutonium, and uranium using alpha spectroscopy. Every two weeks, water was distilled from the silica gel that had been used to collect water vapor in the field. A commercial laboratory used liquid scintillation spectrometry to analyze this distillate for tritium. All analytical procedures meet the requirements of Code of Federal Regulations 40 (CFR) 61, Appendix B. The AIRNET quality assurance project plan provides a summary of the target minimum detectable activity for the biweekly and quarterly samples.

d. Laboratory Quality Control Samples. For 2004, the MAQ Group and the contractor analytical laboratories maintained a program of blank, spike, duplicate, and replicate analyses. This program provided information on the quality of the data received from analytical chemistry laboratories. The chemistry met the quality assurance requirements for the AIRNET program.

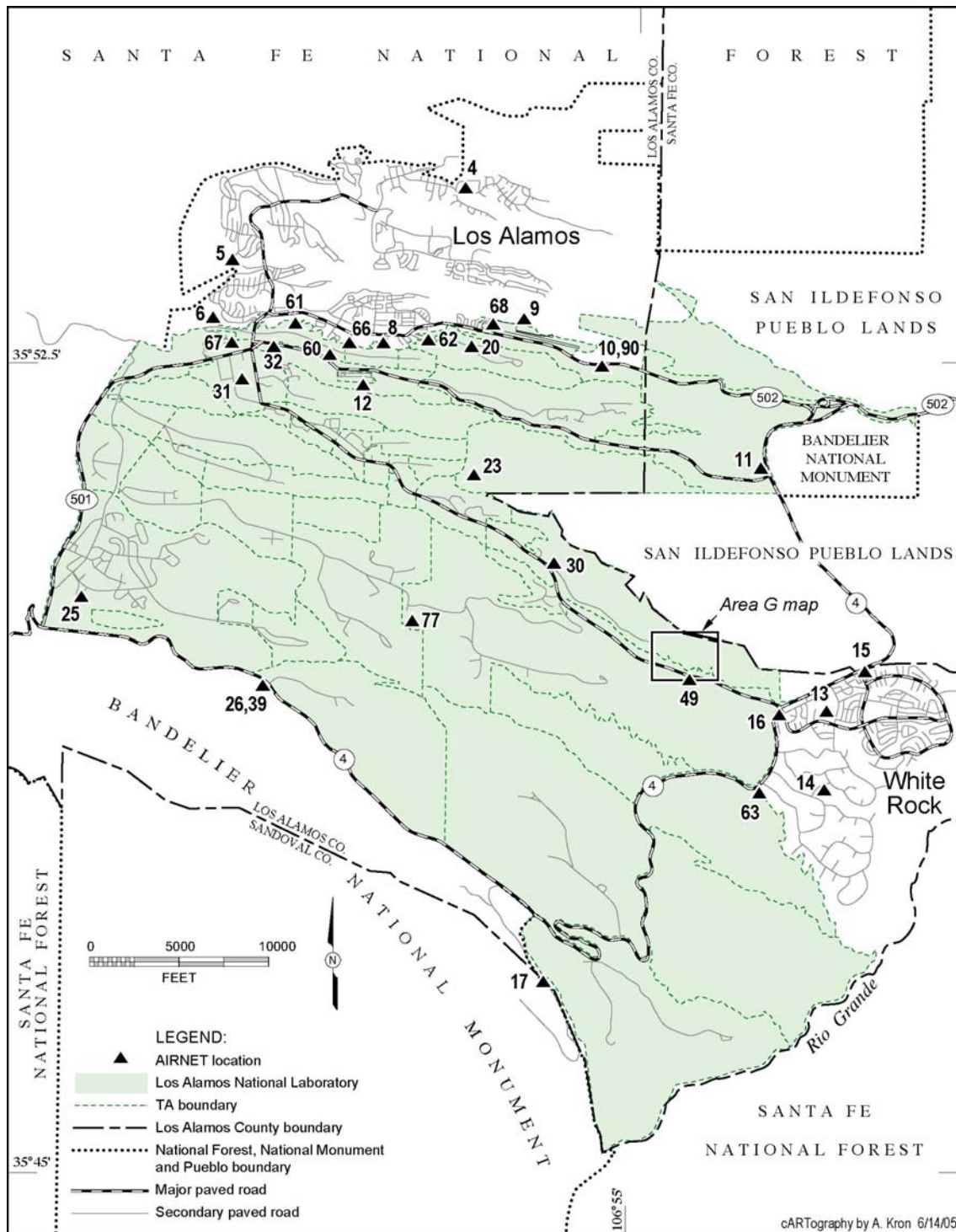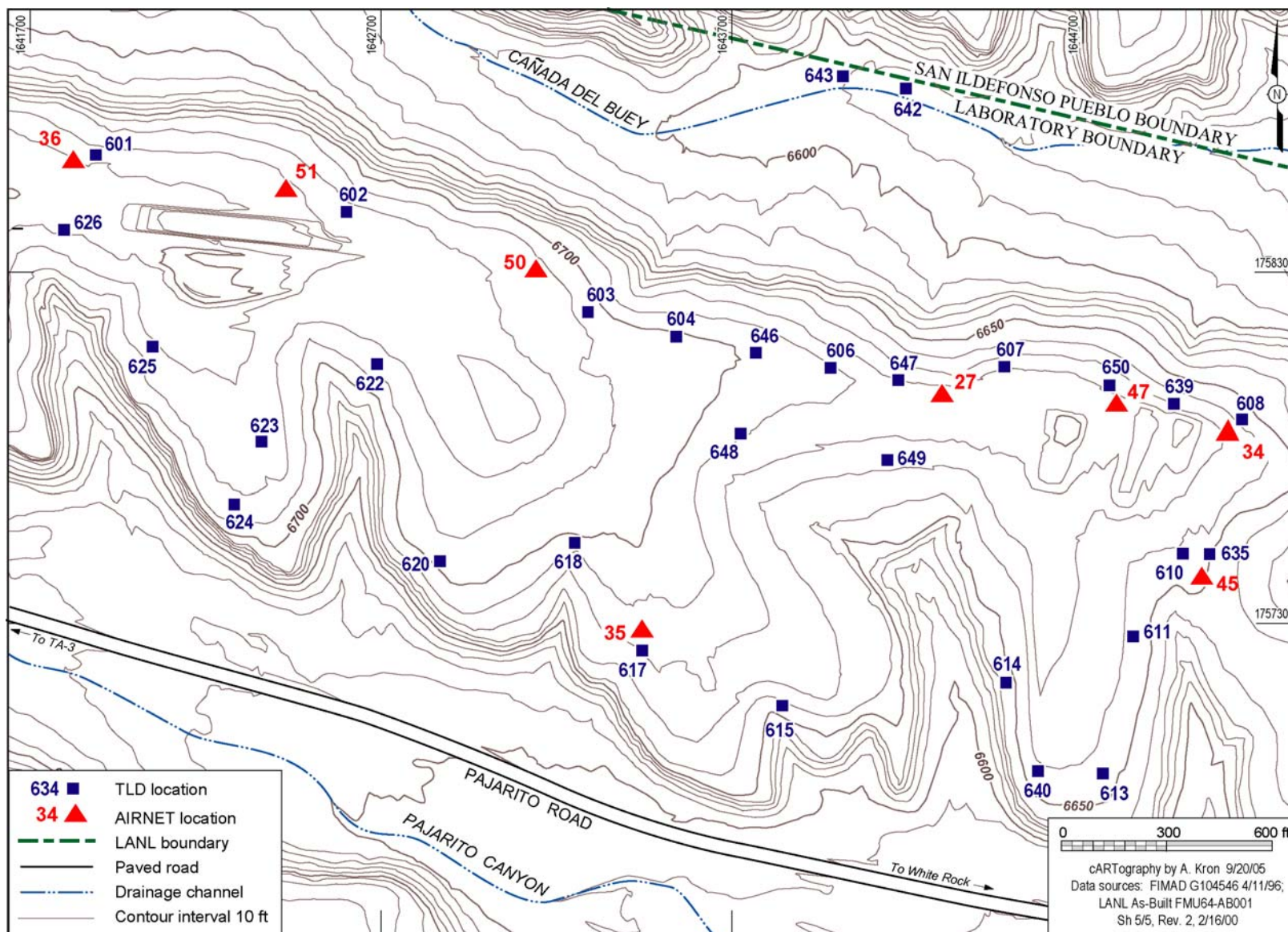**Figure 4-1**. Off-site perimeter and on-site LANL AIRNET locations.

Figure 4-2. AIRNET and thermoluminescent dosimeter locations at TA-54, Area G. (This figure has been edited for operational security purposes.)
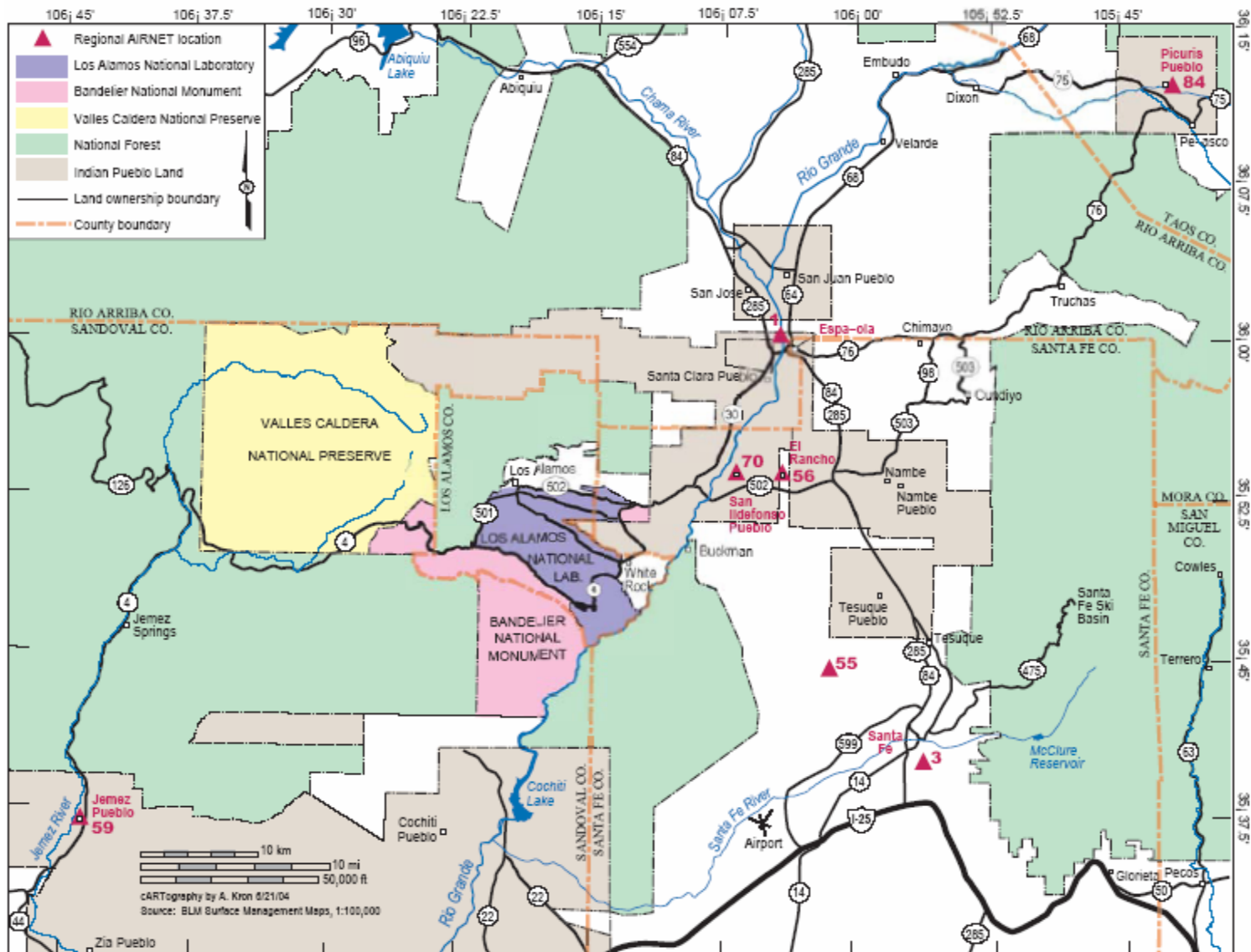
Figure 4-3. Regional and pueblo AIRNET locations.

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4. Ambient Air Concentrations

    a. Explanation of Reported Concentrations. Tables 4-2 through 4-12 summarize the 2004 ambient air concentrations calculated from the field and analytical data. In the Data Supplement, Tables S4-1 though S4-9 provide data from individual sites. The number of measurements is normally equal to the number of samples analyzed. Measurements containing measurable amounts of the material of interest are those in which the value is greater than three times the standard deviation of the measurement's uncertainty. The minimum detectable amounts are the levels that the instrumentation could detect under ideal conditions. All AIRNET concentrations and doses are total measurements without any type of regional background subtractions. However, the air concentrations include corrections for radioactivity from the filter material and the analytical process. The net concentrations are usually somewhat lower because small amounts of radioactivity are present in the filter material, the acids used to dissolve the filter, and the tracers added to determine recovery efficiencies. The net uncertainties include the variation added by correcting for the blank measurements.

Table 4-2. Airborne Long-Lived Gross Alpha Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (fCi/m^3)	95% Confidence Interval[a] (fCi/m^3)	Maximum Annual Concentration	
		>2s	>3s			Station	(fCi/m^3)
Regional	103	103	103	1.10	± 0.08	01	1.19
Pueblo	77	77	77	1.12	± 0.10	70	1.13
Perimeter	622	620	619	0.97	± 0.03	62	1.12
Waste Site	207	206	206	0.94	± 0.04	50	1.01
On-Site	188	176	176	0.94	± 0.04	53	1.06

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.

Table 4-3. Airborne Long-lived Gross Beta Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (fCi/m^3)	95% Confidence Interval[a] (fCi/m^3)	Maximum Annual Concentration	
		>2s	>3s			Station	(fCi/m^3)
Regional	103	103	103	18.3	± 0.9	01	19.3
Pueblo	77	77	77	17.5	± 1.0	70	19.1
Perimeter	622	619	619	16.4	± 0.3	62	18.1
Waste Site	207	206	206	16.4	± 0.5	35	16.9
On-Site	188	176	176	16.6	± 0.5	53	17.6

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.

Table 4-4. Airborne Tritium as Tritiated Water Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (pCi/m^3)	95% Confidence Interval[a] (pCi/m^3)	Maximum Annual Concentration	
		>2s	>3s			Station	(pCi/m^3)
Regional[b]	104	7	1	0.10	± 0.17	55	0.28
Pueblo[b]	76	6	0	0.03	± 0.19	70	0.24
Perimeter[b]	619	306	191	2.09	± 0.22	09	6.47
Waste Site[c]	207	199	183	105	± 59	35	792
On-Site[c]	188	112	86	3.92	± 0.77	25	13.35

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.
[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 1,500 pCi/m3.
[c] DOE DAC Guide for workplace exposure is 20,000,000 pCi/m3.

Table 4-5. Airborne Pu-238 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration	
		>2s	>3s			Station	(aCi/m³)
Regional	15	0	0	0.09	± 0.28	01	0.43
Pueblo	12	0	0	0.14	± 0.32	84	0.33
Perimeter	88	0	0	–0.12	± 0.15	39	0.36
Waste Site	32	1	0	0.20	± 0.30	36	0.70
On-Site	17	0	0	0.20	± 0.34	53	1.29

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.
[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 2,100 aCi/m3.
[c] DOE DAC Guide for workplace exposure is 3,000,000 aCi/m3.

Table 4-6. Airborne Pu-239, 240 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration	
		>2s	>3s			Station	(aCi/m³)
Regional	15	0	0	–0.07	± 0.42	03	0.23
Pueblo	12	1	0	0.47	± 0.53	84	0.73
Perimeter	88	7	3	0.91	± 1.15	66	19.37
Waste Site	32	6	3	1.09	± 0.81	45	3.62
On-Site	17	1	0	–0.02	± 0.39	53	0.97

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.
[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 2,000 aCi/m3.
[c] DOE DAC Guide for workplace exposure is 2,000,000 aCi/m3.

Table 4-7. Airborne Am-241 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration	
		>2s	>3s			Station	(aCi/m³)
Regional	15	1	0	-0.47	± 0.46	03	-0.24
Pueblo	12	0	0	-0.54	± 0.48	70	-0.28
Perimeter	88	5	0	-0.18	± 0.15	68	0.59
Waste Site	32	7	1	0.33	± 0.41	27	1.77
On-Site	17	3	0	-0.17	± 0.50	53	1.13

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.
[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 1,900 aCi/m3.
[c] DOE DAC Guide for workplace exposure is 2,000,000 aCi/m3.

Table 4-8. Airborne U-234 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty		Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration	
		>2s	>3s			Station	(aCi/m³)
Regional	15	15	14	17.4	± 4.7	03	24.3
Pueblo	12	12	12	16.4	± 6.3	59	23.8
Perimeter	88	86	74	8.0	± 1.6	32	32.0
Waste Site	32	31	28	11.4	± 4.6	50	30.5
On-Site	17	17	15	6.2	± 1.7	53	10.2

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.
[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 7,700 aCi/m3.
[c] DOE DAC Guide for workplace exposure is 20,000,000 aCi/m3.

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Table 4-9. Airborne U-235 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty >2s	>3s	Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration Station	(aCi/m³)
Regional	15	5	0	1.17	± 0.64	03	1.93
Pueblo	12	3	0	1.12	± 0.73	59	1.49
Perimeter	88	12	1	0.67	± 0.24	67	2.78
Waste Site	32	5	0	0.91	± 0.33	45	1.52
On-Site	17	5	0	0.58	± 0.58	77	1.07

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.

[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 7,100 aCi/m3.

[c] DOE DAC Guide for workplace exposure is 20,000,000 aCi/m3.

Table 4-10. Airborne U-238 Concentrations for 2004 — Group Summaries

Station Grouping	Number of Biweekly Samples	Number of Samples Exceeding Uncertainty >2s	>3s	Mean (aCi/m³)	95% Confidence Interval[a] (aCi/m³)	Maximum Annual Concentration Station	(aCi/m³)
Regional	15	15	14	17.0	± 5.2	03	23.8
Pueblo	12	12	12	16.4	± 6.8	59	25.0
Perimeter	88	82	74	8.6	± 1.7	32	33.3
Waste Site	32	30	29	12.0	± 4.5	50	28.8
On-Site	17	17	15	8.3	± 3.3	77	16.1

[a] 95% confidence intervals are calculated using all calculated sample concentrations from every site within the group.

[b] EPA 40 CFR Part 61, Appendix E, Table 2. Concentration Limit is 8,300 aCi/m3.

[c] DOE DAC Guide for workplace exposure is 20,000,000 aCi/m3.

Table 4-11. Airborne Gamma-Emitting Radionuclides Potentially Released by Laboratory Operations

Nuclide	Number of Biweekly Samples	Number of Samples > MDA[a]	Mean Concentration (fCi/m³)	Measured MDA as % of Required MDA[b]
As-73	182	0	1.11	0.20
As-74	182	0	–0.02	0
Cd-109	182	0	0.10	0.35
Co-57	182	0	0.002	0.00
Co-60	182	0	–0.02	0
Cs-134	182	0	–0.03	0
Cs-137	182	0	–0.02	0
Mn-54	182	0	–0.01	0
Na-22	182	0	0.002	0.15
Rb-83	182	0	–0.01	0
Rb-86	182	0	0.05	0.16
Ru-103	182	0	–0.006	0
Se-75	182	0	0.001	0.01
Zn-65	182	0	–0.04	0

[a] Minimum detectable amount.

[b] Required MDA is for 0.5-mrem annual dose.

Table 4-12. Airborne Concentrations of Gamma-Emitting Radionuclides that Naturally Occur in Measurable Quantities.

Nuclide	Number of Biweekly Samples	Number of Samples > MDA[a]	Mean[b] Concentration (fCi/m³)
Be-7	182	182	88
Pb-210	182	1	26

[a] Minimum detectable amount.

[b] Measurements less than the MDA are not included in the average.

All data in this AIRNET section, whether in the tables or the text, that are expressed as a value plus or minus (±) another value represent a 95% confidence interval. Because these confidence intervals are calculated with data from multiple sites and throughout the year, they include not only random measurement and analytical errors but also seasonal and spatial variations. As such, the calculated 95% confidence intervals are overestimated for the average concentrations and probably represent confidence intervals that approach 100%. All ambient concentrations are activity concentrations per actual cubic meter of sampled air. Some values in the tables are negative. See Appendix B for an explanation of negative values.

Air concentrations greater than their 3s uncertainties are used to identify samples of interest or detected concentrations. [Where s represents standard deviation, or sigma]. Other multiples of uncertainties could be used, but 3s is consistent with the widely accepted practice of using 3s control limits for statistical quality control charts (Duncan 1986, Gilbert 1987). It also eliminates most of the false positives or detections that occur about 5% of the time at 2s, but less than 0.3% of the time at 3s.

b. Gross Alpha and Gross Beta Radioactivity. We use gross alpha and gross beta analyses primarily (1) to evaluate general radiological air quality, (2) to identify potential trends, and (3) to detect sampling problems. If the gross analytical results appear to be elevated, then analyses for specific radionuclides may be performed to investigate a potential problem, such as an unplanned release.

The National Council on Radiation Protection and Measurements (NCRP) estimated the national average concentration of long-lived gross alpha activity in air to be 2 femtocuries (fCi)/m³. The primary alpha activity is caused by polonium-210 (a decay product of radon) and other naturally occurring radionuclides (NCRP 1975, NCRP 1987). The NCRP also estimated national average concentration levels of long-lived gross beta activity in air to be 20 fCi/m³. The presence of lead-210 and bismuth-210 (also decay products of radon) and other naturally occurring radionuclides is the primary cause of this activity.

In 2004, we collected and analyzed close to 1200 air samples for gross alpha and gross beta activity. The annual mean for all of the stations is about half of the NCRP's estimated average for gross alpha concentrations (Table 4-2). At least two factors contribute to these seemingly lower concentrations: the use of actual sampled air volumes instead of standard temperature and pressure volumes and the burial of alpha emitters in the filter that are not measured by front-face counting. Gross alpha activity is dependent on variations in natural conditions, such as atmospheric pressure, atmospheric mixing, temperature, and soil moisture.

Table 4-3 shows gross beta concentrations within and around LANL. These data show variability similar to the gross alpha concentrations. The annual average is below the NCRP-estimated national average, but the gross beta measurements include little if any lead-210 because of its low-energy beta emission. We calculate the gross beta measurements on the actual sampled air volumes instead of standard temperature and pressure volumes. The primary source of measured gross beta activity in the particulate matter samples is the bismuth-210 in the radon-222 decay chain.

Figures 4-4 and 4-5 show the temporal variability of gross alpha and beta activities in air. Variability among sites within AIRNET is usually much less than variability over time. A good example of seasonal variation is the observation in winter during atmospheric inversions of higher levels of radon, and therefore higher gross alpha and beta count rates, at lower elevations around LANL. The radon is trapped below the inversion layer.

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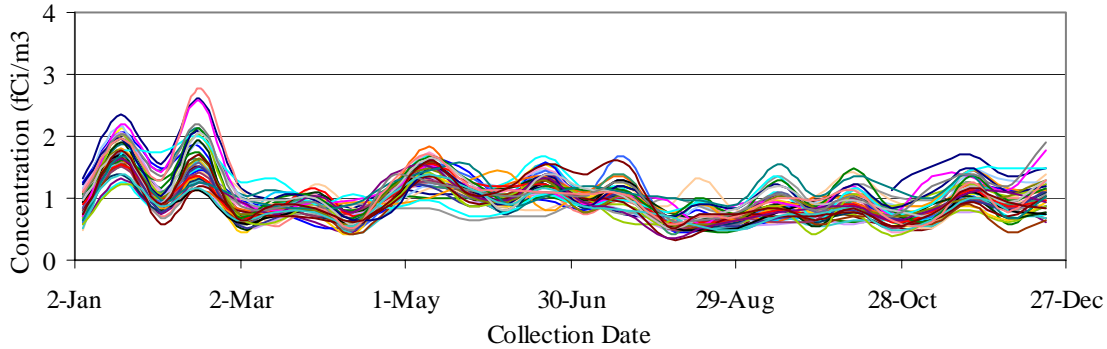
Figure 4-4. Gross alpha measurements (fCi/m^3) by sampling site.
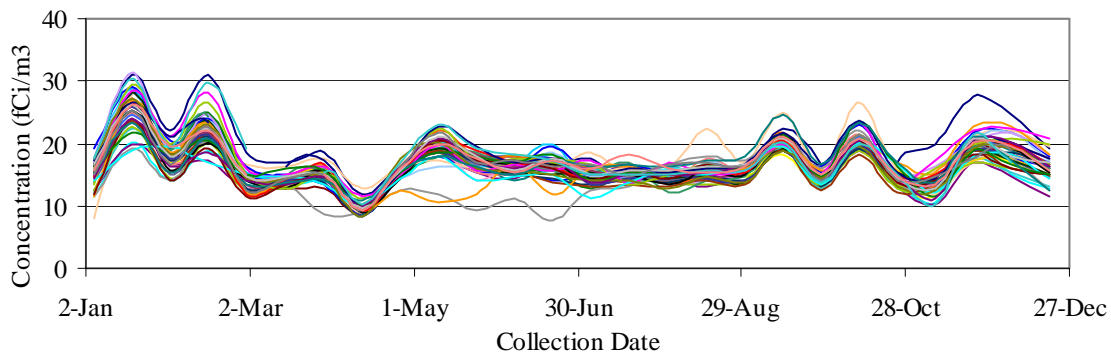
**Figure 4-5.** Gross beta measurements (fCi/m^3) by sampling site.

     c. Tritium. Tritium is present in the environment primarily as the result of nuclear weapons tests and natural production by cosmogenic processes (Eisenbud and Gesell 1997). We measure the tritium in water (HTO or tritiated water) because the dose impact is about 14,000 times higher than if it were hydrogen gas (HT or tritium) (DOE 1988b).

    Water-vapor concentrations in the air and tritium concentrations in the water vapor were used to calculate ambient levels of tritium. Corrections for blanks, bound water in the silica gel, and isotopic distillation effects are included in this calculation (ESP 2002).

    The annual concentrations of tritium for 2004 at the regional and pueblo stations were not significantly different from zero (Table 4-4). The average concentration of tritium for the perimeter samplers was significantly greater than zero as were the average concentrations for the on-site groups. The highest concentrations were measured at TA-54, Area G. These data indicate that LANL does produce measurable amounts of tritium. All annual mean concentrations at all sampling sites were well below the applicable EPA and DOE guidelines.

    Figure 4-6 shows a strong coherence between measured stack emissions at TA-21 and off-site AIRNET measurements nearby in east Los Alamos and generally downwind of the TA-21 stacks. This coherence gives us confidence that AIRNET tritium measurements do reflect tritium releases from LANL.

    The highest off-site annual tritium concentration in 2004, 6.5 picocuries (pCi)/m^3, was at the Los Alamos Airport, which is close to TA-21. This concentration is equivalent to about 0.5 % of the EPA public dose limit. Emissions from TA-21 averaged 2 Ci per day in 2004 and seldom caused concentrations to exceed investigation levels as described in section A.5 of this chapter [Investigation levels are set at values of 5 year averages plus 3s.]. We measured elevated concentrations at a number of on-site stations, with the highest annual concentration at TA-54, Area G. This annual mean concentration, 800 pCi/m^3, is only about 0.004% of the DOE DAC for worker exposure and is measured at a location near shafts containing tritium-contaminated waste.
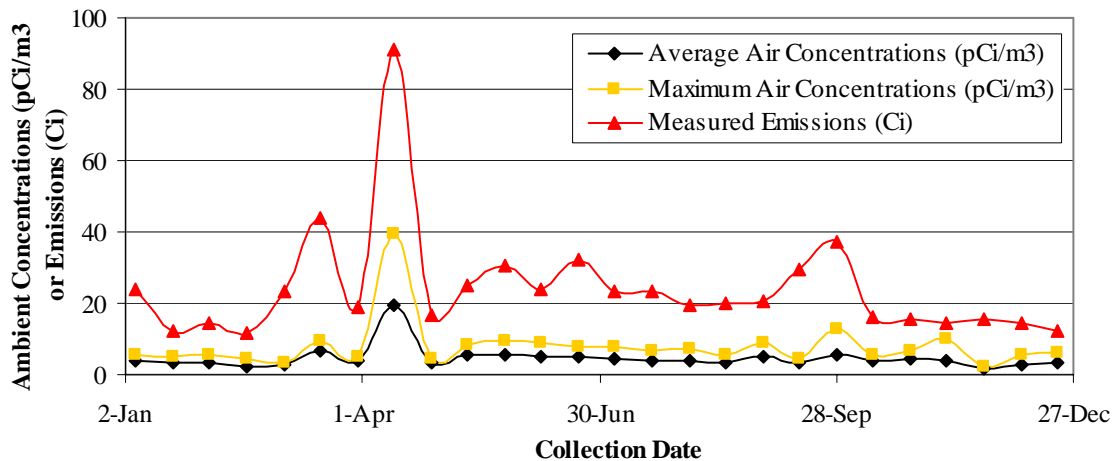
Figure 4-6. Tritium oxide stack emissions at TA-21 and ambient concentrations in east Los Alamos.

d. Plutonium. While plutonium occurs naturally at extremely low concentrations from cosmic radiation and spontaneous fission (Eisenbud and Gesell 1997), this element is not naturally present in measurable quantities in the ambient air. All measurable sources are from plutonium research-and-development activities, nuclear-weapons production and testing, the nuclear fuel cycle, and other related activities. With few exceptions, worldwide fallout from atmospheric testing of nuclear explosives is the primary source of plutonium in ambient air.

Table 4-5 summarizes the plutonium-238 data for 2004. No concentrations of plutonium-238 more than 3s from zero were measured at any station in any quarter. The highest quarterly concentration was on-site and had a value of 2.4 aCi/m^3, which corresponds to much less than 1% of the DOE DAC for worker exposure.

No detectable concentrations of plutonium-239,240 greater than 3s were found at any of the regional or pueblo samplers (Table 4-6). Three perimeter quarterly concentrations were above their 3s uncertainties; all of them were collected at site 66 (Los Alamos Inn-South). The annual mean concentration at this location was 20 aCi/m3, or about 1% of the EPA public dose limit. These higher ambient concentrations are from historical activities at LANL's old main Technical Area (TA-1) that deposited plutonium on the hillside below the Los Alamos Inn. Three on-site quarterly concentrations were above their 3s uncertainties; all of them at Area G and substantially below 1% of the DOE DAC for workplace exposure.

e. Americium-241. As with the plutonium isotopes, americium is present in very low concentrations in the environment. No detected concentrations of americium-241 were measured at any of the regional, pueblo, or perimeter sampling stations (Table 4-7).

One on-site quarterly sample with a concentration of americium-241 greater than 3s was measured at Area G. This on-site concentration was significantly less than 1% of the DOE DAC for worker exposure.

f. Uranium. Three isotopes of uranium are normally found in nature: uranium-234, uranium-235, and uranium-238. In natural uranium, relative isotopic abundances are constant and well characterized. Uranium-238 and uranium-234 are essentially in radioactive equilibrium, with a measured uranium-238 to uranium-234 isotopic activity ratio of 0.993 (as calculated from Walker et al., 1989). Because known LANL emissions are not of natural uranium but of enriched (EU—has excess uranium-234 and -235) or depleted (DU—has excess uranium-238) uranium, comparisons of isotopic concentrations are used to estimate LANL contributions. Using excess uranium-234 to detect the presence of EU may not seem suitable because the enrichment process is usually designed to increase uranium-235 concentrations. However, the enrichment process normally increases uranium-234 at a faster rate than uranium-235.

All annual mean concentrations of the three uranium isotopes were well below 1% of the applicable EPA and DOE guidelines (Tables 4-8 through 4-10). The maximum annual uranium concentrations were at locations with high dust levels from local soil disturbances such as dirt roads at the Los Alamos County

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Landfill and LANL's TA-54, Area G. The regional and pueblo groupings had higher average concentrations of uranium-234 and uranium-238 than the perimeter group because of increased particulate matter concentrations associated with unpaved roads, unpaved parking lots, and other soil disturbances such as construction activities and grazing—but not any known man-made sources of uranium.

During 2004, two samples at the same on-site location had DU, as shown in Figure 4-7. This restricted access location is known to have such surface contamination. This is the smallest number of DU detections in a year since 1995. These excess uranium-283 concentrations were identified by statistically comparing the uranium-234 and uranium-238 concentrations. If the concentrations in a sample were more than 3s apart, the sample was considered to have significant concentrations of EU or DU. (See Section A.6.) We measured no EU during 2004.

g. Gamma Spectroscopy Measurements. In 2004, MAQ personnel conducted gamma spectroscopy measurements (Tables 4-11 and 4-12) on biweekly filters grouped across sites for a single sampling period, which are identified as "clumps." Our practice is to investigate the measurement of any analyte (listed in Table 4.11) above its minimum detectable amount. We do not investigate detectable quantities of beryllium-7, potassium-40, and lead-210, which are natural radionuclides normally present in measurable concentrations. Any other measurable concentration is highly unlikely unless an actual release occurs. Beryllium-7 was routinely detected, and lead-210 was measured on one occasion in 2004.
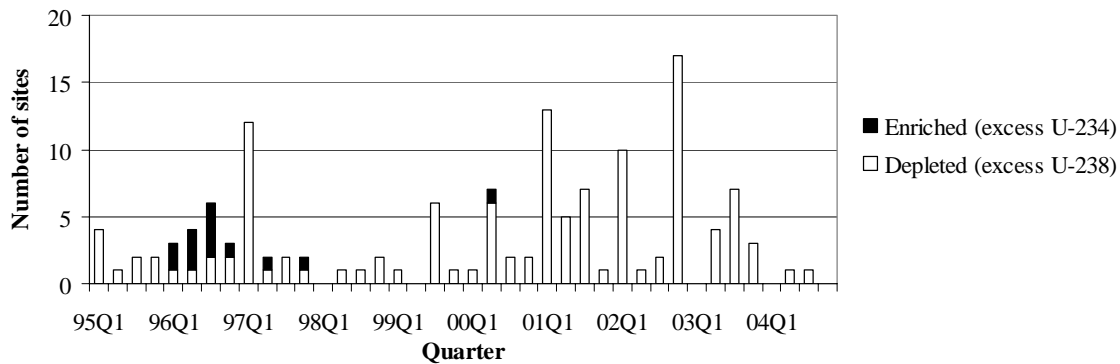

Figure 4-7. AIRNET sites with excess isotopic uranium.

5. Investigation of Elevated Air Concentrations

Two action levels have been established to determine the potential occurrence of an unplanned release: "investigation" and "alert." "Investigation" levels are based on historical measurements and are designed to indicate that an air concentration is higher than expected. These levels are set at values equal to a 5 year rolling average plus 3s. "Alert" levels are based on dose and require a more thorough, immediate follow-up.

In 2004, a few air sampling values exceeded action levels. When a measured air concentration exceeds an action level, the MAQ Group verifies that the calculations were done correctly and that the sampled air concentrations are likely to be representative, i.e., that no cross contamination has taken place. Next, we work with personnel from the appropriate operations to assess potential sources and possible mitigation for the elevated concentrations.

Some investigations were related to slightly elevated tritium concentrations being measured near TA-21, which is known to release both HTO and HT from decommissioning and decontamination activities. Some investigations were of elevated uranium levels caused by wind. And finally, we are conducting an ongoing investigation into an unexpected plutonium reading attributed to the El Rancho site in the final quarter.

a. El Rancho Plutionium-238 Investigation. An analytically rejected unexpected value was noted at the El Rancho station. At this early stage of the investigation, it appears to be due to analytical laboratory contamination or some other cause but not a real presence of the isotope at the station.

As part of the investigation into this occurrence, we revisited all plutonium measurements over the last two years. Previously (in 2003), an unexpected detection of plutonium at the same station had been rejected. We have decided to initiate a more thorough investigation. This investigation is under way at the time of writing and includes collecting swipe samples at the station and reanalyzing the remaining half-filters.

The rejected 2004 annual concentration of plutonium-238 at the El Rancho station was 13.3 aCi/m^3, which corresponds to less than 1% of the publicly permitted EPA 40 CFR Part 61, Appendix E, Table 2 (10 mrem/yr) concentration limit of 2100 aCi/m^3.

6. Long-Term Trends

a. Uranium. Even though the annual and quarterly concentrations of uranium isotopes vary, peak concentrations for all three isotopes occur during the second quarter of each year (Figure 4-8). For years now, the uranium-238 concentrations have been consistently higher than the uranium-234 concentrations, indicating the presence of DU. The station at TA-36 was not included in these averages because of the persistent and known presence of DU in the samples, as discussed below.

Figure 4-6 shows that DU has been detected regularly—most notably in the first quarters of 1997, 2001, and 2002 and the fourth quarter of 2002 when significant differences (3s) were detected in 25% or more of the samples. All of the samples with DU were collected on Laboratory property or within Los Alamos County. In the six years before 2001, 15 quarterly composite samples with DU were collected off-site. During 2001–2003, 23 off-site DU samples were collected—a notable increase since the Cerro Grande fire in 2000. The ongoing drought through the years following the fire has kept DU (and other) dust ready for resuspension. However, in 2004, rainfall was substantially above levels in preceding years, and no DU was detected off-site. Off-site concentrations of DU are comparable to or less than historical natural uranium concentrations.

The station at TA-36 is located in a posted radiation-control area where DU is present (Eberhart et al., 1999; ESP 1999; ESP 2000; and ESP 2001) as surface contamination from explosive tests (Figure 4-9). Over the last decade, of the 40 quarterly composites analyzed for isotopic uranium at this site, 32 have indicated DU. The 2004 uranium-234 and -238 concentrations at this site were respectively 7 and 16 aCi/m^3. Assuming about 15% of the activity in DU is uranium-234, the calculated contributions at this location were about 2 aCi/m^3 of uranium-234 and 11aCi/m^3 of uranium-238. Therefore, the combined estimated LANL contribution at this on-site controlled-access location is below 0.0001% of the DOE DAC for workplace exposure.
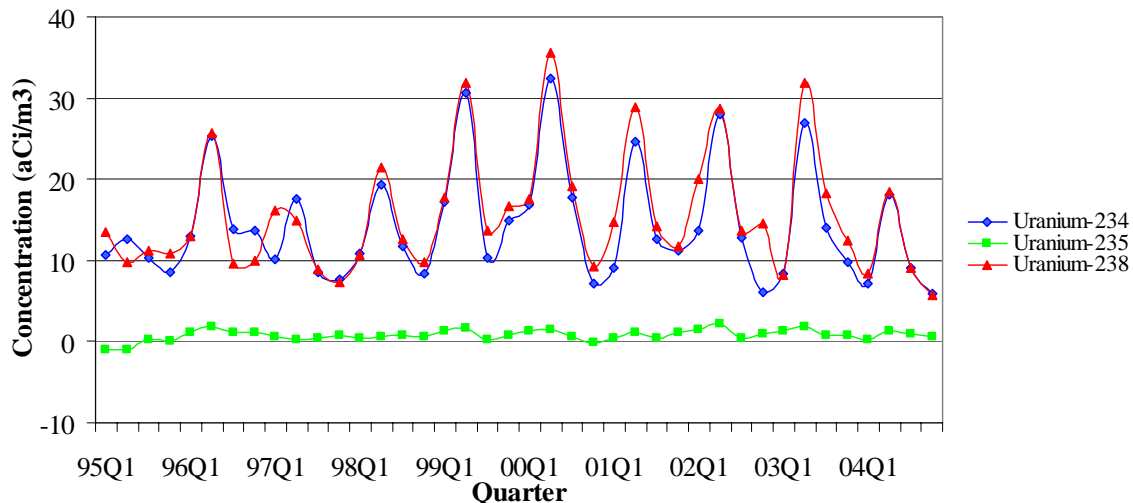
Figure 4-8. AIRNET quarterly uranium concentrations (network-wide excluding site 77).
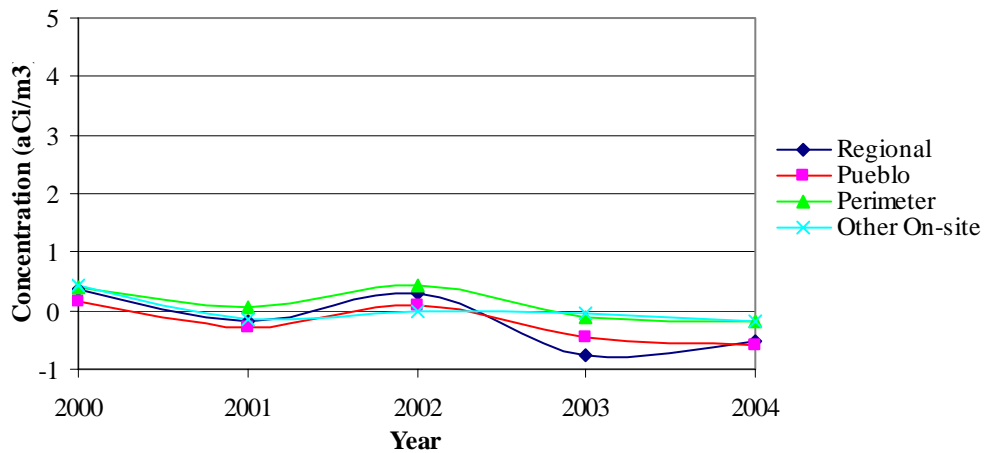
4. Air Surveillance
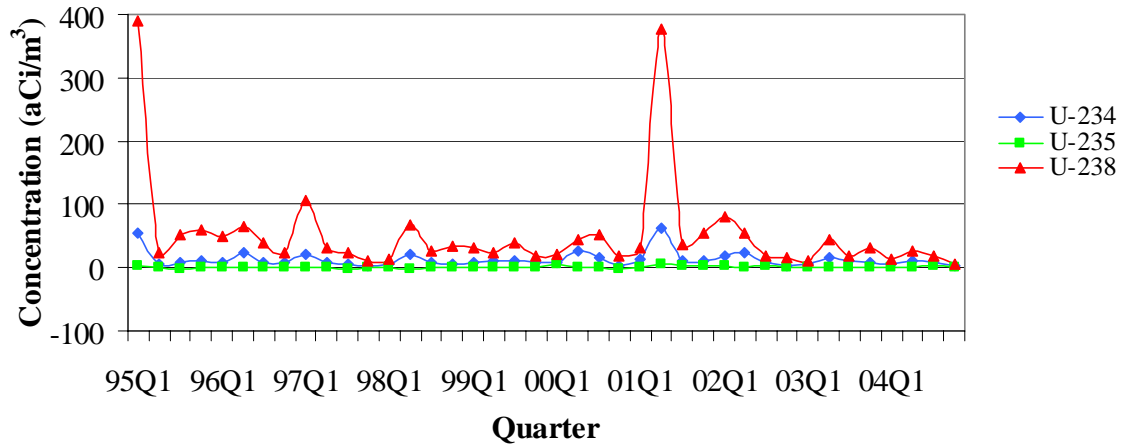
Figure 4-9. Uranium concentrations at site 77 at TA-36.

   b. Plutonium and Americium. Only two quarterly measurements during the last nine years for the regional and pueblo samples were above their 3s analytical uncertainties. However, on-site measurements of plutonium-238, plutonium-239, and americium-241 are clearly higher for the TA-21 and TA-54, Area G, sampling stations, where about one-third of the measurements are detectable concentrations of these radionuclides. Perimeter samplers are somewhere in between, with occasional samples having measurable concentrations. Figures 4-10, 4-11, and 4-12 are graphs of the annual concentrations by isotope and general station locations. Annual average concentrations for plutonium-239 and americium-241 are above zero for the TA-54, Area G, sampling stations. Concentrations at the TA-54 samplers have been decreasing for several years except for the soil-screening operation in 2002 (Figure 4-13) (ESP 2002). The average concentrations for the other sample groupings vary but remain near zero, with occasional samples and/or locations having detectable concentrations.

   c. Tritium. Unlike other contaminants, tritium concentrations are strongly influenced by current operations and emissions with no distinctive trends over this period (Figure 4-14). With fewer decommissioning and decontamination activities at TA-21 during 2004, we currently see lower ambient values nearby. However if such work increases in the future, we expect to see an increase in ambient levels.

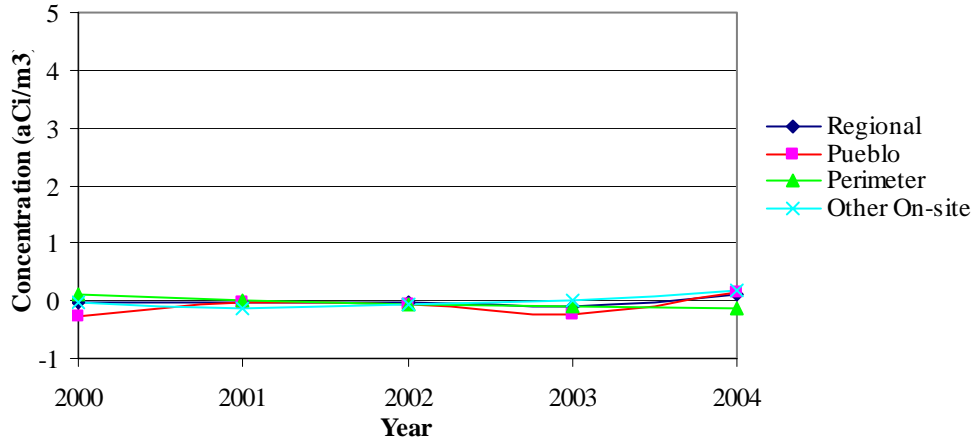**Figure 4-10.** Am-241 concentration trends.
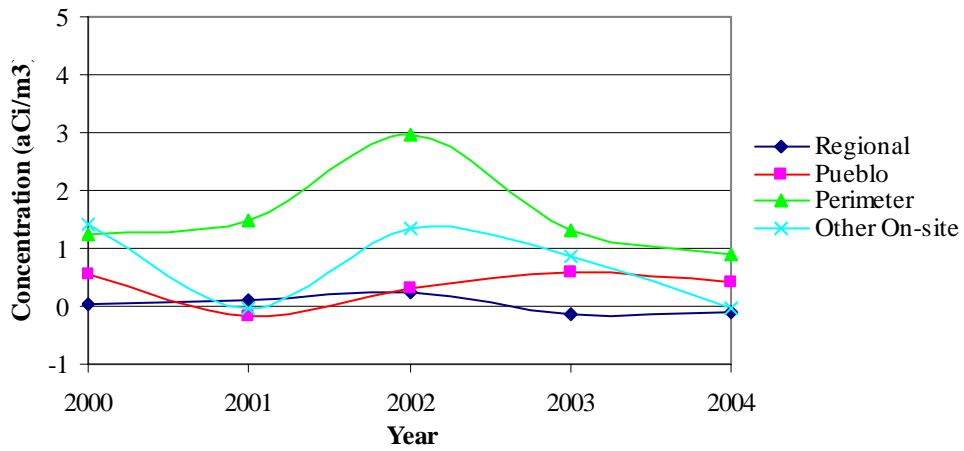
Figure 4-11. Pu-238 concentration trends.

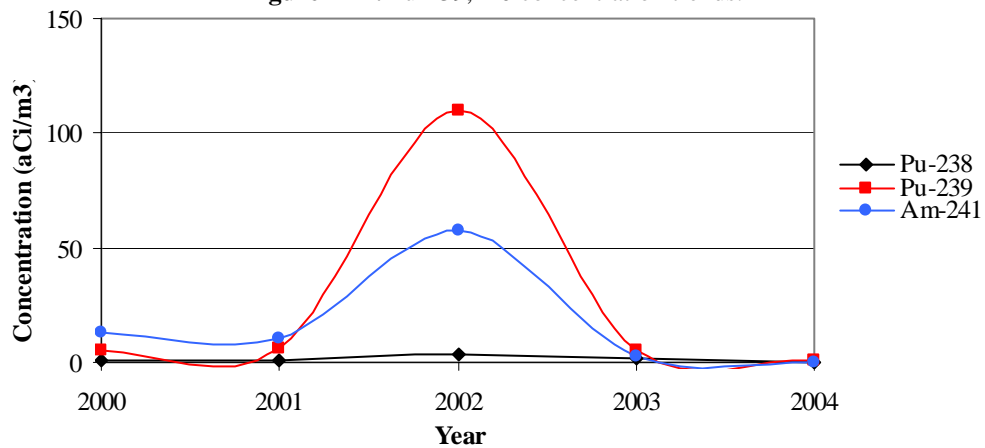**Figure 4-12.** Pu-239,240 concentration trends.

Figure 4-13. Americium and plutonium concentration trends for TA-54, Area G.
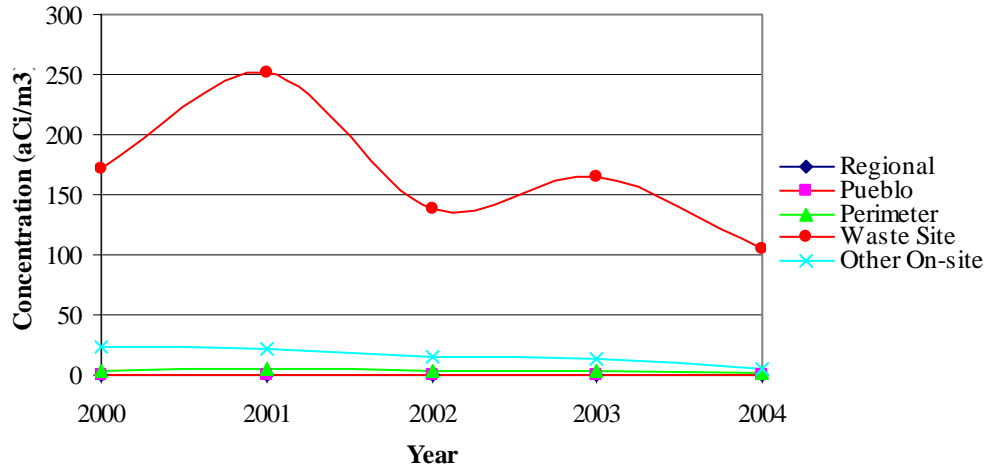
4. Air Surveillance

Figure 4-14. Tritium concentration trends.

B. Stack Sampling for Radionuclides *(Dave Fuehne and Andrew Green)*

1. Introduction

Radioactive materials are an integral part of many activities at LANL. Some operations involving these materials may be vented to the environment through a stack or other forced air release point. ENV-MAQ personnel at LANL evaluate these operations to determine impacts on the public and the environment. If this evaluation shows that emissions from a stack may potentially result in a member of the public receiving as much as 0.1 mrem in a year, LANL must sample the stack in accordance with Title 40 Code of Federal Regulations (CFR) 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" (EPA 1989). During 2004, we identified 27 stacks as meeting this criterion. One additional sampling system is in place to meet DOE requirements for nuclear facilities prescribed in their respective technical or operational safety requirements. Where sampling is not required, emissions are estimated using engineering calculations and radionuclide materials usage information.

2. Sampling Methodology

In 2004, we continuously sampled 28 stacks for the emission of radioactive material to the ambient air. LANL categorizes its radioactive stack emissions into one of four types: (1) particulate matter, (2) vaporous activation products, (3) tritium, and (4) gaseous mixed activation products (GMAP). For each of these emission types, LANL employs an appropriate sampling method, as described below.

Emissions of radioactive particulate matter generated by operations at facilities such as the Chemistry and Metallurgy Research Building and the TA-55 Plutonium Facility are sampled using a glass-fiber filter. A continuous sample of stack air is pulled through the filter that captures small particles of radioactive material. These samples are collected weekly and shipped to an off-site analysis laboratory. This laboratory uses gross alpha/beta counting and gamma spectroscopy to identify any increase in emissions and to identify short-lived radioactive materials. Every six months, the laboratory composites these samples and analyzes these composite samples to determine the total activity of materials such as uranium-234, -235, and -238; plutonium-238 and -239,240; and americium-241. These isotopic data are then used to calculate emissions from each stack for the six-month period.

A charcoal cartridge samples emissions of vapors, such as bromine-82, and highly volatile compounds, such as selenium-75, that operations at the Los Alamos Neutron Science Center (LANSCE) and hot cell activities at the Chemistry and Metallurgy Research Building and TA-48 generate. A continuous sample of stack air is pulled through a charcoal filter that adsorbs vaporous emissions of radionuclides. Gamma spectroscopy determines the amount and identity of the radionuclide(s) present on the filter.

We measure tritium emissions from LANL's tritium facilities with a collection device known as a bubbler. This device enables LANL to determine not only the total amount of tritium released but also

whether it is in the elemental (HT) or oxide (HTO) form. The bubbler pulls a continuous sample of air from the stack, which is then "bubbled" through three sequential vials containing ethylene glycol. The ethylene glycol collects the water vapor from the sample of air, including any tritium that may be part of a water molecule (HTO). "Bubbling" through these three vials removes essentially all HTO from the air, leaving only elemental tritium. The sample containing the elemental tritium is then passed through a palladium catalyst that converts the elemental tritium to HTO. The sample is then pulled through three additional vials containing ethylene glycol, which collect the newly formed HTO. Liquid scintillation counting determines the amount of HTO and HT by analyzing the ethylene glycol for the presence of tritium.

In previous years, stacks at LANSCE were monitored for tritium. After an historical evaluation of HTO emissions from LANSCE in 2001, we discontinued sampling tritium following the July 2001 report period based on the low historical emissions of HTO from TA-53 and the low relative contribution of tritium to the off-site dose from TA-53 emissions. Emissions of tritium reported in 2004 from LANSCE are based on 2001 tritium generation rates.

We measure GMAP emissions from LANSCE activities using real-time monitoring data. A sample of stack air is pulled through an ionization chamber that measures the total amount of radioactivity in the sample. Gamma spectroscopy and decay curves were used to identify specific radioisotopes.

3. Sampling Procedures and Data Analysis

a. Sampling and Analysis. Analytical methods used comply with EPA requirements (40 CFR 61, Appendix B, Method 114). See Section F in this chapter for the results of analytical quality assurance measurements. General discussions on the sampling and analysis methods for each of LANL's emissions follow.

b. Particulate Matter Emissions. We removed and replaced the glass-fiber filters that sample facilities with significant potential for radioactive particulate emissions weekly and shipped to an off-site analytical laboratory. Before screening the samples for the presence of alpha and beta activity, the laboratory allowed approximately 72 hours for the short-lived progeny of radon to decay. These initial screening analyses ensure that potential emissions were within normal values. The laboratory performed final analyses after the sample had been allowed to decay for approximately one week, which allows for more accurate determinations of concentrations of longer-lived isotopes. In addition to alpha and beta analyses, the laboratory used gamma spectroscopy to identify specific isotopes in the sample. LANSCE glass-fiber filters were analyzed using only gamma spectroscopy.

Because gross alpha/beta counting cannot identify specific radionuclides, the glass-fiber filters were composited every six months for radiochemical analysis. We used the data from these composite analyses to quantify emissions of radionuclides such as the isotopes of uranium and plutonium. To ensure that the analyses requested (e.g., uranium-234, -235, and -238 and plutonium-238 and -239, 240, etc.) identified all significant activity in the composites, ENV-MAQ compared the results of the isotopic analysis with gross activity measurements.

c. Vaporous Activation Products Emissions. We generally removed and replaced the charcoal canisters that sample facilities with the potential for significant vaporous activation products emissions weekly, then shipped the samples to the off-site analytical laboratory where gamma spectroscopy identified and quantified the presence of vaporous radioactive isotopes.

d. Tritium Emissions. Tritium bubbler samples used to sample facilities with the potential for significant elemental and oxide tritium emissions were generally collected and transported to LANL's Health Physics Analytical Laboratory on a weekly basis. The Health Physics Analytical Laboratory added an aliquot of each sample to a liquid scintillation cocktail and determined the amount of tritium in each vial by liquid scintillation counting.

e. Gaseous Mixed Activation Products (GMAP) Emissions. Continuous monitoring was used, rather than off-line analysis, to record and report GMAP emissions for two reasons. First, the nature of the emissions is such that standard filter paper and charcoal filters will not collect the radionuclides of interest. Second, the half-lives of these radionuclides are so short that the activity would decay away before any sample could be analyzed off-line. The GMAP monitoring system includes a flow-through ionization chamber in series with a gamma spectroscopy system. Total GMAP emissions were measured with the ionization chamber. The real-time current this ionization chamber measured was recorded on a strip chart,

and the total amount of charge collected in the chamber over the entire beam operating cycle was integrated on a daily basis. The gamma spectroscopy system analyzed the composition of these GMAP emissions. Using decay curves and energy spectra to identify the various radionuclides, MAQ personnel determined the relative composition of the emissions. Decay curves were typically taken one to three times per week based on accelerator operational parameters. When major ventilation configuration changes were made at LANSCE, new decay curves and energy spectra were recorded.

4. Analytical Results

Measurements of LANL stack emissions during 2004 totaled approximately 5,230 Ci. Of this total, tritium emissions composed approximately 790 Ci, and air activation products from LANSCE stacks contributed nearly 4,440 Ci. Combined airborne emissions of materials such as plutonium, uranium, americium, and thorium were less than 0.00001 Ci. Emissions of particulate/vapor activation products (P/VAP) also were less than 0.01 Ci.

Table 4-13 provides detailed emissions data for LANL buildings with sampled stacks.

Table 4-13. Airborne Radioactive Emissions from LANL Buildings with Sampled Stacks in 2004 (Ci)

TA-Bldg	H-3[a]	Am-241	Pu[b]	U[c]	Th[d]	P/VAP[e]	GMAP[f]	Sr-90
TA-03-029		2.06E-07	2.07E-06	2.78E-06	1.33E-06			
TA-03-102				1.99E-08	1.01E-09			
TA-16-205	1.40E+02							
TA-21-155	3.37E+02							
TA-21-209	2.99E+02							
TA-48-001						2.31E-04		
TA-50-001					6.99E-08			
TA-50-037								
TA-50-069				5.02E-11				
TA-53-003	6.30E-01						1.84E+00	
TA-53-007	2.68E+00					7.98E-03	4.44E+03	
TA-55-004	9.41E+00			9.52E-08				
Total[g]	7.89E+02	2.06E-07	2.07E-06	2.90E-06	1.40E-06	8.21E-03	4.52E+03[h]	0.00E+00

[a] Includes both gaseous and oxide forms of tritium.

[b] Includes Pu-238, Pu-239, and Pu-240.

[c] Includes U-234, U-235, and U-238. Does NOT include radioactive progeny of U-238.

[d] Includes Th-228, Th-230, and Th-232.

[e] P/VAP–Particulate/vapor activation products(with measured radionuclides and short-lived radioactive progeny).

[f] GMAP–Gaseous mixed activation products.

[g] Some differences may occur because of rounding.

[h] Total for GMAP includes 82 curies released from diffuse sources at TA-53.

Table 4-14 provides a detailed listing of the constituent radionuclides in the groupings of GMAP and P/VAP.

Table 4-15 presents the half-lives of the radionuclides typically emitted by LANL. During 2004, LANSCE facility (TA-53) nonpoint source emissions of activated air comprised approximately 79 Ci carbon-11 and 3.3 Ci argon-41, whereas TA-18 contributed 0.91 Ci argon-41.

Table 4-14. Detailed Listing of Activation Products Released from Sampled LANL Stacks in 2004 (Ci)

TA-Building	Nuclide	Emission
TA-48-001	Ga-68	1.09E-04
TA-48-001	Ge-68	1.09E-04
TA-48-001	Rb-86	4.55E-06
TA-48-001	Se-75	6.88E-06
TA-48-001	Se-75	5.30E-07
TA-53-003	C-11	1.84E+00
TA-53-007	Ar-41	8.48E+00
TA-53-007	As-72	2.21E-05
TA-53-007	As-73	1.34E-04
TA-53-007	Be-7	1.29E-06
TA-53-007	Br-76	1.84E-03
TA-53-007	Br-77	2.24E-05
TA-53-007	Br-82	1.51E-03
TA-53-007	C-10	8.10E-02
TA-53-007	C-11	3.46E+03
TA-53-007	Hg-197	2.18E-03
TA-53-007	Hg-197m	2.18E-03
TA-53-007	N-13	6.43E+01
TA-53-007	N-16	2.81E-01
TA-53-007	Na-24	8.61E-06
TA-53-007	O-14	4.75E+00
TA-53-007	O-15	8.99E+02
TA-53-007	Os-191	3.01E-05
TA-53-007	Se-75	3.44E-05

Table 4-15. Radionuclide Half-Lives

Nuclide	Half-Life
H-3	12.3 yr
Be-7	53.4 d
C-10	19.3 s
C-11	20.5 min
N-13	10.0 min
N-16	7.13 s
O-14	70.6 s
O-15	122.2 s
Na-22	2.6 yr
Na-24	14.96 h
P-32	14.3 d
K-40	1,277,000,000 yr
41Ar	1.83 h
Mn-54	312.7 d
Co-56	78.8 d
Co-57	270.9 d
Co-58	70.8 d
Co-60	5.3 yr
As-72	26 h
As-73	80.3 d
As-74	17.78 d
Br-76	16 h
Br-77	2.4 d
Br-82	1.47 d
Se-75	119.8 d
Sr-85	64.8 d
Sr-89	50.6 d
Sr-90	28.6 yr
I-131	8 d
Cs-134	2.06 yr
Cs-137	30.2 yr
Os-183	13 h
Os-185	93.6 d
Os-191	15.4 d
Hg-193	3.8 h
Hg-195	9.5 h
Hg-195m	1.67 d
Hg-197	2.67 d
Hg-197m	23.8 h
U-234	244,500 yr
U-235	703,800,000 yr
U-238	4,468,000,000 yr
Pu-238	87.7 yr
Pu-239	24,131 yr
Pu-240	6,569 yr
Pu-241	14.4 yr
Am-241	432 yr

5. Long-Term Trends

Figures 4-15 through 4-18 present radioactive emissions from sampled LANL stacks. These figures illustrate trends in measured emissions for plutonium, uranium, tritium, and GMAP emissions, respectively. As the figures demonstrate, tritium emissions were down slightly from 2003 and on a steady downward trend. GMAP emissions are elevated from 2003 levels, but fairly consistent with 2002. Emissions from plutonium and uranium isotopes stayed relatively steady since 2000. Note that with the suspension of work activity in July 2004, most operations ceased for long periods of time. One side effect of this work suspension is a reduction in air emissions from these operations, as noted by the tritium, uranium, and plutonium emissions plots. The exception to this is GMAP emissions from LANSCE, because the accelerator run cycle was completed in April 2004.

Tritium emissions are also down because of the completion of source removal activities at TA-21-155. Continued emissions from this facility result from off gassing of contaminated equipment remaining in the building. Monitoring will continue until it is felt that the potential emissions levels from TA-21-155 are fully characterized. At TA-21-209, operations are being prepared for transfer to TA-16, where LANL is consolidating most tritium operations, and the 21-209 building is being prepared for decontamination and decommissioning. As tritium-contaminated systems are dismantled and prepared for removal and disposal, increased releases of tritium are expected. However, overall long-term emissions from these facilities will decrease following such decontamination and decommissioning.

The large spike in tritium emissions from 2001 is due to a single release of 7600 curies of tritium gas (HT) on January 31, 2001. No such large-scale releases have occurred since that time. The release in 2001, as well as routine operational releases before and since that time, are well below regulatory limits.

In 2004, LANSCE operated in the same configuration as 2001–2003, with continuous beam operations to the 1L Target and the Lujan Neutron Scattering Center causing the majority of radioactive air emissions. Operations to the 1L Target took place in January 2004 (extending the end of the 2003 cycle) through the end of April 2004. The reductions in GMAP emissions from LANSCE in 2003 were not maintained in 2004, because of elevated beam operation and other parameters.

The emissions control system at the LANSCE 1L target is a "delay line," which retains the short-lived activation products for a short time before release out the stack. This time interval allows decay of the short-lived radionuclides to nonradioactive components. Because of the operating parameters in 2004, the delay line was not as effective as it was in the early 2003 run cycle, and the rate of emissions increased compared with 2003. The overall total emissions from 2004 remained well below any regulatory limits.

Figure 4-19 shows the individual contribution of each of these emission types to total LANL emissions. It clearly shows that GMAP emissions and tritium emissions make up the vast majority of radioactive stack emissions. Bear in mind that this plot does not directly relate to off-site dose, because some radionuclides have a higher dose impact per curie released than others. GMAP and tritium remain the highest contributors to the total curies released. These gaseous nuclides are not easily removed from an exhaust stack air stream by standard control techniques, such as filtration. These two emissions types continue to fluctuate as the major emissions type, changing as tritium cleanup operations, and LANSCE operations vary from year to year. Because of the close proximity of the LANSCE facility with the LANL site boundary, GMAP emissions remain the greatest source of off-site dose from the airborne pathway.
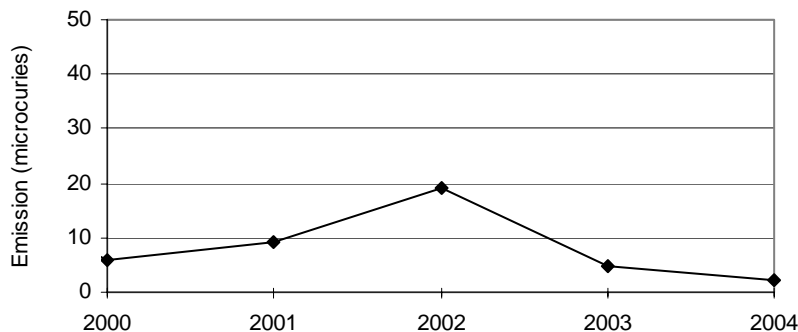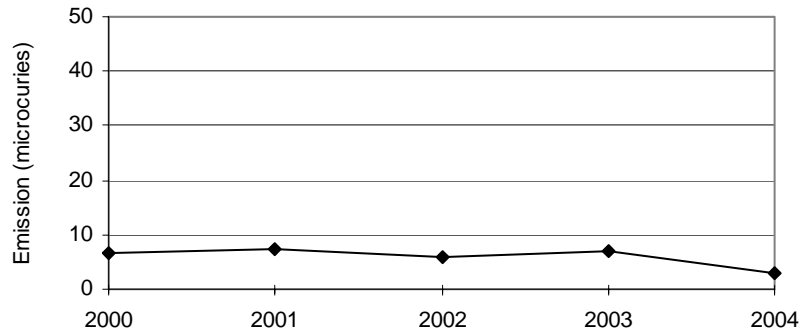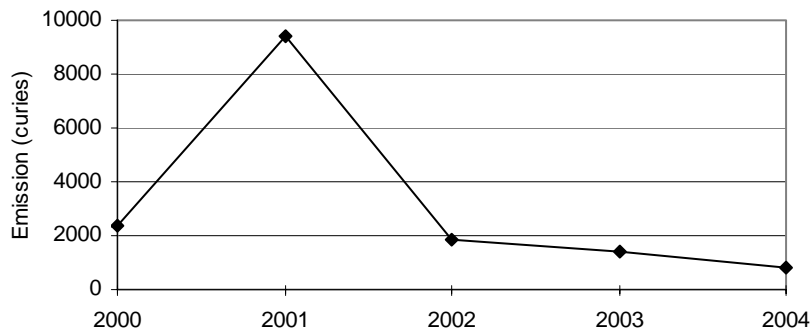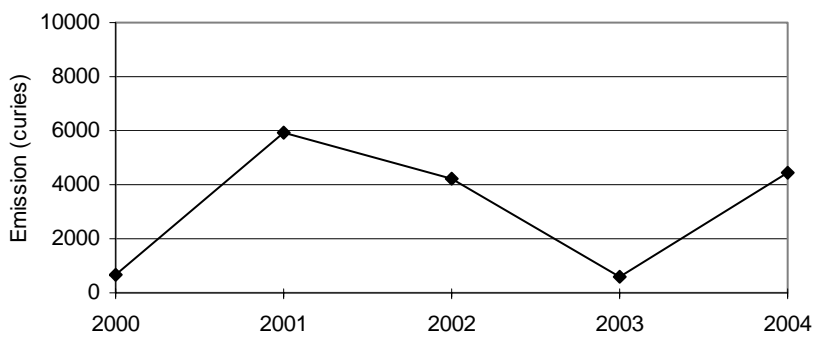

Figure 4-15. Plutonium emissions from sampled LANL stacks.

Figure 4-16. Uranium emissions from sampled LANL stacks.

Figure 4-17. Tritium emissions from sampled LANL stacks.

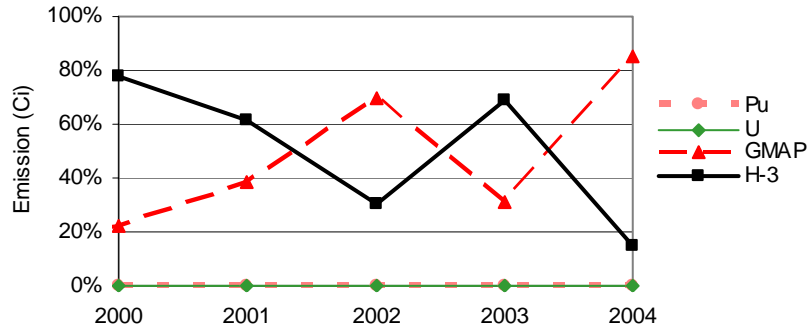**Figure 4-18.** GMAP Emissions from sampled LANL stacks.

4. Air Surveillance

Figure 4-19. Fraction of total stack emissions resulting from plutonium, uranium, tritium, and GMAP.

C. Gamma and Neutron Radiation Monitoring Program *(Andrew Green and Michael McNaughton)*

1. Introduction

ENV-MAQ monitors gamma and neutron radiation in the environment—that is, outside of the workplace—according to the criteria specified in McNaughton et al. (2000). Naturally occurring radiation originates from terrestrial and cosmic sources. Because the natural radiation doses are generally much larger than those from man-made sources, it is extremely difficult to distinguish man-made sources from the natural background. The dose rate from natural terrestrial and cosmic sources varies approximately from 100 to 200 mrem/yr.

2. Monitoring Network

a. Dosimeter Locations. In an attempt to distinguish any impact from LANL operations on the public, ENV-MAQ has located 90 thermoluminescent dosimeter (TLD) stations around LANL and in surrounding communities (Figures 4-2 and 4-20).

b. Neutron Dosimeters. We monitor potential neutron doses with 52 albedo TLD stations. Albedo dosimeters are sensitive to neutrons and use a hydrogenous material to simulate the human body that causes neutron backscatter.

c. Neutron Background. Natural cosmic rays result in a neutron background dose of approximately 10 mrem/yr. However, at stations with no LANL contribution, the neutron dosimeters record a dose of approximately 2 mrem/yr, because the environmental dosimeters are calibrated with a D_2O-moderated neutron source with a different energy spectrum from cosmic-ray neutrons. Therefore, a neutron reading of 2 mrem/yr is a normal background reading.

3. Quality Assurance

ENV Division operating procedures outline the quality assurance/quality control (QA/QC) protocols. In the MAQ group, guidance is provided by ENV-MAQ-QMP. The Health Physics Measurements Group (HSR-4) calibration laboratory calibrates the dosimeters every quarter of the calendar year. The DOE Laboratory Accreditation Program has accredited the dosimeters that HSR-4 provides, and HSR-4 provides QA for the dosimeters. The uncertainty in the TLD data is estimated from the standard deviation of data from dosimeters exposed to the same dose. The overall 1s uncertainty is similar to previous data and is 8%.

4. Results

The annual dose equivalents at almost all stations are consistent with natural background radiation and with previous measurements. Detailed results are listed in the Data Supplement Table S4-11 and at http://www.airquality.lanl.gov/DPRNET.htm.

The locations with a measurable contribution from LANL operations are at TA-18, LANSCE (TA-53), and TA-54, Area G.
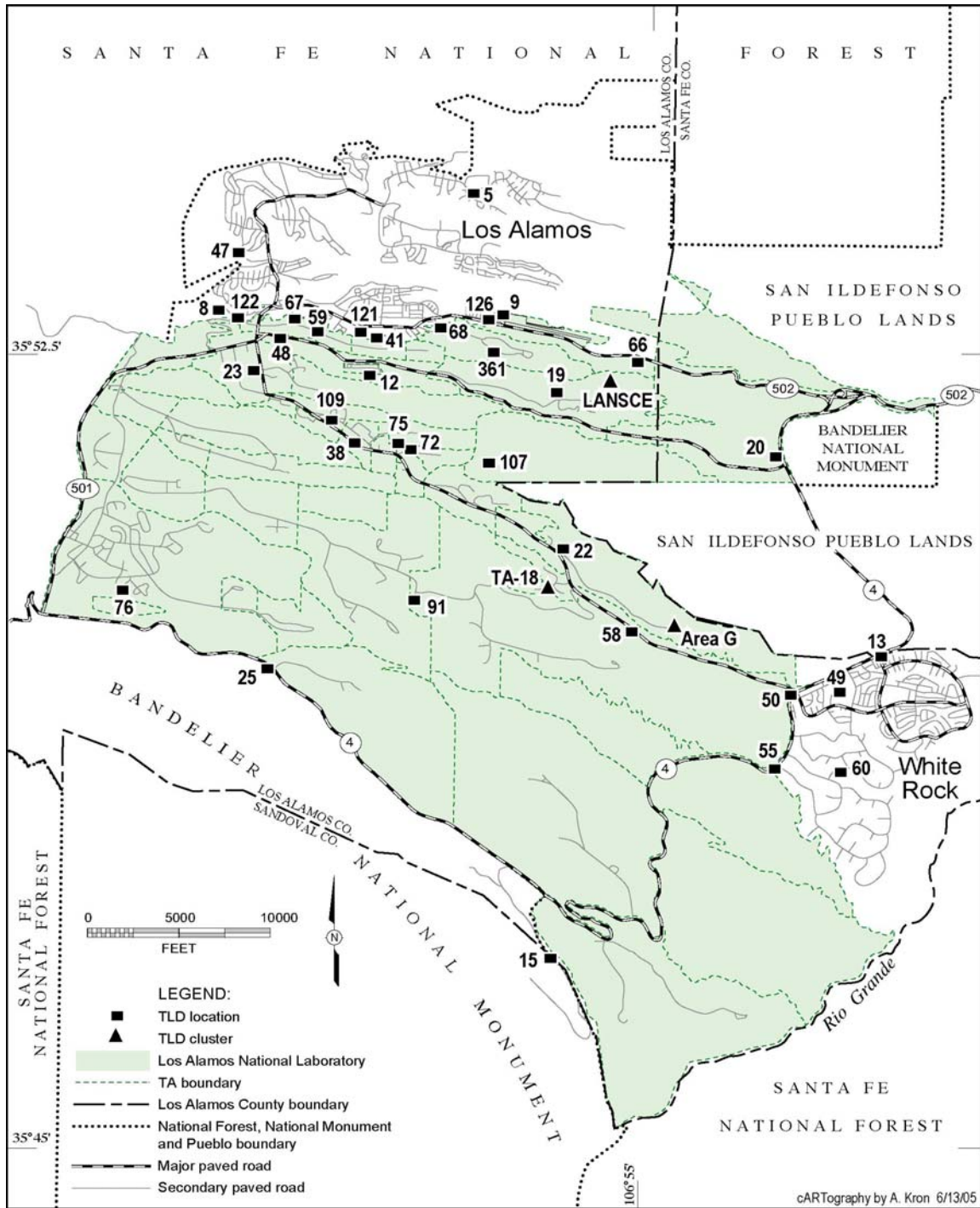
Figure 4-20. Off-site perimeter and on-site LANL TLD locations.

At TA-18, most of the dose is from neutrons; the gamma dose is too small to distinguish from the natural background radiation. The largest measured public neutron dose was 21 mrem on Pajarito Road outside the TA-18 parking lot (Station 187). Pajarito Road had restricted public access throughout 2004.

The TA-53 lagoons, which previously contained activated material, have been remediated, and current doses at stations 114 and 115 are close to background levels. Access by the public to TA-53 is restricted.

4. Air Surveillance

Figure 4-2 shows the locations of the stations at TA-54, Area G, which is a temporary storage area for transuranic waste awaiting shipment to the Waste Isolation Pilot Plant. Area G is a controlled-access area, so most Area G data are not representative of a potential public dose.

In conclusion, the maximum public dose from year-round exposure to direct penetrating radiation during 2004 was 1.25 mrem near TA-18. It is unlikely any member of the public received this dose because of the restricted public access to this location. This dose falls well below the 100-mrem/year maximum allowable limit set by EPA.

D. Nonradioactive Ambient Air Monitoring *(Andrew Green and Craig Eberhart)*

1. Introduction

During 2004, ENV-MAQ continued a reduced version of the nonradiological monitoring (NonRadNet) air-monitoring program implemented in 2001. Currently the objectives of NonRadNet are to conduct monitoring to develop a database of typical background levels of selected nonradiological species in the communities nearest LANL, and to measure LANL's potential contribution to nonradiological air pollution in the surrounding communities. We retain the capability to analyze for volatile organic compounds.

2. Air-Monitoring Network

During 2004, ambient particulate matter monitoring continued at three locations—one in White Rock and two in Los Alamos. The White Rock sampling location is at the White Rock Fire Station. One Los Alamos station is at the Los Alamos Medical Center; the other near 48th Street. Both these latter locations lie between the main LANL technical area and the population center of the Los Alamos town site. Two monitors are operated at each location: one for particles with diameters of 10 micrometers (µm) or less (PM-10), and another for particles with diameters of 2.5 µm or less (PM-2.5).

3. Sampling Procedures, Data Management, and Quality Assurance

A tapered-element oscillating microbalance ambient particulate monitor (fitted with either PM-10 or PM-2.5 sample inlets) collects continuous PM-10 and PM-2.5 concentrations (micrograms per cubic meter). The microbalance has an oscillating ceramic "finger" with a filter that collects particles. The added mass of the particles changes the resonant frequency of the oscillator. The change in frequency is measured; an associated mass of accumulated particulate matter is recorded and saved. The data are later downloaded to a MAQ-maintained database. MAQ personnel use these data as an indicator of natural dust loading in the atmosphere. The sampled air volumes are calculated and the ambient air concentrations derived.

4. Ambient Air Concentrations

a. Particulate Matter. We achieved an overall data collection efficiency exceeding 90% for 2004. Annual averages and 24-hour maxima for both particle sizes at the three locations are shown in Table 4-16. The annual average for PM-10 is about 14 $\mu g/m^3$ at all locations; for PM-2.5 it is half this value. These averages are well below the EPA standards (see Table 4-16). The 24-hour maxima for both PM-2.5 and PM-10 at all three locations are also much less than the EPA standards.

5. Detonation and Burning of Explosives

LANL tests explosives by detonating them at firing sites operated by the Dynamic Experimentation Division. LANL maintains records that include the type of explosives used and other material expended at each site. Table S4-12 (in the Data Supplement) summarizes the amounts of expended materials for the last four years. LANL also burns scrap and waste explosives because of treatment requirements and safety concerns. In 2004, LANL burned 5 tons of high explosives.

An assessment of the ambient impacts of high-explosives testing (DOE 1999) indicates that high-explosives testing produces no adverse air-quality impacts. The quantities of materials detonated during 2004 were less than the amounts for which impacts are analyzed in the DOE (1999) report.

**Table 4-16.** PM-2.5 and PM-10 Concentration Data Summary for 2004

Station Location	Constituent	Maximum 24-Hour (μg/m³)	Annual Average (μg/m³)
48th Street, Los Alamos	PM-10	53	12
	PM-2.5	17	7
Los Alamos Medical Center	PM-10	54	16
	PM-2.5	16	7
White Rock Fire Station	PM-10	43	13
	PM-2.5	15	7
EPA Standard	PM-10	<150	<50[a]
	PM-2.5	<65	<15[a]

[a] EPA 40 CFR Part 50

6. Beryllium Sampling

The state of New Mexico has no ambient-air-quality standard for beryllium. For comparison purposes, we use the National Emission Standard for Hazardous Air Pollutants (NESHAP) standard of 10 ng/m³ (40 CFR Part 61). Beryllium air concentrations for 2004 are very similar to those measured in recent years. All values are 2% of, or less than, the NESHAP standard.

During 2004, we analyzed quarterly composite samples from 22 sites for beryllium, aluminum, and calcium (see Table S4-11 in the Data Supplement). These sites are located near potential beryllium sources at LANL or in nearby communities. Beryllium and aluminum concentrations in soil occur in a fairly constant ratio. Note the linear dependence in Figure 4-21 (correlation coefficient = 0.906). Nonnatural occurrences of beryllium would appear far from the straight line. We believe all the measured beryllium concentrations are of a natural origin—resuspended soil and dust.
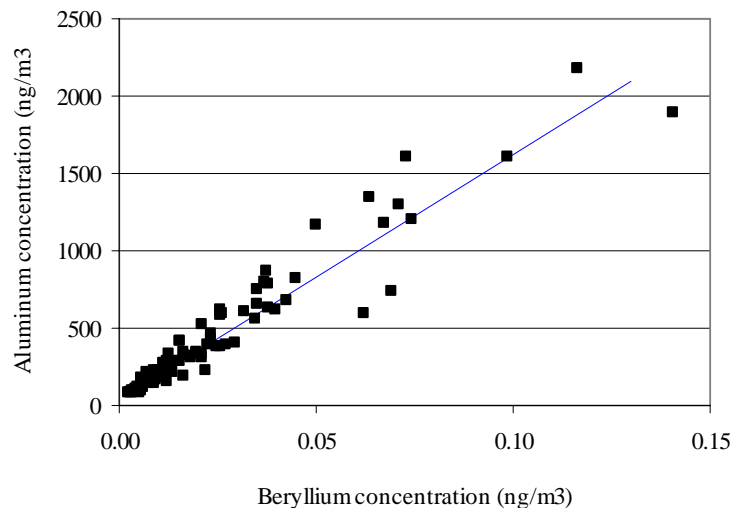
Figure 4-21. Correlation between aluminum and beryllium concentrations in AIRNET samples.

E. Meteorological Monitoring *(Scot Johnson)*

1. Introduction

Data obtained from the meteorological monitoring network support many Laboratory activities, including emergency management and response, regulatory compliance, safety analysis, engineering studies, and environmental surveillance programs. To accommodate the broad demands for weather data at the Laboratory, the meteorology team of the ENV-MAQ Group measures a wide variety of meteorological variables across the network, including wind, temperature, pressure, relative humidity and dew point, precipitation, and solar and terrestrial radiation. The Meteorological Monitoring Plan (Rishel et al. 2003)

4. Air Surveillance

provides details of the meteorological monitoring program. An electronic copy of the "Meteorological Monitoring Plan" is available on the Internet at http://www.weather.lanl.gov/.

2. Monitoring Network

A network of six towers gathers meteorological data (winds, atmospheric state, precipitation, and fluxes) at the Laboratory. Four of the towers are located on mesa tops (TA-6, TA-49, TA-53, and TA-54), one is in a canyon (TA-41), and one is on top of Pajarito Mountain. The TA-6 tower is the official meteorological measurement site for the Laboratory. A sonic detection and ranging (SODAR) instrument is located adjacent to the TA-6 meteorological tower. Precipitation is also measured at TA-16, TA-74, and in North Community of the Los Alamos town site.
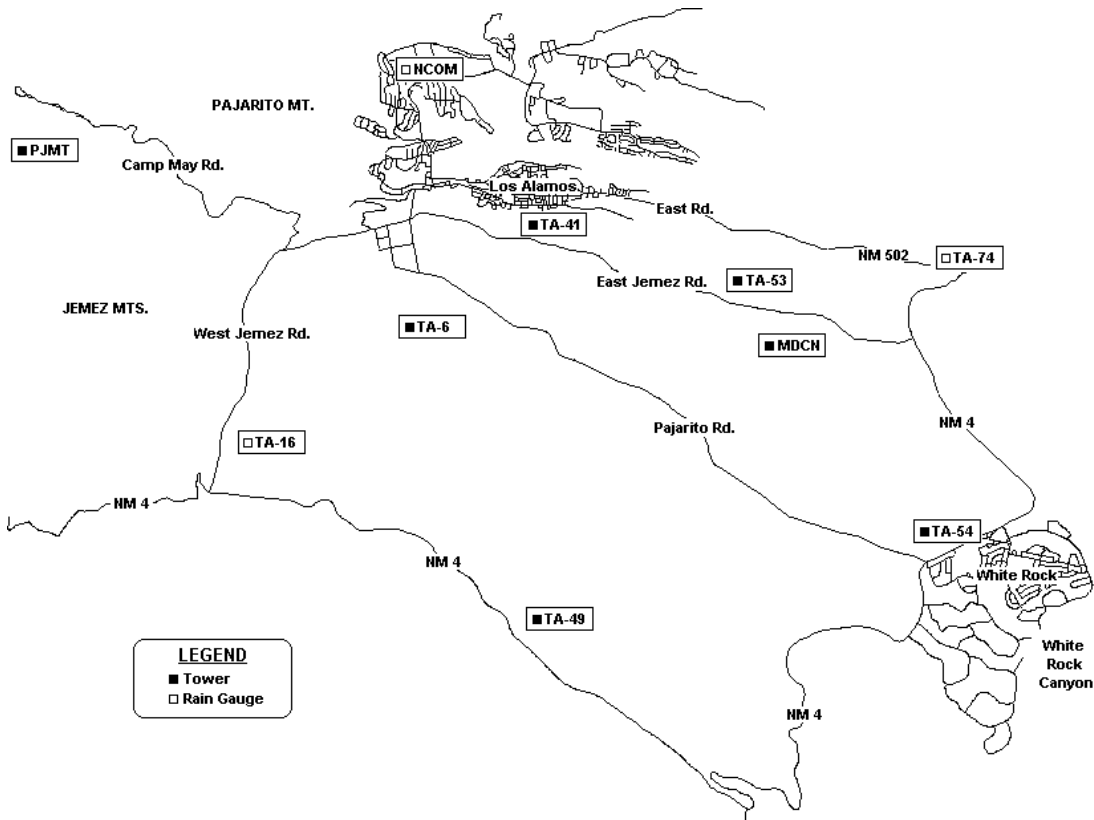

Figure 4-22. Meteorological network.

3. Sampling Procedures, Data Management, and Quality Assurance

We place instruments in the meteorological network in areas with good exposure to the elements being measured, usually in open fields, to avoid wake effects (from trees and structures) on wind and precipitation measurements. Temperature and wind are measured at multiple levels on open lattice towers. The multiple levels provide a vertical profile of conditions important in assessing boundary layer flow and stability conditions. The multiple levels also provide redundant measurements that support data quality checks. The boom-mounted temperature sensors are shielded and aspirated to minimize solar-heating effects.

Data loggers at the tower sites sample most of the meteorological variables at 0.33 hertz (Hz), store the data, average the samples over a 15-min period, and transmit the data to a Hewlett-Packard workstation by telephone or cell phone. The workstation automatically edits measurements that fall outside of allowable ranges. Time-series plots of the data are also generated for a meteorologist's data-quality review. Daily statistics of certain meteorological variables (i.e., daily minimum and maximum temperatures, daily total precipitation, maximum wind gust, etc.) are also generated and checked for quality. During the past 45 years, a similar once-daily set of statistics has been telephoned to the National Weather Service. Observers log cloud type and percentage cloud cover three times daily.

All meteorological instruments are annually refurbished and calibrated during an internal audit/inspection. Field instruments are replaced with backup instruments, and the replaced instruments are checked to verify that they remained in calibration while in service. All instrument calibrations are traceable to the National Institute of Standards and Technology. An external audit is typically performed once every 2–3 years, with the most recent audit performed (on only the TA-54 tower) during 2003.

4. Climatology

Los Alamos has a temperate, semiarid mountain climate. However, large differences in locally observed temperature and precipitation exist because of the 1,000-ft elevation change across the Laboratory site. Four distinct seasons occur in Los Alamos. Winters are generally mild, with occasional winter storms. Spring is the windiest season. Summer is the rainy season, with frequent afternoon thunderstorms. Fall is typically dry, cool, and calm. The climate statistics summarized here are from analyses provided in Bowen (1990 and 1992) and from historical meteorological databases maintained by the meteorology team of the ENV-MAQ Group.

Temperatures at Los Alamos have wide daily variations (a 23°F range on average) because of the semiarid climate. Atmospheric moisture levels are low, and clear skies are present about 75% of the time. These conditions lead to high solar heating during the day and strong long-wave radiative cooling of the earth at night.

Winter temperatures range from 30°F to 50°F during the daytime and from 15°F to 25°F during the nighttime, with a record low temperature of -18°F recorded in 1963. The Sangre de Cristo Mountains to the east of the Rio Grande valley act as a barrier to wintertime arctic air masses that descend into the central United States, making the occurrence of local subzero temperatures rare. Winds during the winter are relatively light, so extreme wind chills are uncommon. Summer temperatures range from 70°F to 88°F during the daytime and from 50°F to 59°F during the nighttime, with a record high temperature of 95°F recorded in 1998.

By convention, the 30-yr period of 1971 to 2000 is used to determine climatological averages. The average annual precipitation (which includes both rain and the water equivalent for frozen precipitation) from 1971 to 2000 is 18.95 in. The average annual snowfall is 58.7 in.

Winter precipitation in Los Alamos is often caused by storms approaching from the Pacific Ocean or by cyclones forming and/or intensifying leeward of the Rocky Mountains. Large snowfalls may occur locally as a result of orographic lifting of the storms by the high terrain. The record single-day snowfall is about 39 in., which occurred between 11am on January 15th, 1987 and 11 am the next day. The record single-season snowfall is 153 in. set in 1986–87.

The 2 months of July and August account for 36% of the annual precipitation and encompass the bulk of the rainy season, which typically begins in early July and ends in early September. Afternoon thunderstorms form as moist air from the Gulf of California and the Gulf of Mexico is convected and/or orographically lifted by the Jemez Mountains. The thunderstorms yield short, heavy downpours and an abundance of lightning.

The complex topography of Los Alamos influences local wind patterns, notable in the absence of large-scale disturbances. Often a distinct diurnal cycle of winds occurs. As air close to the ground is heated during the day, it tends to be displaced by cooler air from aloft and tends to rise and flow upslope along the ground. This is called "anabatic" flow. During the night, cool air that forms close to the ground tends to flow downslope and is known as "katabatic" flow. Daytime upslope flow of heated air on the Pajarito Plateau adds a southerly component to the winds on the plateau as it flows up the Rio Grande valley. Nighttime downslope flow of cooled air from the mountains and plateau adds a light westerly-to-northerly component to local winds. Flow in the east-west-oriented canyons that interrupt the Pajarito Plateau is often

aligned with the canyons, so winds are usually from the west at night as katabatic flow and from the east during the day.

5. 2004 in Perspective

Figure 4-23 presents a graphical summary of Los Alamos weather for 2004. The figure depicts the year's monthly average temperature ranges, monthly precipitation, and monthly snowfall totals compared to monthly normals (averages for each of 12 calendar months during the 1971–2000 time period).

Following a 6-year trend of warmer-than-normal temperatures and a dryer-than-normal climate, 2004 weather returned to normal in Los Alamos County. The average annual temperature in 2004 of 48.1˚F slightly exceeded the normal annual average of 47.9˚F. The total precipitation in 2004 of 18.78 in. was 99% of normal (18.95 in.). February was considerably colder than normal while March and May were much warmer than normal. Cold (warm) and wet (dry) usually go together and not surprisingly, February was much wetter than normal while March and May were drier than normal. February and April experienced surprisingly abundant precipitation, exceeding twice the normal amount during both months. The February precipitation came as snow during three storm events and totaled 38 inches, more than four times the normal February snow amount of 9 inches. The annual snowfall total of 82.4 in. was 140% of normal (58.7 in.).

Temperature and precipitation data have been collected in the Los Alamos area since 1910. Figure 4-24 shows the historical record of temperatures in Los Alamos from 1924 through 2004. The data before 1924 are sparse and are therefore omitted. The annual average temperature is not the average temperature per se, but rather the midpoint between daily high and low temperatures, averaged over the year. One-year averages are shown in green in Figure 4-24 To aid in showing longer-term trends, the 5-year running mean is also shown. It can be seen, for example, that the warm spell during the past few years is not as severe as warm spells during the early-to-mid 1950s.

Figure 4-25 shows the historical record of the annually summed total precipitation. As with the historical temperature profile, the 5-year running mean is also shown. The precipitation in 2004 was close to average. The previous year, 2003, was the second driest year during the 80-year record; only 1956 was drier. The 5-year average shows that the recent drought appears to be the most severe drought on record in Los Alamos. But note that only Los Alamos measurements are shown. It may be that droughts of the late 1930s and early-to-mid 1950s were more widespread and more severe in measurements elsewhere, if not in Los Alamos.
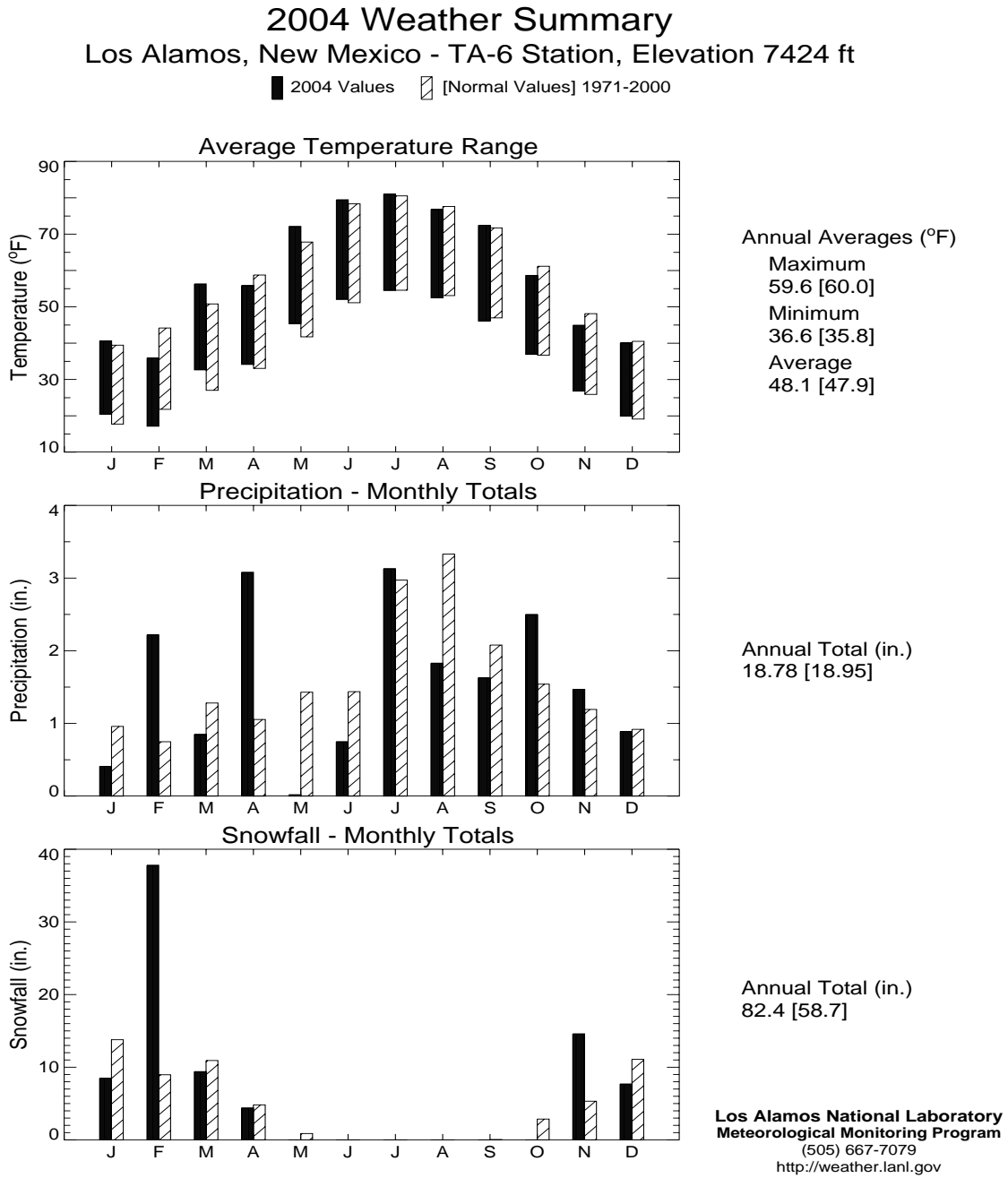
Daytime winds (sunrise to sunset), based on 15-minute-averaged wind observations for 2004 at the four Pajarito Plateau towers and the Pajarito Mountain tower, are shown in the form of wind roses (Figures 4-26 and 4-27). The wind roses depict the percentage of time that the wind blows from each of 16 compass rose points and the distribution of wind speed for each of the 16 directions, represented by shaded wind-rose barbs. Wind roses from different years are almost identical.

Daytime winds measured by the four Pajarito Plateau towers are predominately from the south (Figure 4-26), consistent with the typical upslope flow of heated daytime air moving up the Rio Grande valley. Nighttime winds (sunset to sunrise) on the Pajarito Plateau were lighter and more variable than daytime winds and typically from the west, resulting from a combination of prevailing winds from the west and downslope katabatic flow of cooled mountain air (Figure 4-27). Winds atop Pajarito Mountain are more representative of upper-level flows and primarily ranged from the northwest to the southwest, mainly because of the prevailing westerly winds.

F. Quality Assurance Program in the Air Quality Group *(Terrance Morgan)*

1. Quality Assurance Program Development

During 2004, ENV-MAQ revised two quality plans that affect collection and use of air-quality-compliance data. We also issued three new implementing procedures and revised approximately 36 procedures to reflect the constant improvements in the processes. Together, these plans and procedures describe or prescribe all the planned and systematic activities believed necessary to provide adequate confidence that MAQ processes perform satisfactorily. All current quality-related documents are available on the MAQ public (Green) Web site (www.airquality.lanl.gov).

2004 Weather Summary
Los Alamos, New Mexico - TA-6 Station, Elevation 7424 ft

■ 2004 Values   ▨ [Normal Values] 1971-2000

Average Temperature Range

Annual Averages (°F)
  Maximum
  59.6 [60.0]
  Minimum
  36.6 [35.8]
  Average
  48.1 [47.9]

Precipitation - Monthly Totals

Annual Total (in.)
18.78 [18.95]

Snowfall - Monthly Totals

Annual Total (in.)
82.4 [58.7]

Los Alamos National Laboratory
Meteorological Monitoring Program
(505) 667-7079
http://weather.lanl.gov

Figure 4-23. Weather summary for Los Alamos in 2004 at TA-6 station, elevation 7,424 ft. (Numbers in brackets are 30-year averages, and nonbracketed numbers are 2004 figures.)
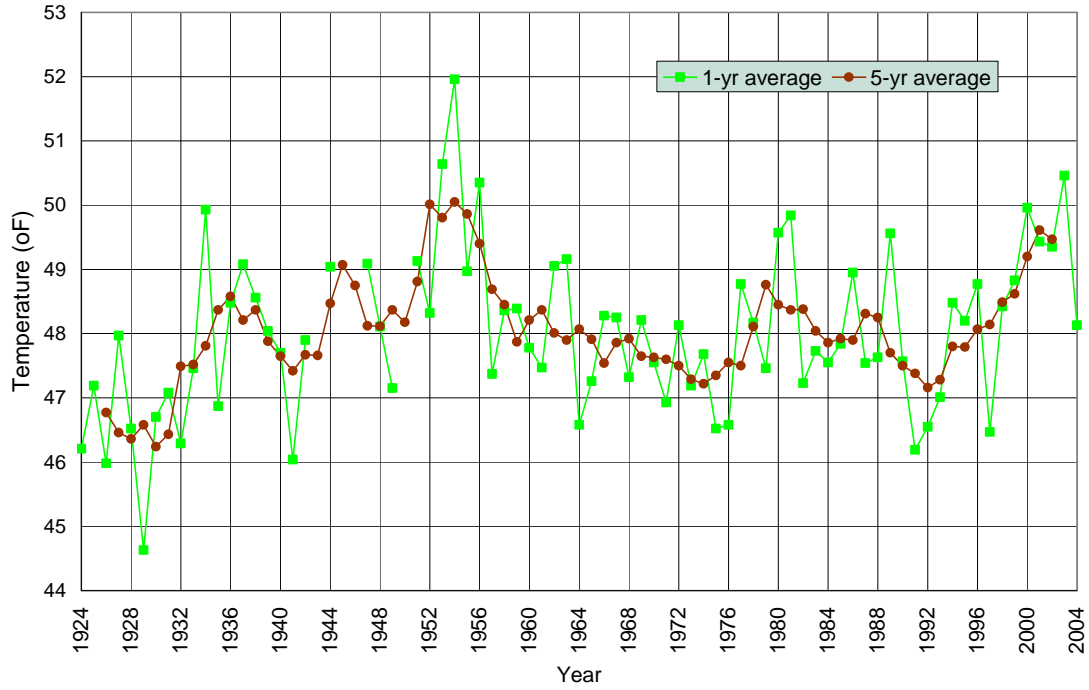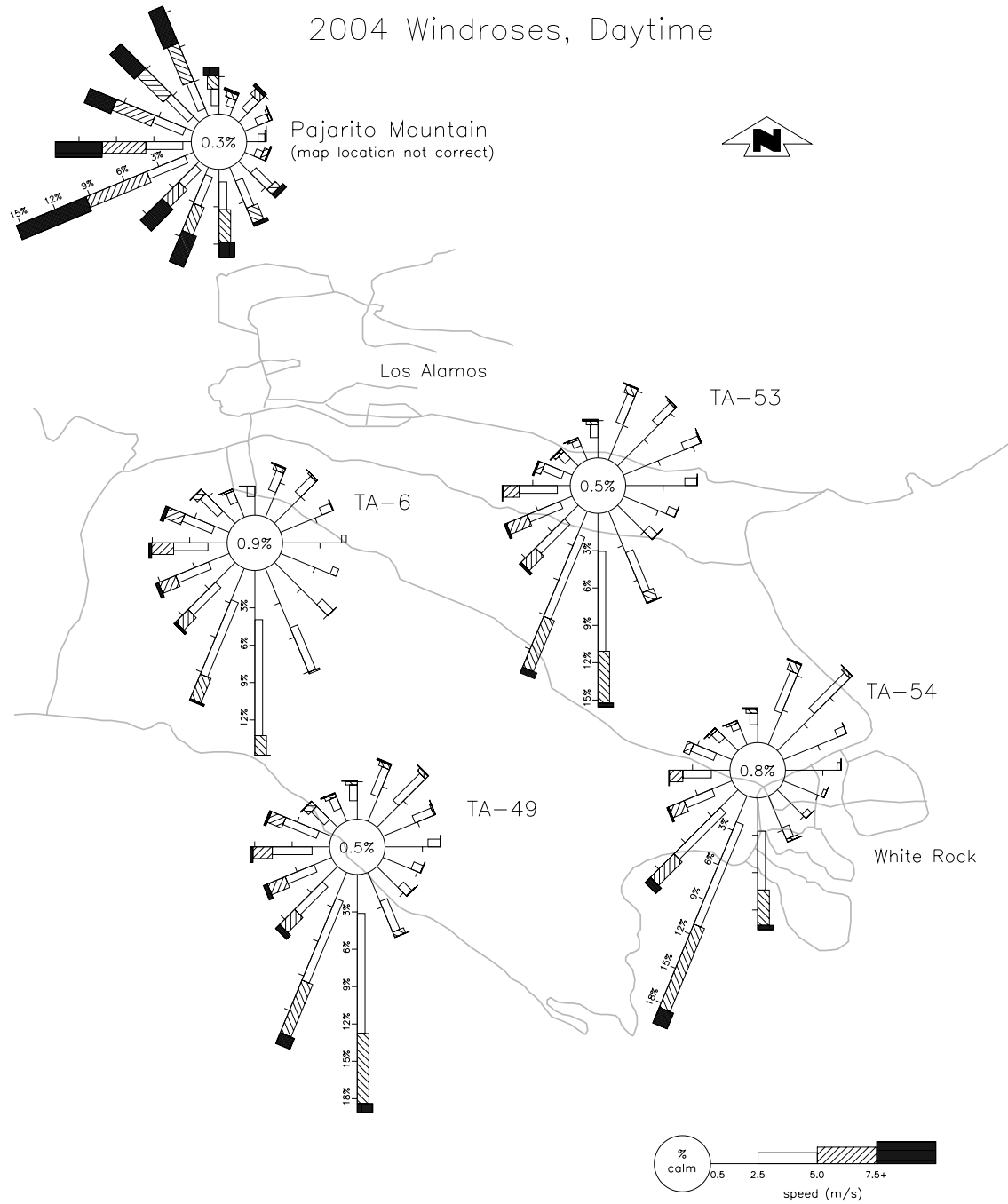
Figure 4-24. Temperature history for Los Alamos.
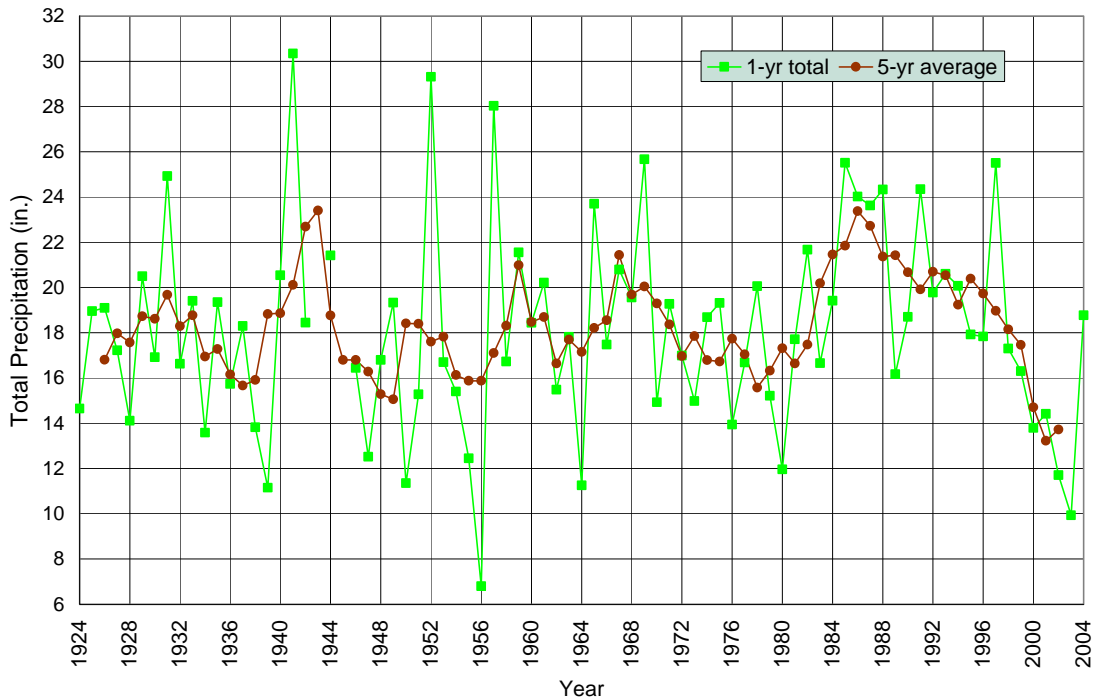
Figure 4-25. Total precipitation history for Los Alamos.

2004 Windroses, Daytime

Pajarito Mountain
(map location not correct)

Los Alamos

TA-53

TA-6

TA-49

TA-54

White Rock
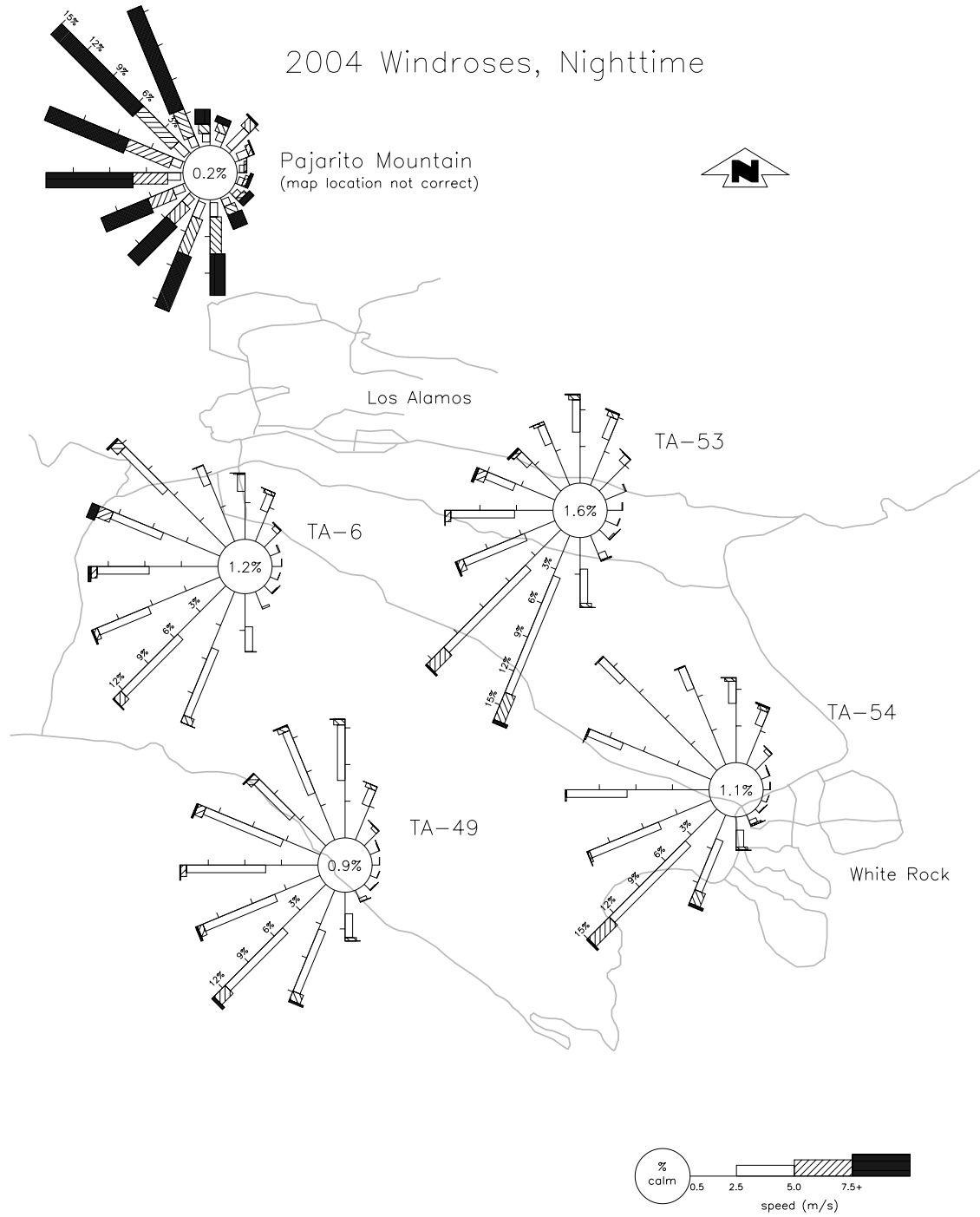
Figure 4-26. Daytime wind roses, 2004.

Figure 4-27. Nighttime wind roses, 2004.

2. Field Sampling Quality Assurance

Overall quality of this portion of the program is maintained through the rigorous use of carefully documented procedures that govern all aspects of the sample-collection program.

Particulate and water-vapor samples are (1) collected from commercially available media of known performance, (2) collected under common EPA chain-of-custody procedures using field-portable electronic data systems to minimize the chances of data transcription errors, and (3) prepared in a secure and radiologically clean laboratory for shipment. They are then delivered to internal and external analytical laboratories under full chain-of-custody including secure FedEx shipment to all external vendors and tracked at all stages of their collection and analysis through the AIRNET and RADAIR relational databases.

Field-sampling completeness is assessed every time the analytical laboratory returns the AIRNET biweekly gross alpha/beta data. RADAIR field-sampling completeness is evaluated each week upon receipt of the gross alpha/beta and tritium bubbler data. All these calculations are performed for each ambient-air and stack-sampling site and are included in the quality-assessment memo that is prepared by MAQ staff to evaluate every data group received from a supplier.

3. Analytical Laboratory Quality Assessment

Specific statements of work are written to govern the acquisition and delivery of analytical-chemistry services after the Data Quality Objective process has identified and quantified our program objectives. These statements of work are sent to potentially qualified suppliers who then undergo a pre-award on-site assessment by experienced and trained MAQ quality systems and chemistry-laboratory assessors. Statement of work specifications, professional judgment, and quality-system performance at each lab (including recent past performance on nationally conducted performance-evaluation programs) are primarily used to award contracts for specific types of radiochemical and inorganic analyses.

Each analytical laboratory conducts its chain-of-custody and analytical processes under its own quality plans and analytical procedures. ENV-MAQ submits independently prepared blind spiked samples with each sample set to be analyzed for tritium. Preliminary data are returned to MAQ by e-mail in an electronic data deliverable of specified format and content. The analytical laboratory also submits a full paper set of records that serves as the legally binding copy of the data. Each set of samples contains all the internal QA/QC data the analytical laboratory generates during each phase of chemical analysis (including laboratory control standards, process blanks, matrix spikes, duplicates, and replicates, when applicable). The electronic data are uploaded into either the AIRNET or RADAIR databases and immediately subjected to a variety of quality and consistency checks. Analytical completeness is calculated, tracking and trending of all blank and control-sample data is performed, and all are included in the quality-assessment memo mentioned in the field-sampling section. All parts of the data-management process are tracked electronically in each database, and periodic reports to management are prepared.

4. Field Data Quality Assessment Results

Field data completeness for AIRNET and stacks was 100%. Sample run time was greater than 95% for the compliance stations in each network.

5. Analytical Data Quality Assessment Results

Analytical data completeness for both sampling programs was >90% for all compliance stations. The Clean Air Act requires an EPA-compliant program of QC samples be included as an integral part of the sampling and analysis process. MAQ sample- and data-management procedures document the specific evaluations of each type of QC sample for each analytical measurement. All QC data are tracked, trended, and reported in specific QC evaluation memos that are submitted to project staff along with each set of analytical data received from our chemistry laboratories. The overall results of the 2004 program of quality monitoring indicate that all analytical laboratories maintained the same high level of control that MAQ has observed in the past several years.

6. Analytical Laboratory Assessments

During 2004, one internal and one external laboratory performed all chemical analyses reported for AIRNET and RADAIR samples. Paragon Analytics, Inc., Fort Collins, Colorado, provided the following analyses:

- biweekly gross alpha, gross beta, and gamma analyses of filters for AIRNET.

- biweekly analyses for tritium in AIRNET silica gel.

- weekly gross alpha, gross beta, gamma, and stable beryllium analyses on stack samples.

- quarterly analyses for alpha-emitting isotopes (americium, plutonium, and uranium) and stable beryllium, calcium, and aluminum on AIRNET quarterly composite samples.

- semester analyses of composites of stack filters for gross alpha, gross beta, Am-241, gamma-emitting isotopes, lead-210, polonium-210, plutonium isotopes, strontium-90, thorium isotopes, and uranium isotopes.

The Laboratory's on-site Health Physics Analytical Laboratory in the Health Physics Measurements Group (HSR-4) performed instrumental analyses of tritium in stack emissions.

MAQ personnel performed an assessment of Paragon Analytics during 2004. The laboratory participated in national performance-evaluation studies during 2004. The detailed results of these performance evaluations are included in the assessment report. Overall, the study sponsors judged the analytical lab to have acceptable performance for almost all analytes attempted in all matrices.

7. Program Audits

In December 2004, ENV-MAQ hosted an audit to evaluate areas of the Laboratory's Rad-NESHAP compliance program. The auditors were an external QA professional and stack monitoring experts who run the same type of programs at other DOE sites. The audit looked at engineering, data handling, and a general program review. While the program was pronounced in good health overall, several observations were made to improve processes. These observations include keeping procedures up to date, following through on formal close-out of deficiencies, meeting internal commitments made in our QA plans, and improved system inspection methods.

G. Unplanned Releases

There were no unplanned airborne releases from LANL during 2004.

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5. Groundwater Monitoring

primary authors:
David B. Rogers, William R. Turney, and Mark P. Haagenstad

A. Introduction

Los Alamos National Laboratory (LANL or the Laboratory) routinely analyzes groundwater samples to monitor water quality on the Pajarito Plateau and the surrounding area. The Laboratory conducts groundwater monitoring and characterization programs to comply with the requirements of the Department of Energy (DOE) Orders and New Mexico and federal regulations. The objectives of the Laboratory's groundwater programs are to determine compliance with waste discharge requirements and to evaluate any impact of Laboratory activities on groundwater resources. This program addresses environmental monitoring, resource management, aquifer protection, and hydrogeologic investigations (LANL 1996, 1998).

Groundwater resource management and protection efforts at the Laboratory focus on (1) the regional aquifer underlying the region and include (2) the shallow perched groundwater found within canyon alluvium and (3) the perched groundwater at intermediate depths above the regional aquifer. The Los Alamos County public water supply comes from supply wells that draw water from the regional aquifer, which lies at a depth of 600 to 1,200 feet.

Since the 1940s, liquid effluent disposal by the Laboratory has degraded water quality in the shallow perched groundwater that lies beneath the floor of a few canyons. These water quality impacts extend in a few cases to perched groundwater at depths of a few hundred feet beneath these canyons. The contaminated perched groundwater bodies are separated from the regional aquifer by hundreds of feet of dry rock, so recharge from the shallow perched groundwater occurs slowly. As a result, little contamination reaches the regional aquifer from the shallow perched groundwater bodies, and water quality impacts on the regional aquifer, though present, are low. With one exception (perchlorate in well O-1 in Pueblo Canyon), drinking water in the Los Alamos area has not been adversely impacted by Laboratory actions. All drinking water produced by the Los Alamos County water supply system meets federal and state drinking water requirements.

The Environmental Stewardship Division Environmental Remediation and Surveillance Program and Water Quality and Hydrology Group (ENV-WQH) implement the Laboratory's groundwater monitoring program. The ENV-WQH Group collects groundwater samples from wells and springs within or adjacent to the Laboratory and from the nearby San Ildefonso Pueblo.

B. Hydrogeologic Setting

Additional information on groundwater studies at Los Alamos and a more detailed discussion of the Laboratory's hydrogeologic conceptual model appear in the Laboratory's annual groundwater status report (Nylander et al., 2003).

1. Geologic Setting

Los Alamos National Laboratory is located in northern New Mexico on the Pajarito Plateau, which extends eastward from the Sierra de los Valles (the eastern range of the Jemez Mountains) (Figure 5-1).

5. Groundwater Monitoring

The Rio Grande borders the Laboratory on the east. Rocks of the Bandelier Tuff cap the Pajarito Plateau. The tuff formed from volcanic ashfall deposits and pyroclastic flows erupted from the Jemez Mountains volcanic center approximately 1.2 to 1.6 million years ago. The tuff is more than 1,000 ft thick in the western part of the plateau and thins eastward to about 260 ft adjacent to the Rio Grande.

On the western part of the Pajarito Plateau, the Bandelier Tuff overlaps the Tschicoma Formation, which consists of older volcanics that form the Jemez Mountains (Figure 5-1). The Puye Formation conglomerate underlies the tuff beneath the central and eastern portion of the plateau. The Cerros del Rio basalt flows interfinger with the Puye Formation conglomerate beneath the Laboratory. These formations overlie the sediments of the Santa Fe Group, which extend across the Rio Grande Valley and are more than 3,300 ft thick.

2. Groundwater Occurrence

Groundwater beneath the Pajarito Plateau occurs in three modes, two of which are perched (Figure 5-2). Perched groundwater is retained above a less permeable layer and separated from underlying groundwater by unsaturated rock. The three modes of groundwater occurrence are (1) perched alluvial groundwater in canyon bottoms, (2) zones of intermediate-depth perched groundwater whose location is controlled by availability of recharge and by subsurface changes in rock type and permeability, and (3) the regional aquifer beneath the Pajarito Plateau.

Streams have filled some parts of canyon bottoms with alluvium up to 100 ft thick. Many relatively dry canyons have little surface water flow and little or no alluvial groundwater. In wet canyons, stream runoff percolates through the alluvium until downward flow is impeded by less permeable layers of tuff, maintaining shallow bodies of perched groundwater within the alluvium. Evapotranspiration and infiltration into underlying rocks deplete the alluvial groundwater as it moves down the canyon. The chemical quality of some of the alluvial groundwater shows the effects of Laboratory discharges.

Underneath portions of Pueblo, Los Alamos, Mortandad, and Sandia canyons, intermediate perched groundwater occurs within the lower part of the Bandelier Tuff and within the underlying Puye Formation and Cerros del Rio basalt (Figure 5-2). These intermediate-depth groundwater bodies are formed in part by recharge from the overlying perched alluvial groundwater. Intermediate groundwater occurrence is controlled by availability of recharge and variations in permeability of the rocks underlying the plateau. Depths of the intermediate perched groundwater vary: approximately 120 ft in Pueblo Canyon, 450 ft in Sandia Canyon, and 500–750 ft in Mortandad Canyon.

Some intermediate perched water occurs in volcanics on the flanks of the Sierra de los Valles to the west of the Laboratory. This water discharges at several springs (Armstead and American) and yields a significant flow from a gallery in Water Canyon. Intermediate perched water also occurs within the Laboratory border just east of the Sierra de los Valles, in the Bandelier Tuff at a depth of approximately 700 ft. The source of this perched water may be infiltration from streams that discharge from canyons along the mountain front and also underflow of recharge from the Sierra de los Valles. The intermediate groundwater in various locations shows localized radioactive (tritium), organic (high explosives [HEs] cyclonite [RDX], trinitrotoluene [2,4,6-TNT], and HE degradation products), and inorganic (perchlorate and nitrate) contamination from Laboratory operations.
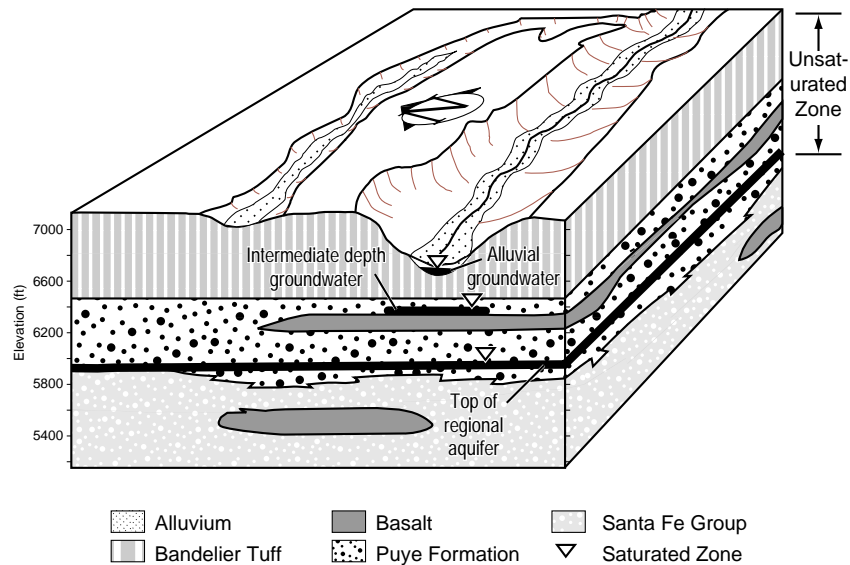
The regional aquifer of the Los Alamos area occurs at a depth of 1,200 ft along the western edge of the plateau and 600 ft along the eastern edge (Figures 5-1 and 5-3). The regional aquifer lies about 1,000 ft beneath the mesa tops in the central part of the plateau. This aquifer is the only aquifer in the area capable of serving as a municipal water supply. Water in the aquifer flows generally east or southeast toward the Rio Grande, and groundwater model studies indicate that underflow of groundwater from the Sierra de los Valles is the main source of recharge for the regional aquifer (Nylander et al., 2003). Groundwater velocities vary spatially but are typically 30 ft/yr.

The surface of the aquifer rises westward from the Rio Grande within the Tesuque Formation, part of the Santa Fe Group (Figure 5-1). Underneath the central and western part of the plateau the aquifer rises farther into the Cerros del Rio basalt and the lower part of the Puye Formation.

WEST   EAST
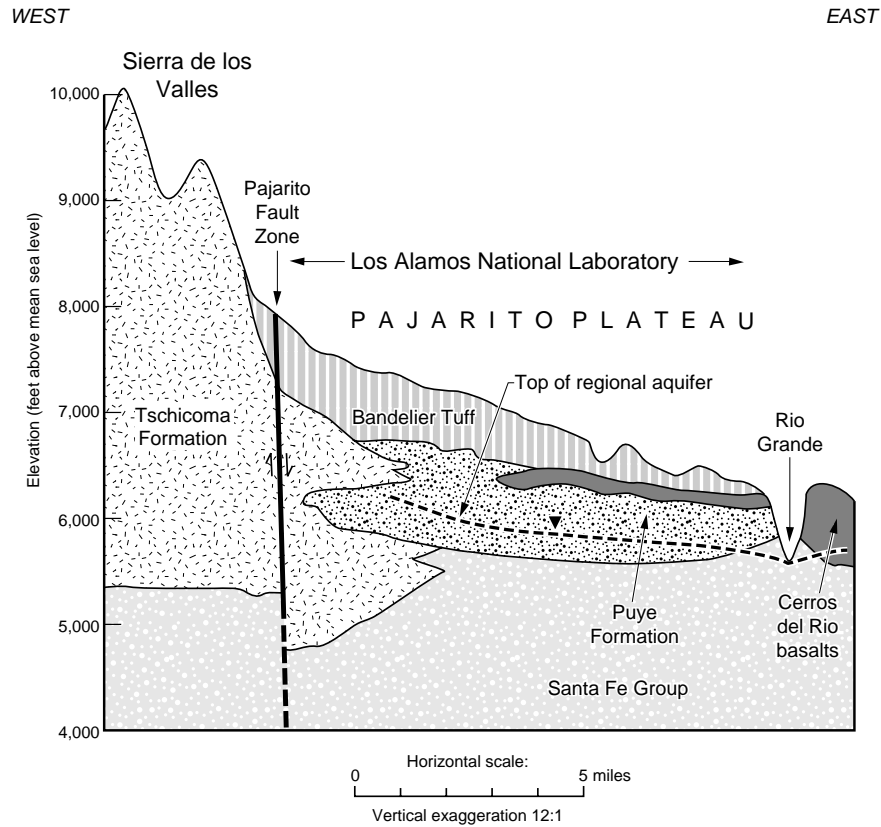
Figure 5-1. Generalized geologic cross section of the Pajarito Plateau.

Figure 5-2. Illustration of geologic and hydrologic relationships in the Los Alamos area, showing the three modes of groundwater occurrence.
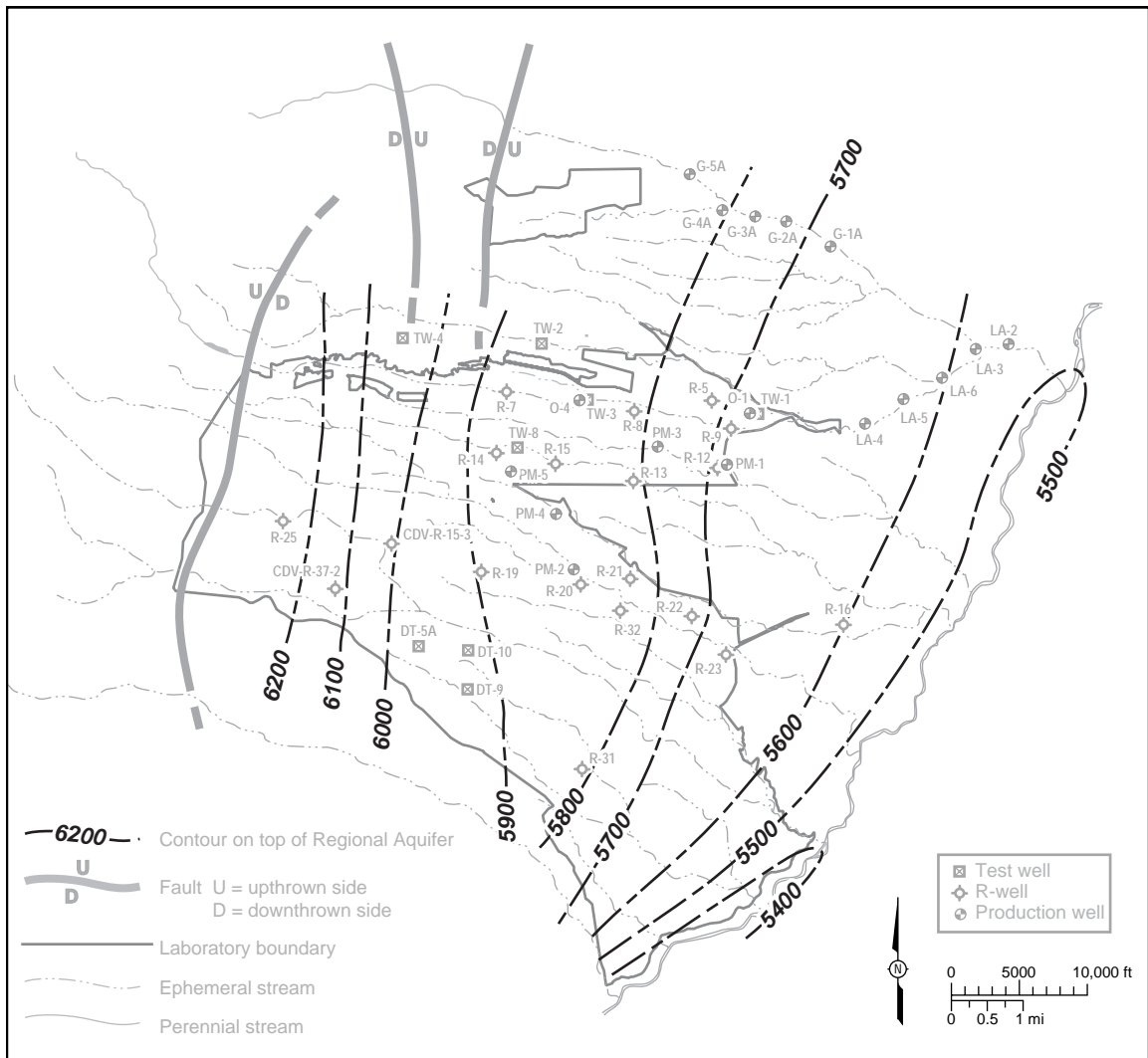
5. Groundwater Monitoring

Figure 5-3. Generalized water level contours for the regional aquifer (Nylander et al., 2003).

The regional aquifer is separated from alluvial and intermediate perched groundwater by approximately 350 to 620 ft of unsaturated tuff, basalt, and sediments with generally low (<10%) moisture content. Water lost by downward seepage from alluvial and intermediate groundwater zones travels through the underlying rock by unsaturated flow. This percolation is a source of contaminants that may reach the regional aquifer within a few decades. The limited extent of the alluvial and intermediate groundwater bodies, along with the dry rock that underlies them, limits their volumetric contribution to recharge reaching the regional aquifer.

3. Overview of Groundwater Quality

Liquid effluent disposal is the primary means by which Laboratory contaminants have had a limited effect on the regional aquifer. In most cases where Laboratory contaminants are found at depth, the setting is either a canyon where alluvial groundwater is usually present (perhaps because of natural runoff or Laboratory effluents) or a location beneath a mesa-top site where large amounts of liquid effluent have been discharged. The discharge of effluents to canyons or mesa-top locations in the Laboratory's semiarid setting initiates or increases downward percolation of water. Even under unsaturated flow conditions, this

percolation may move significant amounts of water and contaminants to the regional aquifer within a few decades.

Liquid effluent disposal at the Laboratory has significantly affected the quality of alluvial groundwater in some canyons (Figure 5-4). These effluents have to a lesser degree affected deeper intermediate perched groundwater and the regional aquifer. Drainages that received liquid radioactive effluents include Mortandad Canyon, Pueblo Canyon from its tributary Acid Canyon, and Los Alamos Canyon from its tributary DP Canyon. Rogers (2001) and Emelity (1996) summarize radioactive effluent discharge history at the Laboratory.

Water Canyon and its tributary Cañon de Valle have received effluents produced by HE processing and experimentation (Glatzmaier 1993; Martin 1993). Over the years, Los Alamos County has operated three sanitary treatment plants in Pueblo Canyon (ESP 1981). Only the Bayo plant is currently operating. The Laboratory has also operated numerous sanitary treatment plants, three of which are shown in Figure 5-4.

C. Groundwater Standards

We apply regulatory standards and risk levels to evaluation of groundwater samples according to the plan shown in Table 5-1. For water supply wells, which draw water from the regional aquifer, we compare concentrations of radionuclides in samples to (1) the derived concentration guides (DCGs) for ingested water calculated from DOE's 4-mrem drinking water dose limit and (2) the Environmental Protection Agency (EPA) maximum contaminant levels (MCLs). For groundwater sources other than water supply wells, DCGs based on the DOE's 100-mrem/yr public dose limit for water ingestion apply. For risk-based screening, groundwater samples from sources other than water supply wells may be compared with DOE's 4-mrem drinking water DCGs and with EPA MCLs.

The New Mexico drinking water regulations and EPA MCLs apply as regulatory standards to nonradioactive constituents in water supply samples and may be used as risk-based screening levels for other groundwater samples. The New Mexico Water Quality Control Commission (NMWQCC) groundwater standards (NMWQCC 2002) apply to concentrations of nonradioactive chemical quality parameters in all groundwater samples. We screened the toxic pollutants listed in the NMWQCC groundwater standards at a risk level of 10^{-5} for cancer-causing substances or a hazard index of one (HI = 1) for noncancer causing substances. A hazard index value of 1 or less indicates that no (noncancer) adverse human health effects are expected to occur. We used the EPA Region VI tap water screening levels to screen the NMWQCC toxic pollutant compounds (*http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm*). For cancer-causing substances, the Region VI tap water screening levels are at a risk level of 10^{-6}, so we use 10 times these values to screen for a risk level of 10^{-5}.

Groundwater is a source of flow to springs and other surface water that neighboring tribal members and wildlife use. The standards for groundwater or NMWQCC's (NMWQCC 2000) surface water standards, including the wildlife habitat standards (see Chapter 6), apply to this water.

D. Monitoring Network

Groundwater sampling locations are divided into three principal groups, related to the three modes of groundwater occurrence: the regional aquifer, perched alluvial groundwater in the bottom of some canyons, and localized intermediate-depth perched groundwater systems (Figures 5-5, 5-6, and 5-7). The springs and wells are described by Purtymun (1995), Nylander et al. (2003), and individual well completion reports. To document the potential impact of Laboratory operations on San Ildefonso Pueblo land, the DOE entered into a Memorandum of Understanding in 1987 with the Pueblo and the Bureau of Indian Affairs to conduct environmental sampling on pueblo land. Groundwater monitoring stations at San Ildefonso Pueblo mainly sample the regional aquifer and are shown in Figure 5-8. Basalt Spring is an intermediate groundwater sampling point, and wells LLAO-1B and LLAO-4 sample alluvial groundwater.

### 1. Regional Aquifer and Intermediate Groundwater Monitoring

Sampling locations for the regional aquifer and intermediate perched groundwater include monitoring (test) wells, supply wells, and springs. Wells recently constructed under the Hydrogeologic Workplan are intended for additional groundwater characterization efforts and to extend the Laboratory's groundwater monitoring system. Several of these wells were added to the monitoring well network beginning in 2002.

5. Groundwater Monitoring

Table 5-1. Application of Groundwater Standards to LANL Monitoring Data

| Constituent	Sample Location	Standard or DCG	Risk-Based Screening Level	Reference	Location	Notes
Radionuclides	Water Supply Wells	DOE 4-mrem Derived Concentration Guides, EPA MCLs		DOE Order 5400.5, 40 CFR 141-143	On-site and off-site	A 4-mrem/year dose rate limit and EPA MCLs apply to drinking water systems
Radionuclides	Other groundwater samples	DOE 100-mrem Derived Concentration Guides	4-mrem Derived Concentration Guides, EPA MCLs	DOE Order 5400.5, 40 CFR 141-143	On-site and off-site	DOE Public Dose Limit is 100 mrem/yr. A 4-mrem/year dose rate limit and EPA MCLs are for comparison because they apply only to drinking water systems
Non-radionuclides	Water Supply Wells	EPA MCLs, NM Groundwater Standards, EPA 10^{-5}, and HI = 1 risk levels for NM toxic pollutants with no NM standard		40 CFR 141-143, 20.6.2 New Mexico Administrative Code, NMED Consent Order	On-site and off-site	EPA MCLs apply to drinking water systems. Use EPA Region VI table for 10^{-5} and HI = 1 risk values
Non-radionuclides	Other groundwater samples	NM Groundwater Standards, EPA 10^{-5} and HI = 1 risk levels for NM toxic pollutants with no NM standard	EPA MCLs	40 CFR 141-143, 20.6.2 New Mexico Administrative Code, NMED Consent Order	On-site and off-site	NMED regulations protect all groundwater. EPA MCLs are for comparison because they apply only to drinking water systems. Use EPA Region VI table for 10^{-5} and HI = 1 risk values
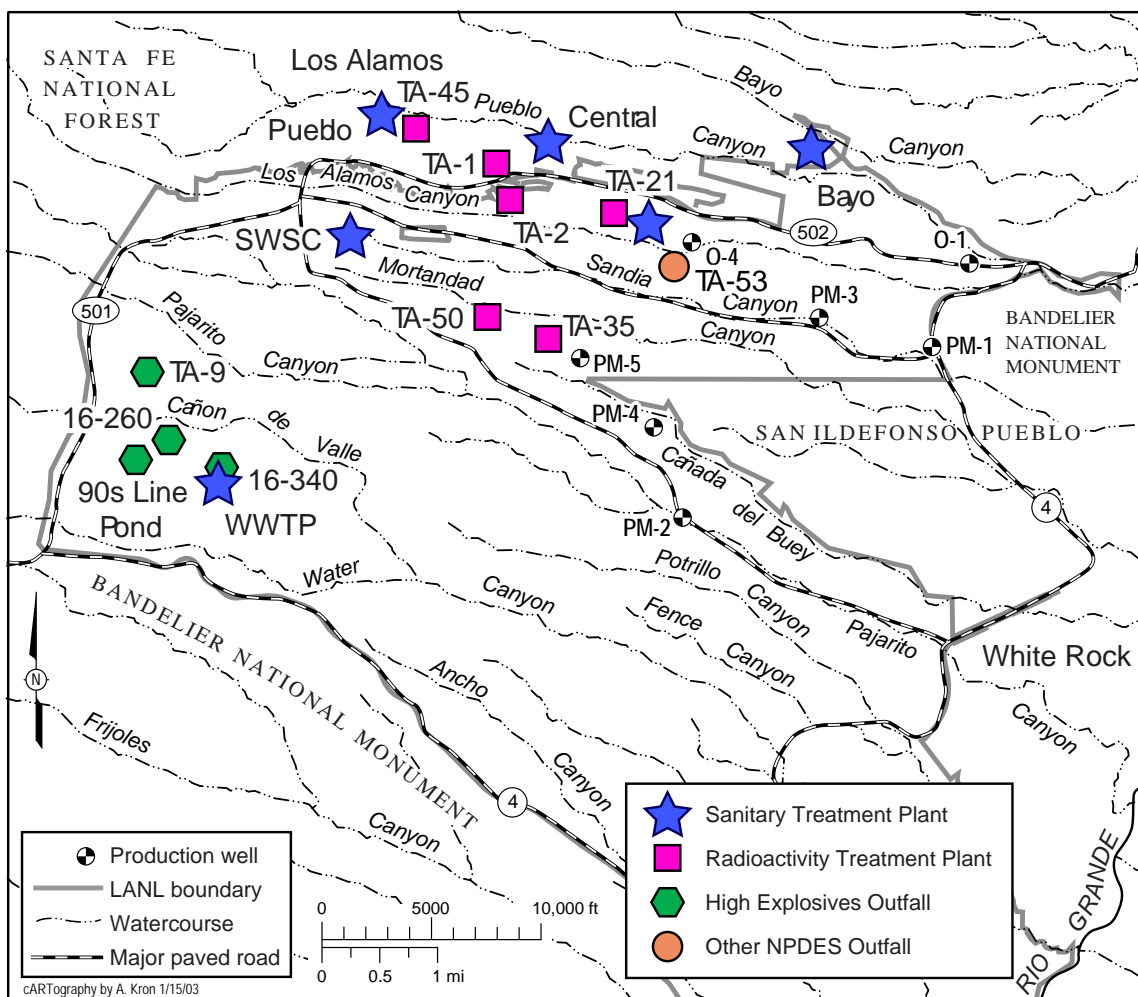
Figure 5-4. Major liquid release sources (effluent discharge) potentially affecting groundwater. Most sources shown are inactive.

In the 1950s and 1960s, the Laboratory located the first regional aquifer monitoring wells where they might detect contaminants infiltrating from areas of effluent disposal or underground weapons-testing operations. These wells penetrate only a few tens or hundreds of feet into the upper part of the regional aquifer. Although the wells have surface casing to seal off entrance of surface water or shallow groundwater, the casings are not cemented, which would prevent deeper infiltration along the boreholes. The newer characterization wells were installed beginning in 1998 (Nylander et al., 2003). Some of these newer wells penetrate down to 600 ft into the regional aquifer, and several have multiple sampling ports within intermediate perched zones and the regional aquifer. A column on the data tables identifies the groundwater zones sampled by different ports of these wells and gives the depth of the port or top of the well screen.

ENV-WQH collects samples from 12 deep water supply wells in 3 well fields that produce water for the Laboratory and the community. The water supply wells are screened up to lengths of 1,600 ft within the regional aquifer, and the wells draw samples that integrate water over a large depth range. The County of Los Alamos owns and operates these wells. The county is responsible for demonstrating that the supply system meets Safe Drinking Water Act requirements. This chapter reports on supplemental sampling that ENV-WQH has carried out. Koch and Rogers (2003) summarized operation of the water supply system for the years 1998–2001.

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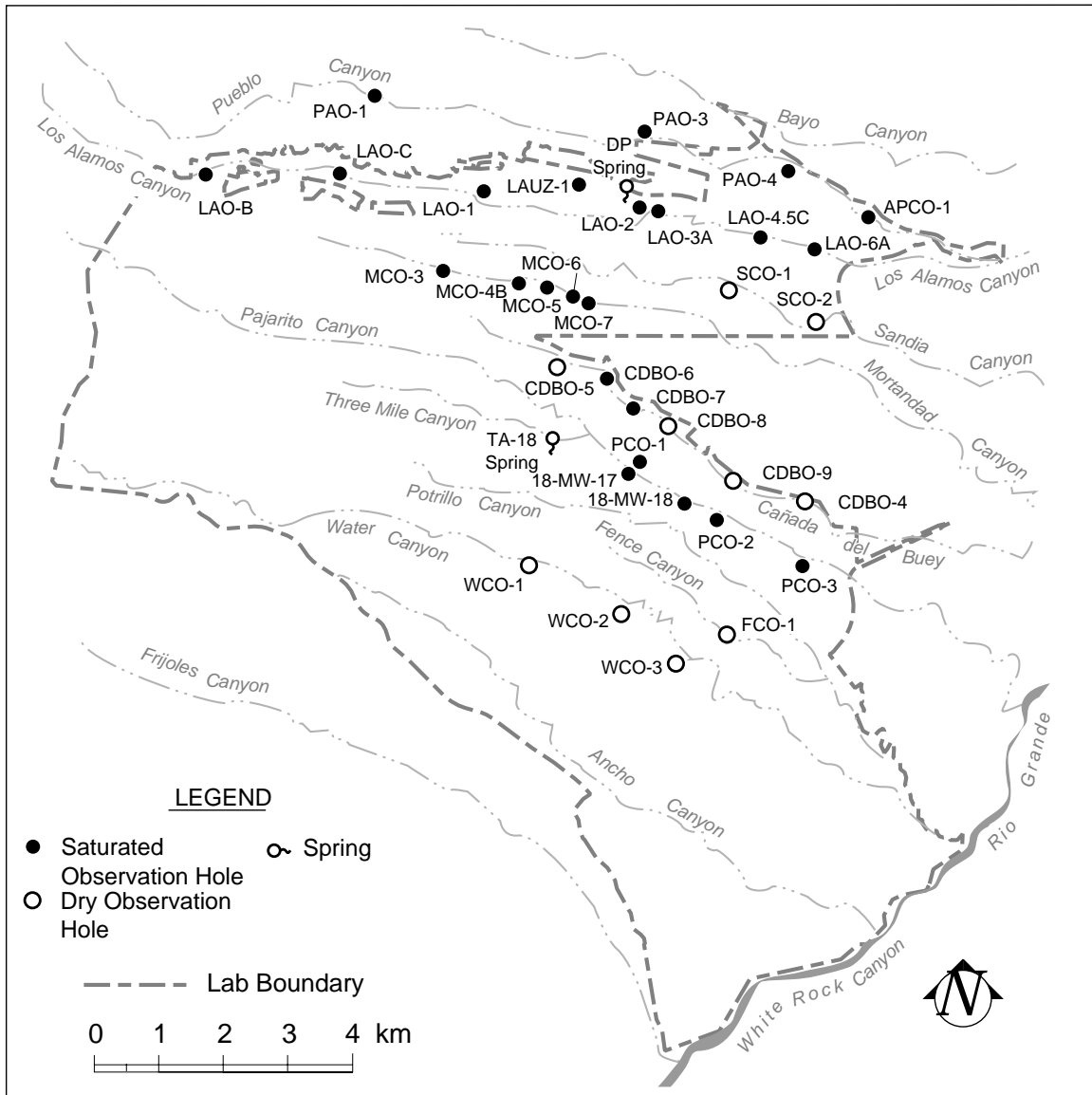
Figure 5-5. Springs and wells used for alluvial groundwater monitoring.

Additional regional aquifer samples come from wells located on San Ildefonso Pueblo and from the Buckman well field operated by the City of Santa Fe.

We sample numerous springs near the Rio Grande because they represent natural discharge from the regional aquifer (Purtymun et al., 1980). The springs serve to detect possible discharge of contaminated groundwater from underneath the Laboratory into the Rio Grande.

2. Alluvial Groundwater Monitoring

To determine the effect of present and past industrial discharges on water quality, ENV-WQH uses shallow wells to sample the perched alluvial groundwater in five canyons (Pueblo, Los Alamos, Mortandad, and Pajarito Canyons and Cañada del Buey). In any given year, some of these alluvial observation wells may be dry, and water samples cannot be obtained. Observation wells in Water, Fence, and Sandia canyons have been dry since their installation in 1989. All but one of the wells in Cañada del Buey are generally dry.
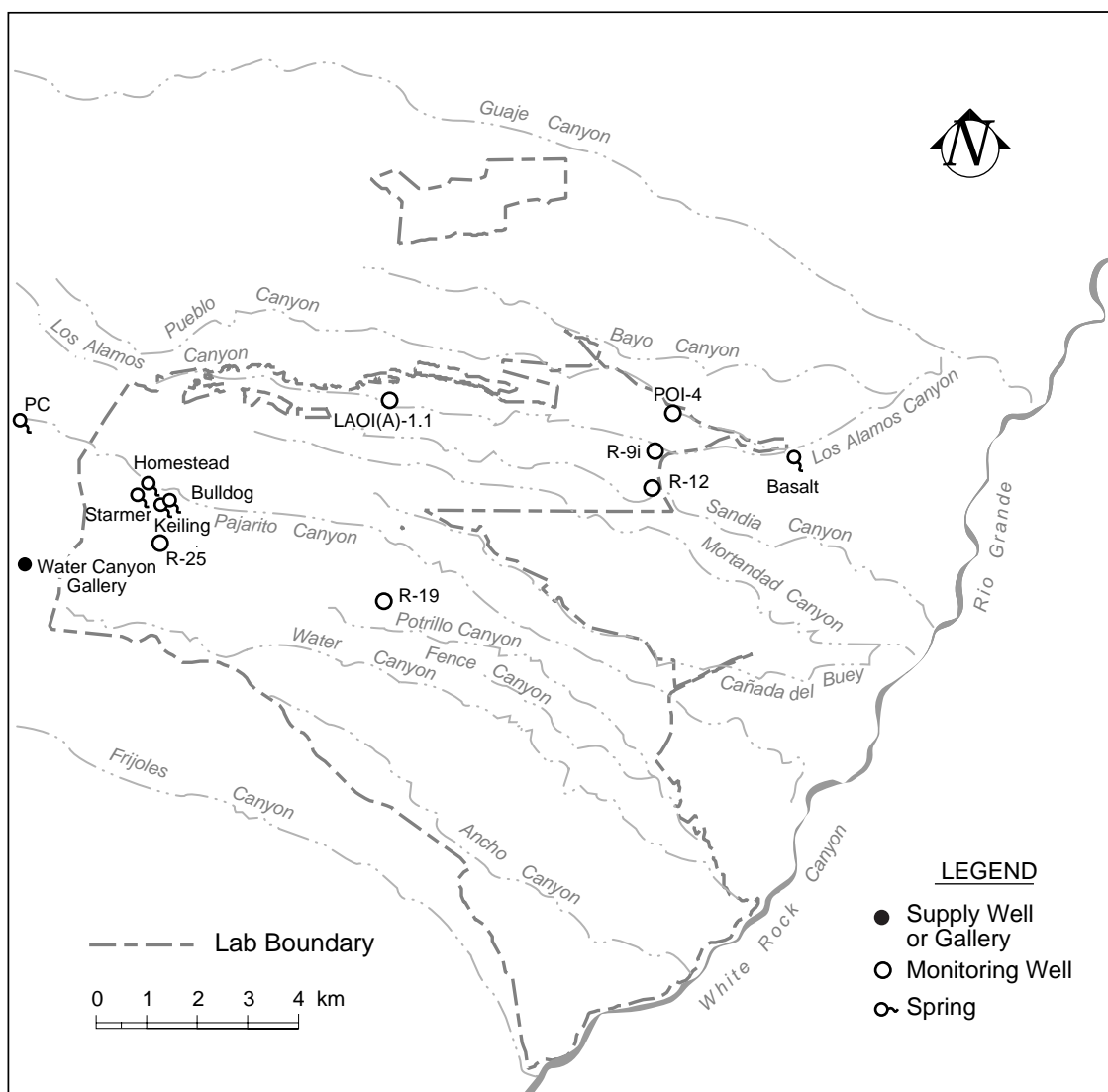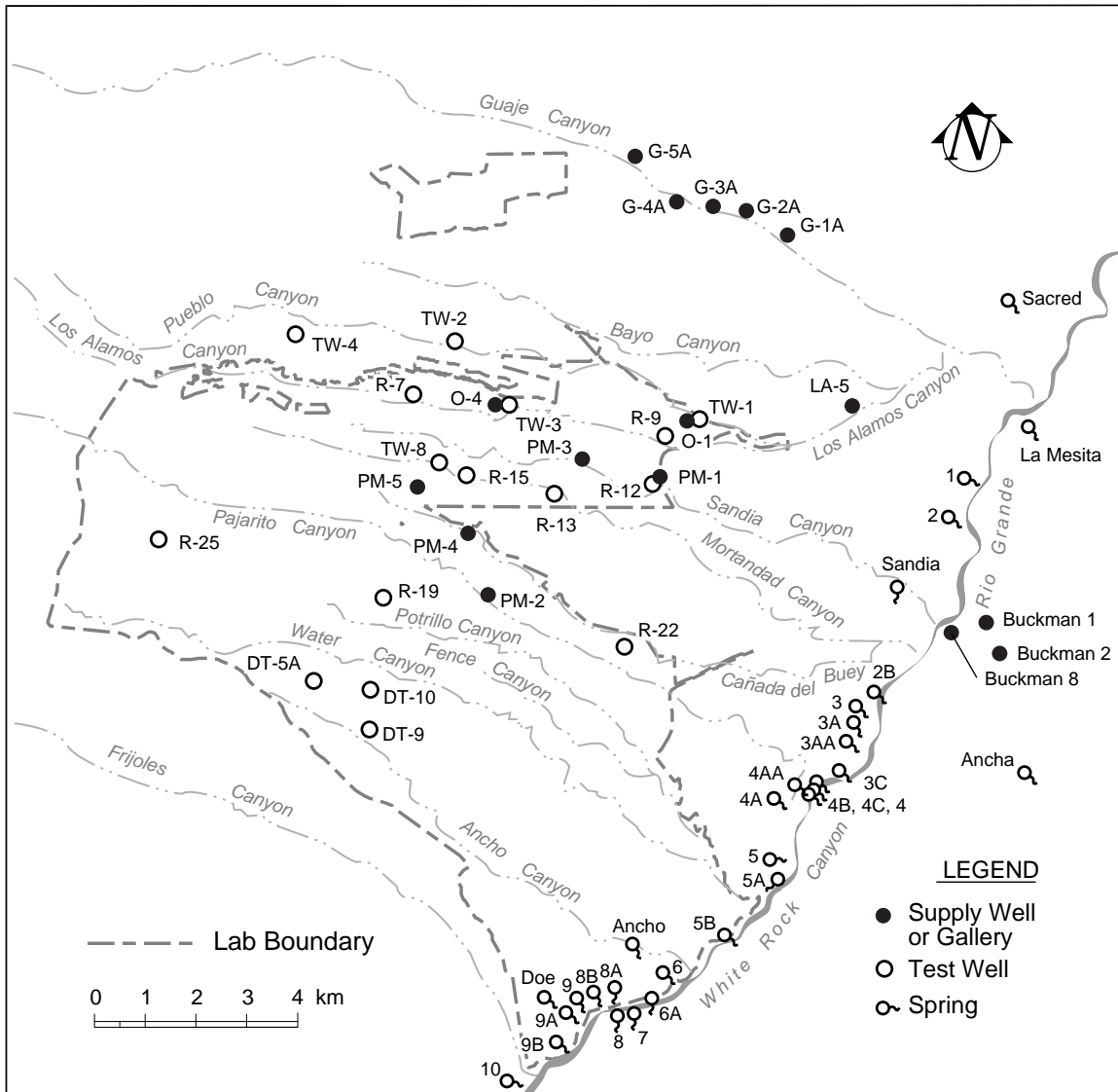
Figure 5-6. Springs and wells used for intermediate perched zone monitoring.

E. Groundwater Sampling Results by Constituents

Tables in the Data Supplement present groundwater monitoring data for 2004. Columns on the data tables identify the groundwater zones sampled—whether alluvial, intermediate, or regional—and indicate if the location is a spring. For wells with several sampling ports, the saturated zone sampled and the port depth appear in the table. The depth of screen top is given for other wells, with a value of –1 if depth is unknown. Table S5-1 in the Data Supplement provides definitions for sample description codes used in the data tables.

Table S5-2 in the Data Supplement lists the results of radiochemical analyses of groundwater samples for 2004. The table also gives the total propagated one-sigma (one standard deviation) analytical uncertainty and the analysis-specific minimum detectable activity (MDA), where available. Uranium was analyzed by chemical methods and by isotopic methods; total uranium is also calculated in the table from the isotopic values using specific activities for each isotope. Table S5-3 shows low-detection-limit tritium results from analyses done by the University of Miami. To emphasize analytical results that are detections, Table S5-4 in the Data Supplement lists radionuclides detected in groundwater samples.
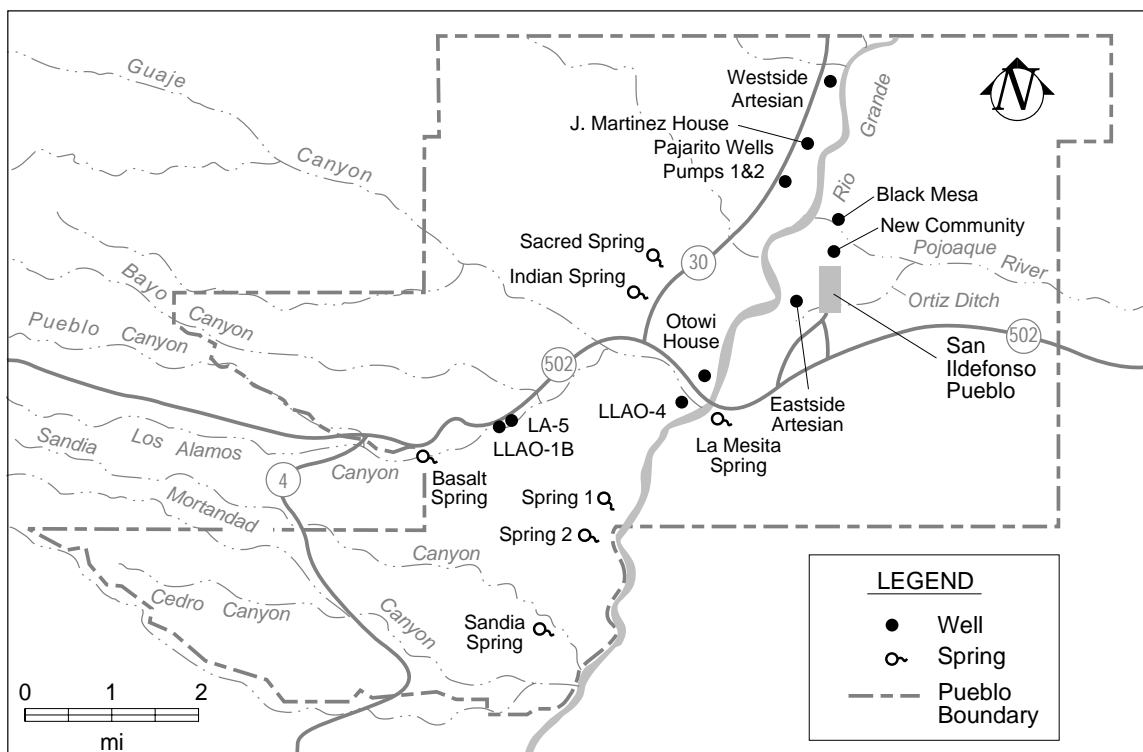
5. Groundwater Monitoring

Figure 5-7. Springs and wells used for regional aquifer monitoring.

We define detections as values that exceed both the analytical method measurement-specific detection limit (where available) and three times the individual measurement uncertainty.

Qualifier codes are shown in Table S5-4 to provide additional information on analytical results that meet the detection criteria but are not detections: in some cases, for example, the analyte was found in the laboratory blank, or there were other analytical issues. The table shows two categories of qualifier codes: those from the analytical laboratory and those from secondary validation (Tables S5-5, S5-6, and S5-7 in the Data Supplement). After ENV-WQH staff receive the analytical laboratory data packages, they receive secondary validation by an independent contractor, Analytical Quality Associates (AQA). The reviews by AQA include verifying, for example, that holding times were met, that all documentation is present, and that analytical laboratory quality control measures were applied, are documented, and are within contract requirements.

Figure 5-8. Springs and wells used for groundwater monitoring on San Ildefonso Pueblo.

Because gross alpha and gross beta are usually detected in water samples, Table S5-4 indicates occurrences of these measurements only above threshold values. The specific levels are 5 pCi/L for gross alpha and 20 pCi/L for gross beta and are lower than the EPA MCLs or screening levels. The right-hand columns of Table S5-4 indicate radiochemical detections that are greater than one-half of either the 100-mrem DOE DCGs for public dose for ingestion of environmental water or the other standards shown on the table. For gross alpha, the DCG assumes that the radioactivity comes solely from americium241 and plutonium-239,240; for gross beta, from strontium-90; thus, these values are for screening purposes and are conservative.

Table S5-8 in the Data Supplement lists the results of general chemical analyses of groundwater samples for 2004. Table S5-9 lists groundwater perchlorate results. We analyzed samples for perchlorate by two methods. This table includes all perchlorate results determined by liquid chromatography/mass spectrometry (LC/MS/MS) method [SW-846:8321A(M)] and all detections by ion chromatography perchlorate MDL (EPA:314.0). The value for the ion chromatography perchlorate MDL (EPA:314.0) is 4 ppb according to our independent analytical laboratory. The LC/MS/MS method [SW-846:8321A(M)] detection limit is 0.05 ppb, or larger if the sample had higher concentrations and was analyzed using sample dilution. In the latter case, the MDL is the dilution factor times 0.05 ppb. The results of trace metal analyses appear in Table S5-10.

In the following sections, we discuss groundwater quality results for each of the three groundwater modes in the major watersheds that encompass the Laboratory. The accompanying groundwater contaminant distribution maps depict contaminants that exceed regulatory or risk levels. Rather than showing data for 2004 alone, the maps represent a synthesis of the last several years of groundwater data collected for Laboratory groundwater monitoring and characterization programs.

The contaminant distribution maps show contaminant locations extrapolated beyond the area covered by monitoring wells. This extrapolation takes into account the location of contaminant sources and direction of groundwater flow. Question marks on the maps indicate where contaminant extent is inferred, but not confirmed by monitoring coverage. Within alluvial groundwater in canyons, the extent of contamination

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lateral to the canyon is not to scale: contamination is confined to the alluvium within the canyon bottom and is quite narrow at the map scale.

1. Organic Sample Analysis

In 2004, ENV-WQH personnel analyzed samples from selected springs and monitoring wells for organic constituents. Table S5-11 in the Data Supplement summarizes stations sampled and organic suites for which samples were analyzed. These samples were analyzed for some or all of the following organic suites: volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls (PCBs), pesticides, diesel-range organics (DROs), and HEs. The Quality Assurance section of this chapter covers analytes and analytical methods. We rejected many of the possible organic detections the analytical laboratory reported because the compounds were either detected in method blanks (that is, they were introduced during laboratory analysis) or were detected in field quality control (QC) samples, including equipment and trip blanks. Equipment blanks use distilled water with which sampling equipment is rinsed before sampling to check for organic contamination acquired during sampling. Trip blanks go along during sampling to determine if organic constituents come from sample transportation and shipment. Table S5-12 in the Data Supplement shows organic compounds detected above the analytical laboratory's reporting level in 2004, as well as results from field QC samples.

      a. Organic Sample Quality Control Program. Because of the sensitive nature of organic chemical sampling and analysis, a carefully designed field and analytical laboratory quality control program is essential for evaluating the presence of organic constituents in environmental samples. Organic analytes may be detected in field quality control samples such as field blanks or equipment blanks, indicating that they are not truly present in associated groundwater samples. These analytes may be present in the quality control samples because of inadvertent contamination of sampling or analytical laboratory equipment by organic constituents that come from other sources.

Most analytical methods require the analysis of laboratory-prepared method blanks or instrument blanks with each batch of samples. Organic target analytes that are detected in these blanks indicate contamination from the sampling or analytical environments. Certain organic compounds used in analytical laboratories are frequently detected in laboratory blanks, that is, contamination introduced by the analytical process is common for these compounds. These compounds include acetone, methylene chloride, toluene, 2-butanone, di-n-butyl phthalate, di-n-octyl phthalate, and bis(2-ethylhexyl)phthalate (Fetter 1993). Numerous field, trip, and equipment blanks WQH collected during this reporting period contained toluene, acetone, butanone[2-], and hexanone[2-], which suggests inadvertent sample contamination in either the field or analytical laboratory.

      b. Pesticide Sample Contamination. In August 2004, ENV-WQH personnel identified several positive pesticide results, notably results for 4,4'-DDT and 4,4'-DDE, in LANL samples. These results were supported by neither previous data nor process knowledge at the sample locations. Subsequent examination of the analytical laboratory's (General Engineering Laboratory or GEL) data revealed that some glassware used in the process was only rinsed, with no further cleaning, between uses. This finding meant that pesticide contamination could be transferred from one sample to another during the sample preparation. As a result, all pesticide results for 2004 are considered unusable. See Section H.3 for more details about this issue.

2. Radioactivity in Groundwater

The main radioactive element detected in the regional aquifer is naturally occurring uranium, found in springs and wells throughout the Rio Grande Valley. The large gross alpha values found in samples from springs and wells in the Rio Grande Valley result from the decay of naturally occurring uranium in the water. Other naturally occurring radioactivity in groundwater samples comes from members of the uranium isotope decay chains, including isotopes of thorium and radium. Potassium-40 is also a source of natural radioactivity. In 2004, the only radioactivity values that exceeded half the 100-mrem DOE public dose DCG values in groundwater samples were results for gross alpha from two City of Santa Fe water supply wells. The gross alpha is from decay of natural uranium, and the DOE DCG does not apply because the radioactivity is not from a DOE source. The EPA MCL for gross alpha also does not apply, because that

standard does not include contribution of uranium to gross alpha; uranium is covered by a separate EPA MCL.

None of the radionuclide activities in perched alluvial groundwater were above the 100-mrem DOE DCG for public dose for ingestion of environmental water. For non-natural radioactivity, only results for strontium-90 from alluvial groundwater in Mortandad and DP/Los Alamos canyons were near or exceeded the 4-mrem DOE DCGs applicable to drinking water (but are not applicable to the alluvial groundwater itself, which is not a source of drinking water). The maximum 2004 strontium-90 values in Mortandad and DP/Los Alamos Canyon alluvial groundwater were also respectively 7.6 and 4.6 times the EPA MCL (Figure 5-9). Total LANL-derived radioactivity exceeded 4 mrem in Mortandad Canyon alluvial groundwater samples from MCO-3 (the highest at 2.14 times the 4-mrem DCGs), MCO-4B, MCO-5, and MCO-6 (Figure 5-10). Gross beta values in some samples from alluvial wells in Mortandad and DP/Los Alamos Canyon exceeded the EPA 50 pCi/L screening level. Natural U-234 and U-238 values in Buckman well No. 2 exceeded the 4-mrem DOE DCGs applicable to drinking water.

Our analytical laboratory (GEL) indicates that the MDA for tritium analysis by liquid scintillation counting lies between about 140 pCi/L and 230 pCi/L, averaging about 200 pCi/L. For 2004, using this analytical method, about 16 groundwater results between 145 and 875 pCi/L are indicated as detections. Parallel analyses at a detection limit of 1 pCi/L provided results of nondetect for many of these samples, suggesting that the GEL MDAs are optimistic.

Seven samples (including a deionized water blank QC sample) produced high values of cesium-137 during 2004. After review, the analytical laboratory qualified these as nondetections.

3. Perchlorate in Groundwater

During the last decade, the EPA has recognized the potential for perchlorate toxicity at concentrations in the ppb range. The California Department of Public Health was instrumental in developing a new analytical method to measure perchlorate concentrations in this range for the first time, using ion chromatography. No EPA regulatory limit exists for perchlorate in drinking water, though several states have set limits in the range of 10 to 20 ppb, and California has a public health goal of 6 ppb. EPA Region VI has established a risk level of 3.7 ppb.

LANL and the New Mexico Environment Department (NMED) DOE Oversight Bureau (DOB) have found perchlorate in most groundwater samples analyzed from across northern New Mexico. The perchlorate concentrations in samples not affected by known contaminant sources range from about nondetect (<0.05 ppb) to 0.85 ppb. This result suggests that perchlorate has widespread occurrence in groundwater at concentrations below 1 ppb. A study reported in *Environmental Science and Technology* (EST 2003) found that perchlorate was present in 73% of 217 public water supply wells across a large portion of northwest Texas, with 35% at levels near or above 4 ppb. The presence of perchlorate did not appear to be related to any known anthropogenic perchlorate sources.

The NMED DOE Oversight Bureau's recent study concluded that a value of 0.6 ppb constituted an upper limit for background for naturally occurring perchlorate in local groundwater samples. Regardless of the merits of this study, the value of 0.6 ppb has some interesting ramifications. Water samples from most LANL locations show low perchlorate concentrations, but samples taken downstream from inactive perchlorate release sites show distinctly higher values. These two groups appear to be separated at about 0.6 ppb.

4. Metals in Groundwater

The occurrence in groundwater samples of most high metals values (compared with regulatory standards) are due to ubiquitous well-sampling-related issues rather than to LANL contamination. In some new LANL characterization wells, the use of fluids to assist well drilling led to temporary effects on chemistry of groundwater samples (Bitner 2004). With varying success, new wells undergo extensive well development to reduce the turbidity of water samples and to remove drilling fluids from the rock formations. Drilling fluid effects on water quality appear to linger longer in multiple completion wells than in single completion wells, as the latter can be developed more vigorously.

Most Pajarito Plateau groundwater is under chemically oxidizing conditions, meaning that free oxygen is dissolved in the water. Addition of organic matter in drilling fluids into the aquifer near a well stimulates bacterial activity, which reduces available oxygen and changes the chemical behavior of several

# 5. Groundwater Monitoring
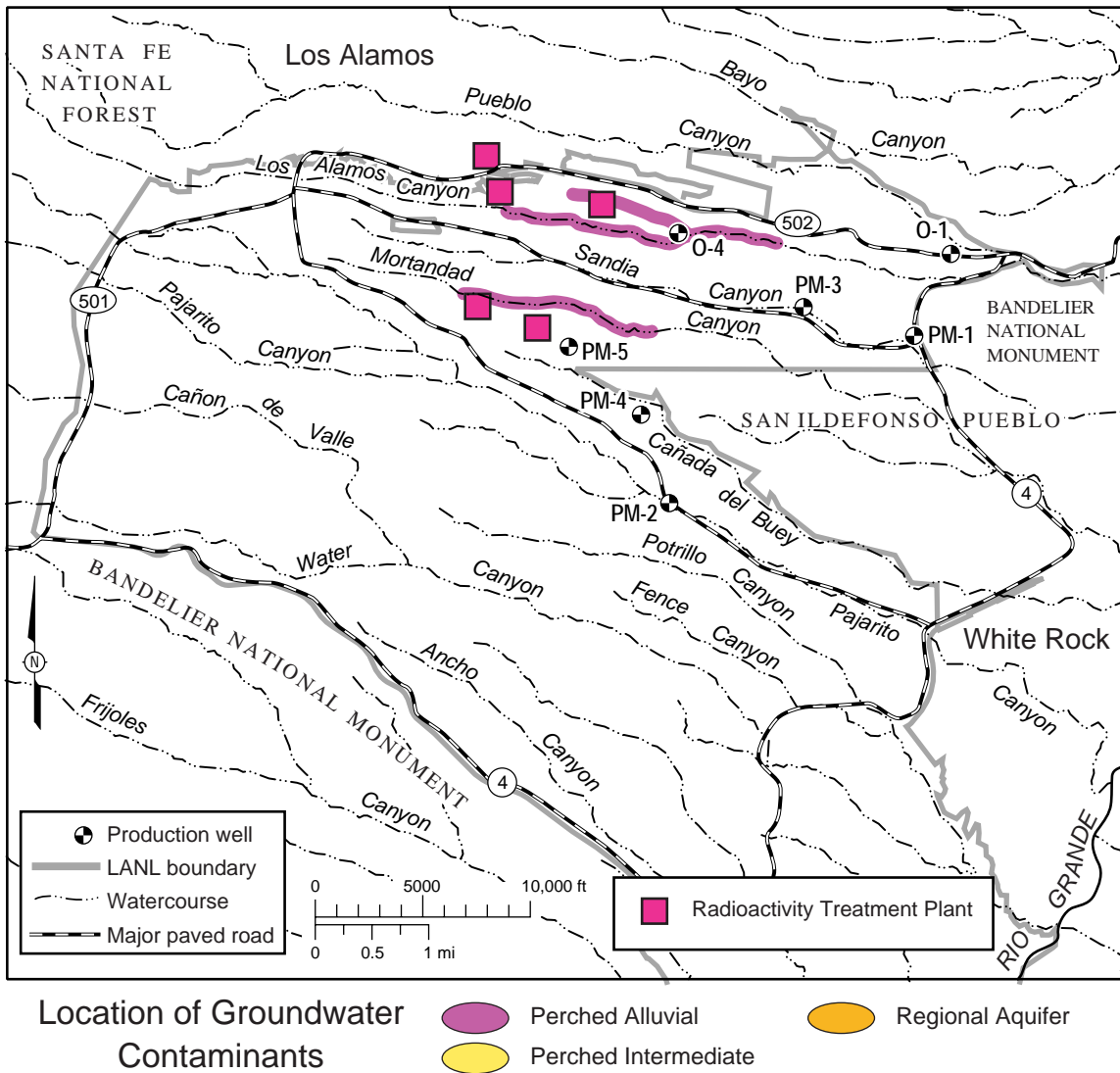
Figure 5-9. Location of groundwater contamination by Sr-90 above the 8 pCi/L EPA MCL. The maximum 2004 values in Mortandad and DP/Los Alamos Canyon alluvial groundwater were 7.6 and 4.6 times the MCL, respectively. Different colors indicate the affected groundwater zones. Along canyons, the extent of alluvial groundwater contamination lateral to the canyon is not to scale: contamination is confined to the alluvium within the canyon bottom and is narrow at the map scale.

constituents found in groundwater and adjacent aquifer material. With reducing conditions (absence of oxygen), the solubility of metals such as manganese and iron increases, and they are dissolved from the surface of minerals that make up the aquifer's rock framework or possibly from well fittings. Several other chemical constituents may also increase or decrease in concentration as a result of the temporary effect of the drilling fluids on the region near the well (Bitner 2004). The unusual presence of nickel, chromium, and other trace metals in samples from new characterization wells is also attributed to the low oxidation state.

In addition to the effect of drilling fluids, well samples may have relatively high turbidity. The presence in water samples of residual aquifer material leads to detection of metals such as aluminum, iron, and manganese, which are primary constituents of the silicate minerals that make up the aquifer framework. These effects of turbidity on water quality (with high values of iron, manganese, and aluminum) are also seen in many samples from alluvial wells and springs (in the case of springs, because of soil material).
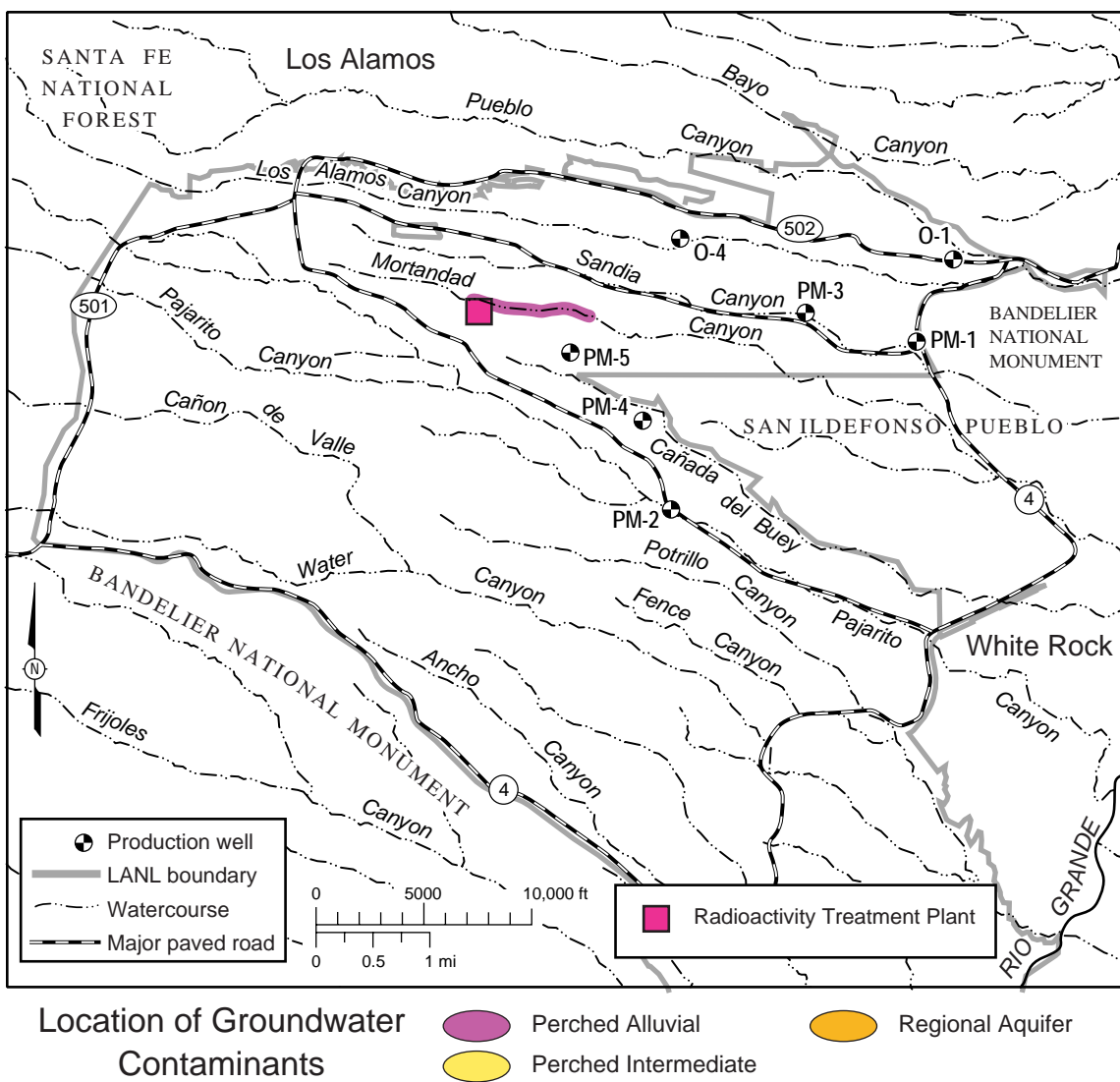
Figure 5-10. Location of groundwater contamination by the sum of Sr-90, Pu-238, Pu-239,240, and Am-241 above the 4-mrem DOE DCG for drinking water. The 2004 maximum values in Mortandad Canyon alluvial groundwater for Sr-90, Pu-238, Pu-239,240, and Am-241 were 1.53, 0.35, 0.35, and 0.47 times the 4-mrem limit, respectively. Different colors indicate the affected groundwater zones.

The older LANL test wells have steel casings and galvanized metal well fittings that are subject to rust and metal flaking. Over time and with wear, corrosion, and work on the wells, water samples have shown increasing content of metals like iron, lead, manganese, and zinc.

A number of groundwater samples have selenium results that exceed the NM Livestock Watering Standard of 5 µg/L. The highest values were in Ancho Spring (9.3 µg/L) and several other regional aquifer wells and springs. The selenium is apparently of natural origin. Selenium concentrations in surface water, for example, increased substantially after the Cerro Grande fire as a result of ash content in the water, but have fallen in recent years.

5. Groundwater Monitoring

F. Groundwater Sampling Results by Watershed

1. Guaje Canyon (includes Rendija and Barrancas Canyons)

Guaje Canyon is a major tributary in the Los Alamos Canyon watershed that heads in the Sierra de los Valles and lies north of Laboratory land. The canyon has not received any effluents from LANL activities. The Guaje well field, located northeast of the Laboratory, contains five water supply wells. No tritium was detected in low-detection-limit (1 pCi/L) analysis of samples from these wells (Table S5-3). Tritium was detected in analyses of the same samples using liquid scintillation (with an MDA of about 200 pCi/L), indicating a lack of precision for that method near the MDA. Groundwater with a tritium activity below approximately 1.6 pCi/L is probably old and isolated from surface recharge. The age of such groundwater is more than 3,000 years, but large dating uncertainties may be associated with small tritium activities (Blake et al., 1995).

G-2A had arsenic at about 20% of the EPA MCL of 50 ppb. For the new MCL of 10 ppb which will be effective in 2006, this value would be 99% of the MCL. Using the LC/MS/MS method, perchlorate was found in each well at concentrations ranging from 0.27 to 0.43 ppb, which is consistent with background levels.

2. Los Alamos Canyon (includes Bayo, Acid, Pueblo, and DP Canyons)

a. Pueblo Canyon. Pueblo Canyon receives effluent from Los Alamos County's Bayo Sewage Treatment Plant. Acid Canyon, a tributary, received radioactive industrial effluent from 1943 to 1964. Little radioactivity shows up in groundwater at this time. Tritium and perchlorate results from regional aquifer groundwater in this canyon may show small but lingering influence of discharges from radioactive wastewater outfalls in Acid Canyon. High nitrate found in groundwater may be due to sanitary effluent from the Los Alamos County Bayo Sewage Treatment Plant.

Eight low-detection-limit tritium results for supply well O-1 averaged 43.9 pCi/L, indicating a subdued effect of past tritium-bearing surface water recharge on tritium activity at the regional aquifer. Eight O-1 samples showed perchlorate at an average of 2.6 ppb using the LC/MS/MS method (Figure 5-11), and O-1 also has above-background nitrate (Figure 5-12). Because of a leaking fuel tank found at Technical Area (TA) -21 during 2002, well O-1 was tested three times for DROs; the DRO compound was found at a low level only in January 2004 but not in other samples, suggesting a false positive.

Test Well 1 (near O-1) showed nitrate (as nitrogen) at 48% of the 10-mg/L EPA MCL in the regional aquifer (Figure 5-12). Past Test Well 1 samples have shown tritium at 277 pCi/L to 360 pCi/L. In 2004, a Test Well 1 sample showed 118 pCi/L, in line with earlier data (and confirming a sample mix-up in 2003). Test Well 1 also had 1.6 ppb of perchlorate. Other low-detection-limit tritium values in Pueblo Canyon included 23 pCi/L in intermediate well POI-4.

Test Well 1 has shown levels of iron, lead, and manganese in the range of the EPA MCLs. These levels were related to aging steel and galvanized well components. Test Well 1 showed high levels of aluminum, iron, manganese, and lead in 2004.

Alluvial well APCO-1 had strontium-90 at 8% of the 8-pCi/L EPA MCL as well as detectable plutonium-239,240 as in prior years. Nitrate (as nitrogen) in this well was 110% of the NM groundwater limit, likely because of sanitary effluent from the Bayo Sewage Treatment Plant. APCO-1 shows the effects of high turbidity by high aluminum and iron, much of these apparently colloidal. This well also has high manganese as well as nitrate, phosphate, fluoride, turbidity, and total suspended solids; the solutes indicating the influence of sanitary effluent from the Bayo Sewage Treatment Plant. Higher organic content of the effluent or the well's location in marshland may result in anoxic groundwater conditions, resulting in higher concentrations of dissolved or colloidal manganese. A sample from Pueblo Canyon alluvial groundwater (APCO-1) had a perchlorate value below 0.6 ppb.

b. Los Alamos Canyon. Los Alamos Canyon received releases of radioactive effluents during the earliest Manhattan Project operations at TA-1 (1942–1945) and until 1993 from nuclear reactors at TA-2. From 1952 to 1986, a liquid-waste treatment plant discharged effluent containing radionuclides from the former plutonium-processing facility at TA-21 into DP Canyon, a tributary to Los Alamos Canyon. Los Alamos Canyon also received radionuclides and metals in discharges from the sanitary sewage lagoons and cooling towers at the Los Alamos Neutron Science Center (LANSCE) at TA-53.
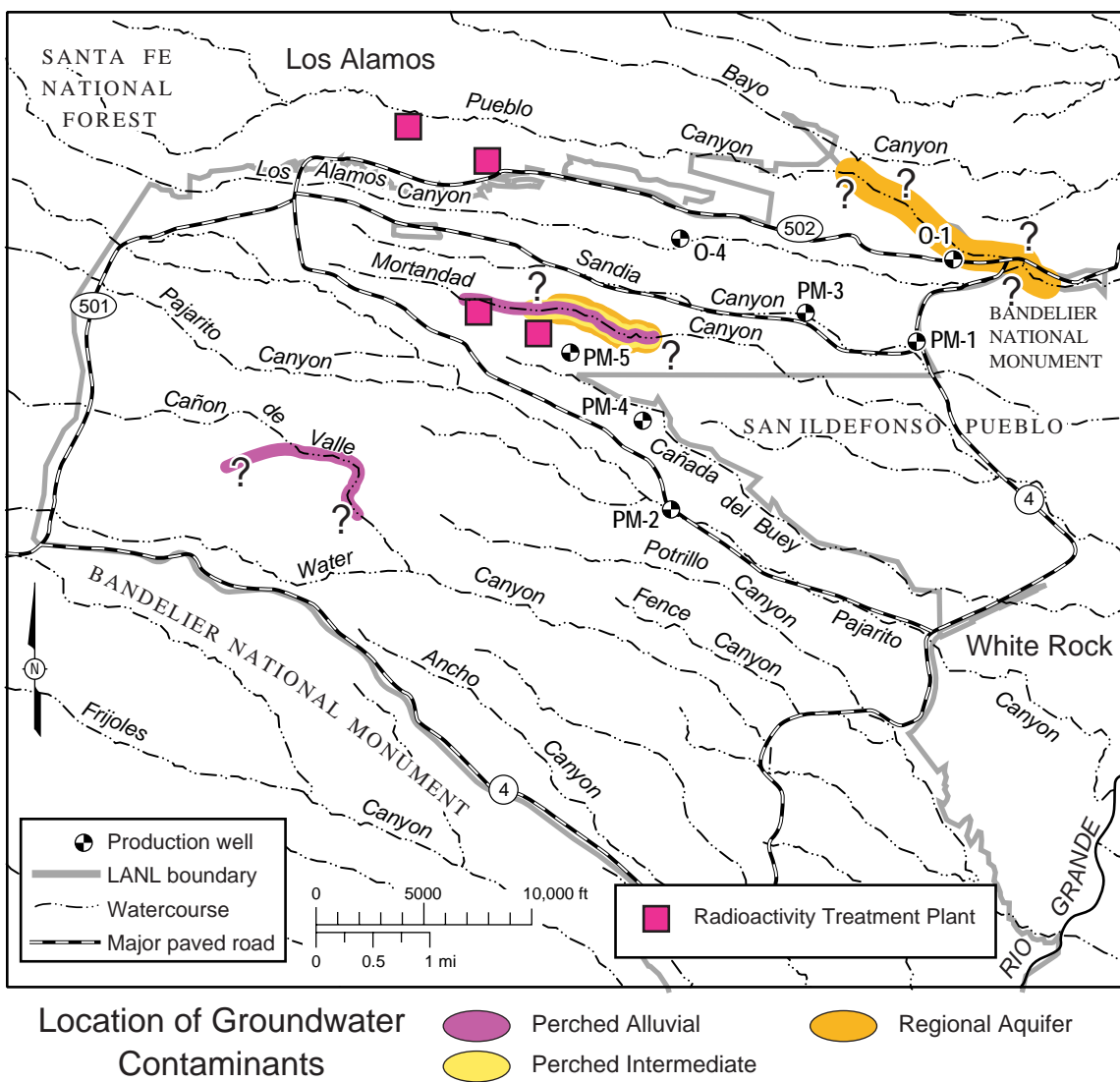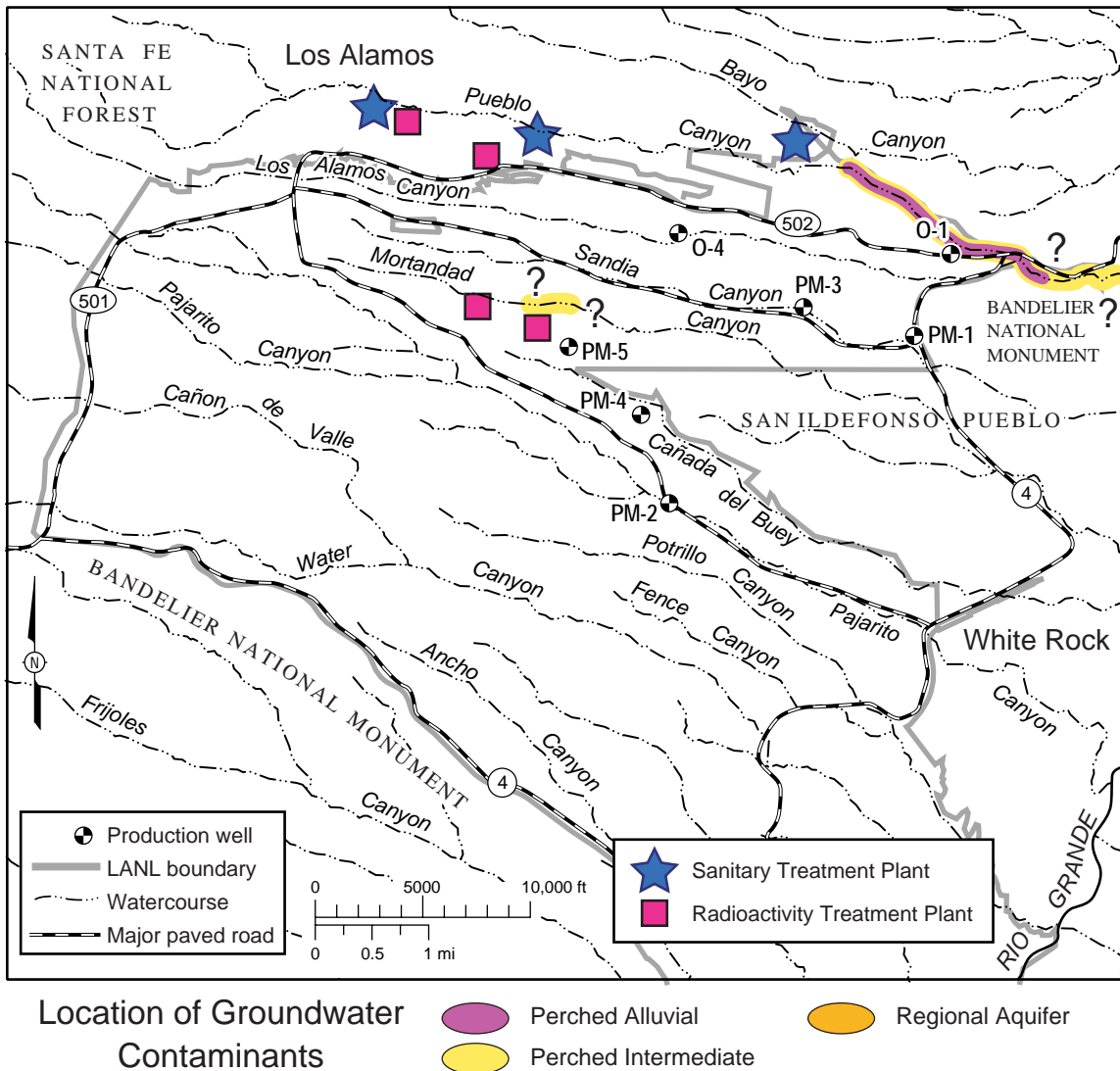
Figure 5-11. Location of groundwater contamination by perchlorate above the 3.7 ppb EPA Region VI risk level. Maximum values in Mortandad Canyon were 99 ppb in alluvial groundwater during 2004 and 142 ppb in intermediate groundwater during 2002. In Pueblo Canyon, regional groundwater the maximum was 3.0 ppb using the LC/MS/MS method. Different colors indicate the affected groundwater zones. The extent of intermediate groundwater and regional aquifer contamination is based on a limited number of wells: question marks on the maps indicate where contaminant extent is inferred, not necessarily substantiated.

Alluvial groundwater in DP and Los Alamos canyons continues to show strontium-90 at up to 4.6 times the 8-pCi/L EPA MCL (Figure 5-9). The strontium-90 value in LAO-3A was also 90% of the 4-mrem DOE DCG for drinking water dose. A few other LANL-derived radionuclides were found in alluvial groundwater at values well below the 4-mrem DCGs.

Tritium levels in alluvial groundwater in these two canyons have fallen sharply since the cessation of discharges. In Los Alamos Canyon alluvial groundwater, low-detection-limit tritium values ranged from 81 pCi/L upstream of the former Omega West Reactor to 208 pCi/L downstream of DP Canyon. Intermediate groundwater values were 8 pCi/L at LAOI(A)-1.1, 250 pCi/L at R-9i, and 48 pCi/L at Basalt Spring. R-9 in the regional aquifer showed 16 pCi/L and O-4 showed 1.5 pCi/L, whereas results from other regional wells (R-7, TW-3, and LA-5) were nondetections. Duplicates, reanalyses, and other samples from O-4 were nondetections.

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Figure 5-12. Location of groundwater contamination by nitrate (as nitrogen) above the 10 mg/L EPA MCL. Maximum values in Mortandad Canyon were 74% of the MCL in alluvial groundwater during 2004 and 132% of the MCL in intermediate groundwater during 2002. In Pueblo Canyon, maximum values in alluvial and intermediate groundwater and the regional aquifer were 116%, 79%, and 48% of the MCL. Pueblo Canyon values have ranged to 100% of the MCL in recent years. Different colors indicate the affected groundwater zones. The extent of intermediate groundwater and regional aquifer contamination is based on a limited number of wells: question marks on the maps indicate where contaminant extent is inferred, not necessarily substantiated.

In Lower Los Alamos Canyon, the maximum nitrate (as nitrogen) value in intermediate groundwater was 79% (Basalt Spring) of the EPA MCL, likely because of sanitary effluent from the Los Alamos County Bayo Sewage Treatment Plant.

In Los Alamos Canyon alluvial groundwater, the perchlorate concentration in LAO-C, which is upstream from most LANL sources, was 0.1 ppb. Values from LAO-2 and LAO-3A range from 0.64 to 0.72 ppb, and may show a residual effect from past discharges that entered DP Canyon from TA-21. A little farther downstream, LAO-4.5C shows 0.25 ppb of perchlorate. Intermediate groundwater values were 0.15

ppb at LAOI(A)-1.1, not detected at R-9i, and 0.7 ppb at Basalt Spring. In the regional aquifer, perchlorate was not detected at R-7 or TW-3, was 0.98 ppb at R-9, and was about 0.37 ppb at O-4 and LA-5.

Metals concentrations in alluvial wells and some intermediate and regional wells in Los Alamos Canyon showed the effect of turbidity, with relatively high values of aluminum and iron. Wells R-7, R-9, and R-9i showed high levels of iron and manganese reflecting lingering influence of drilling fluid on quality of water samples. As with other older monitoring wells, Test Well 3 has high iron, lead, and manganese because of aging steel and galvanized well components. In Los Alamos Canyon, molybdenum in LAO-2 was 105% of the NM Groundwater Limit and in LAO-3A was at 70% of the Limit (Figures 5-13 and 5-14). The molybdenum comes from cooling towers at TA-53 (LANSCE). Use of sodium molybdate was discontinued in June 2002. Molybdenum concentrations in Los Alamos Canyon alluvial groundwater have been quite variable in recent years, perhaps because of large variation in stream flow caused by drought conditions.

No organic compounds other than those related to sampling or analysis artifacts were found in Los Alamos Canyon groundwater samples.

3. Sandia Canyon

Sandia Canyon has a small drainage area that heads at TA-3. The canyon receives water from the cooling tower at the TA-3 power plant. Treated effluents from the TA-46 Sanitary Wastewater Systems (SWWS) Plant are rerouted to Sandia Canyon.

Well R-12 at the eastern Laboratory boundary had low levels of tritium in two intermediate zones (2 to 5 pCi/L) and the regional aquifer (1.6 pCi/L), indicating a slight effect on these horizons by recent recharge. Samples from supply well PM-1 showed no tritium using the 1 pCi/L detection limit. Analyses for some samples from PM-3 detected tritium, whereas reanalyses of those samples and results from other samples were nondetections.

In Sandia Canyon, perchlorate values at R-12 in the regional aquifer were nondetects or just above the MDL. Values in supply wells PM-1 and PM-3 were about 0.42 ppb, similar to prior results.

Several R-12 samples had high iron or manganese (in the range of EPA MCLs), a temporary result of well construction (Longmire 2002b). The supply wells were tested for DROs and for HE; none of these compounds were detected.

4. Mortandad Canyon (includes Ten Site Canyon and Cañada del Buey)

Mortandad Canyon has a small drainage area that heads at TA-3. This drainage area receives inflow from natural precipitation and a number of National Pollutant Discharge Elimination System (NPDES) outfalls, including one from the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50. Past discharges into tributary Ten Site Canyon included a previous radioactive-effluent treatment plant at TA-35.

Cañada del Buey, a tributary to Mortandad Canyon, contains a shallow perched alluvial groundwater system of limited extent, and only two observation wells have ever contained water. Because treated effluent from the Laboratory's SWWS Facility may at some time be discharged into the Cañada del Buey drainage system, a network of five shallow groundwater monitoring wells and two moisture-monitoring holes was installed during the early summer of 1992 within the upper and middle reaches of the drainage. Past discharges included accidental releases from experimental reactors and laboratories at TA-46.

a. 2004 Radioactive Liquid Waste Treatment Facility Discharges. RLWTF's yearly radionuclide discharge data into Mortandad Canyon from 2002 through 2004 appear in Table S5-13 in the Data Supplement. Table S5-13 also shows mean annual levels in effluent for each radionuclide and the ratio of this to the 100-mrem DOE DCG for public dose. Figure 5-15 shows the relationship of RLWTF average annual radionuclide activities and mineral concentrations in discharges to DOE DCGs or New Mexico groundwater standards since 1996. The 2004 discharges from the RLWTF met all DOE and New Mexico requirements. The RLWTF has met all DOE radiological discharge standards for five consecutive years; has met all NPDES requirements for five consecutive years; and has met NM groundwater standards for fluoride, nitrate, and total dissolved solids (TDS) for all but two weeks of the past five years. Two weekly composite samples exceeded the fluoride standard in 2003. A new reverse osmosis and ultrafiltration system began operating at the RLWTF in April 1999. This system removes additional radionuclides from the effluent so that the discharges meet the DOE DCGs for public dose. Americium-241; plutonium-238; and plutonium-239,240 in the discharge have not exceeded the public dose DCGs since December 1999. At

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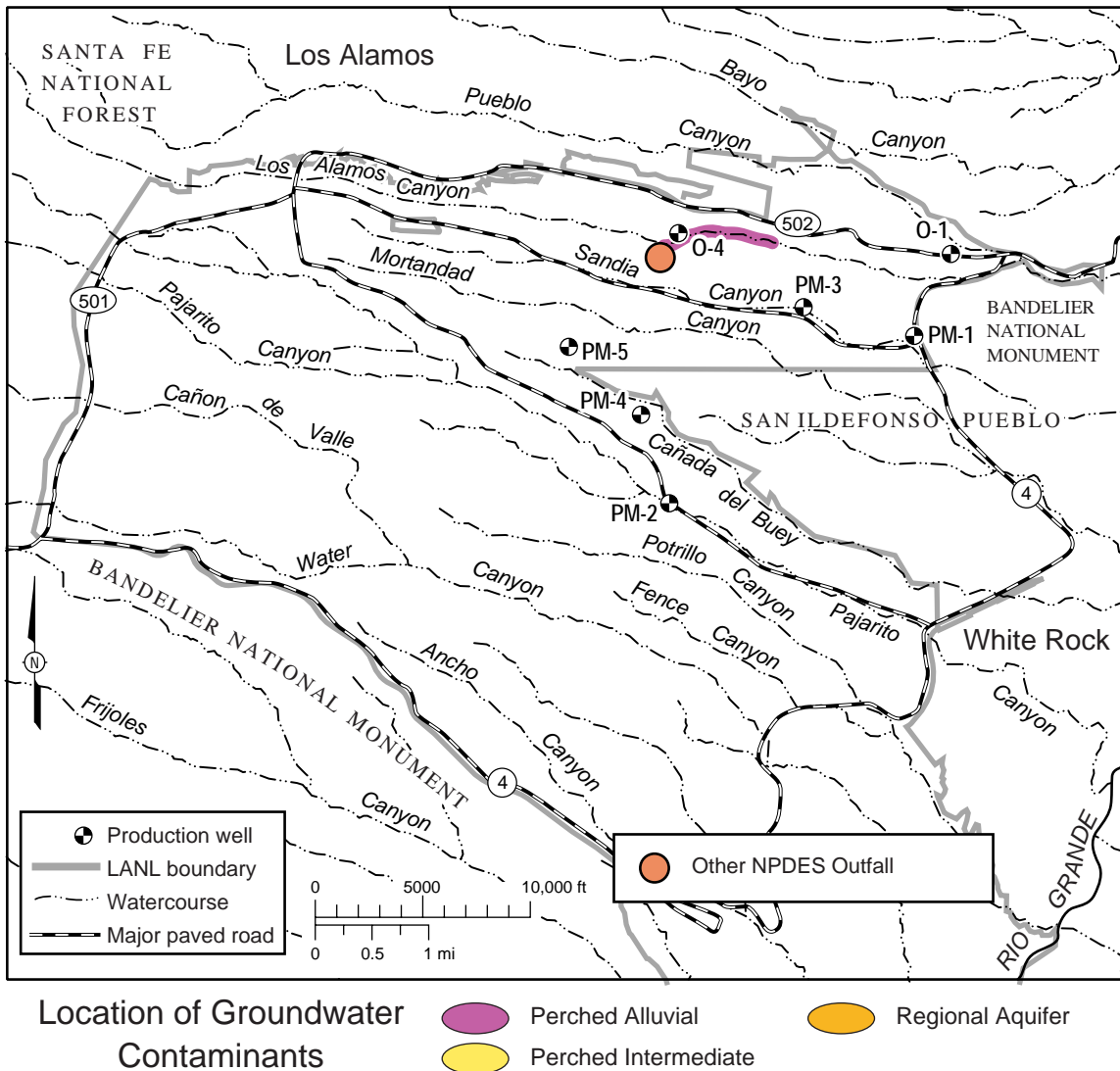
Figure 5-13. Location of groundwater contamination by molybdenum above the 1 mg/L New Mexico Groundwater Standard for Irrigation Use. The maximum 2004 value in Los Alamos Canyon alluvial groundwater was 105% of the groundwater standard. Different colors indicate the affected groundwater zones.

the end of 2000, the RLWTF adopted a voluntary goal to keep tritium activity in its effluent below 20,000 pCi/L. This limit is the EPA MCL and is also 1% of the public dose DCG. Whenever possible, effluent with tritium above 20,000 pCi/L is segregated and trucked to the TA-53 RLWTF evaporation basins for evaporation. Since 2000, tritium activity in the effluent has been below 20,000 pCi/L.

During 2004, the nitrate + nitrite (as nitrogen) concentrations of all effluent discharges from the RLWTF were less than the New Mexico groundwater standard for nitrate (as nitrogen) of 10 mg/L (Figure 5-16). The average 2004 effluent total nitrate + nitrite (as nitrogen) concentration was 4.5 mg/L. In 2004, the nitrate concentration in Mortandad Canyon base-flow grab sample from the surface water station Mortandad below Effluent Canyon was 13.5 mg/L.
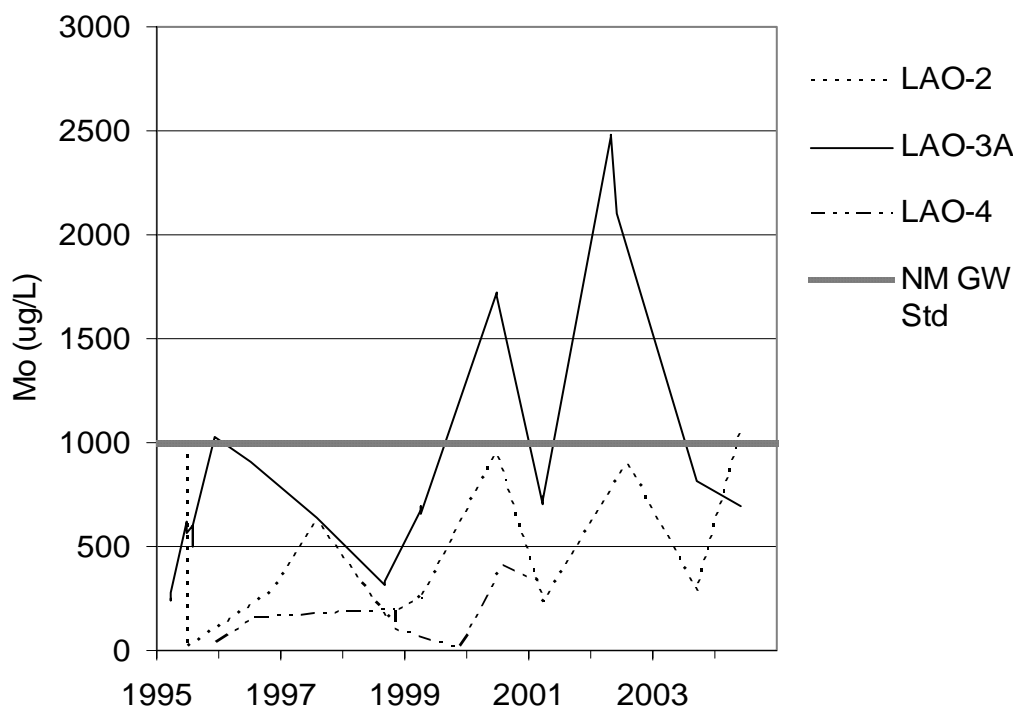
Figure 5-14. Molybdenum histories in Los Alamos Canyon alluvial groundwater compared with the New Mexico groundwater standard.

The fluoride concentration in the discharge has also declined over the last few years. The 2004 effluent fluoride concentration (average value of 0.19 mg/L) was below the New Mexico groundwater standard of 1.6 mg/L. In 2004, the fluoride concentration in Mortandad Canyon at the surface water station Mortandad below Effluent Canyon was 0.44 mg/L.

A system for removing perchlorate from the RLWTF effluent became operational on March 26, 2002; no perchlorate has been detected in the effluent after this date. RLWTF annual perchlorate discharges in 2000, 2001, and 2002 were 4.74 kg, 2.29 kg, and 0.175 kg, respectively. For 2003 and 2004, the annual perchlorate discharge was effectively zero. The resulting annual average effluent concentrations in 2000, 2001, and 2002 were 254 µg/L, 169 µg/L, and 16 µg/L, respectively, with none detected in 2003 or 2004. This low value in TW-8 confirms the long trend for that well and a sample mix-up in 2003. No tritium was detected in R-13.

b. Mortandad Canyon Intermediate Groundwater and Regional Aquifer. The regional aquifer beneath Mortandad Canyon shows a slight impact of past LANL discharges; intermediate groundwater shows a larger effect. Regional aquifer wells TW-8 had 6 pCi/L of tritium, and R-15 averaged 23 pCi/L. Regional aquifer perchlorate values in Test Well 8 and R-13 were 0.35 ppb and 0.40 ppb. Perchlorate in R-15 was around 6 ppb (Figure 5-11), indicating an impact of recharge from shallow groundwater on the regional aquifer (no MCL, EPA Region VI risk level of 3.7 µg/L, which corresponds to HI = 1).

In 2002, initial results from new well MCOBT-4.4, drilled to an intermediate perched zone, showed several contaminants at concentrations of concern (Broxton et al., 2002a). No additional data were collected in 2003 or 2004 because of mechanical problems with the well. Because of well design problems, the well is under evaluation for plugging and abandonment and replacement. In 2002, the 500-ft-deep intermediate perched zone sample found about 13,000 pCi/L of tritium (MCL of 20,000 pCi/L), 13.2 mg/L of nitrate (as nitrogen, MCL 10 mg/L, Figure 5-12), and 142 µg/L of perchlorate (Figure 5-11).

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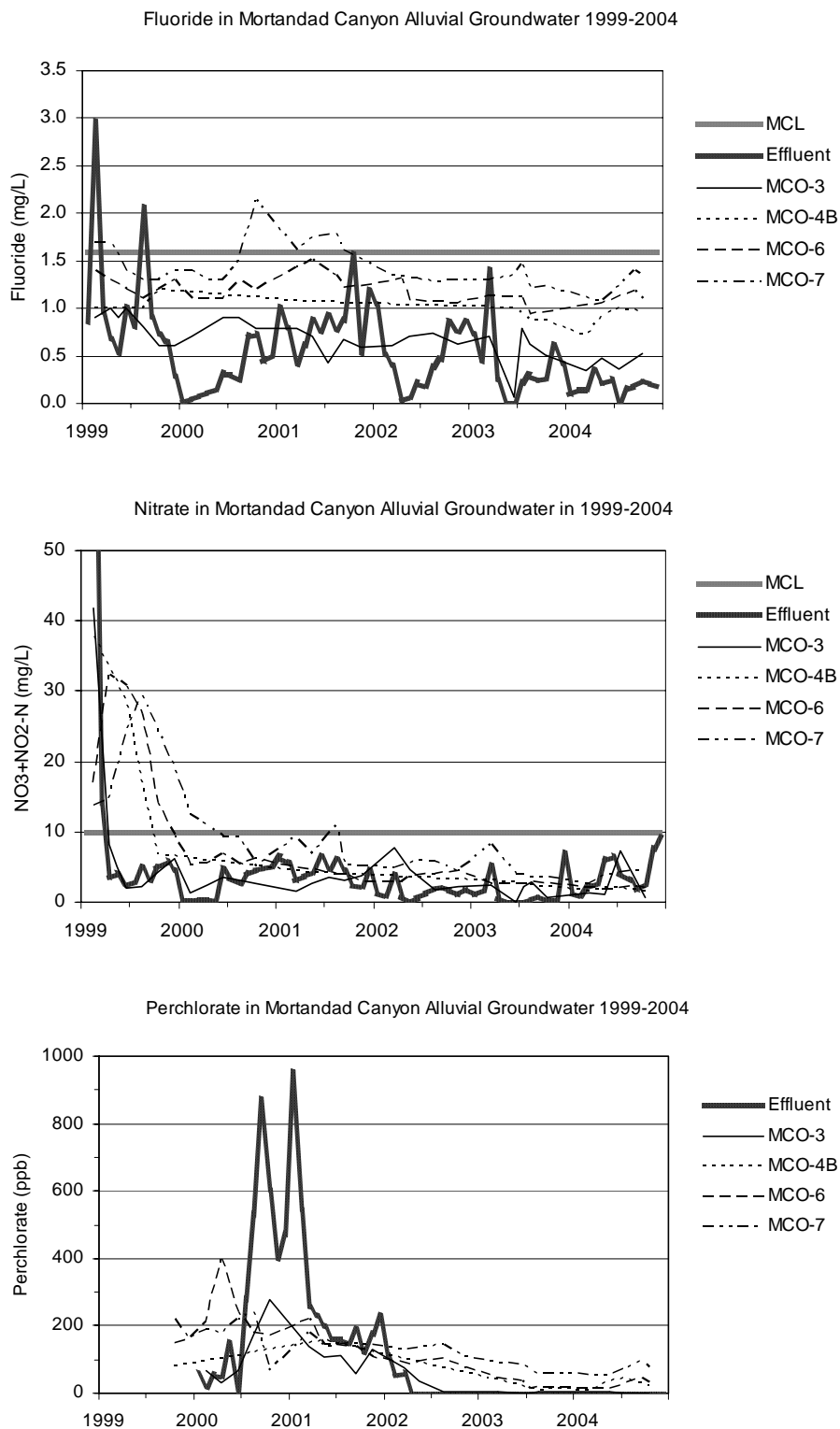### RLWTF Mean Annual Radionuclide Activity Compared to DCG
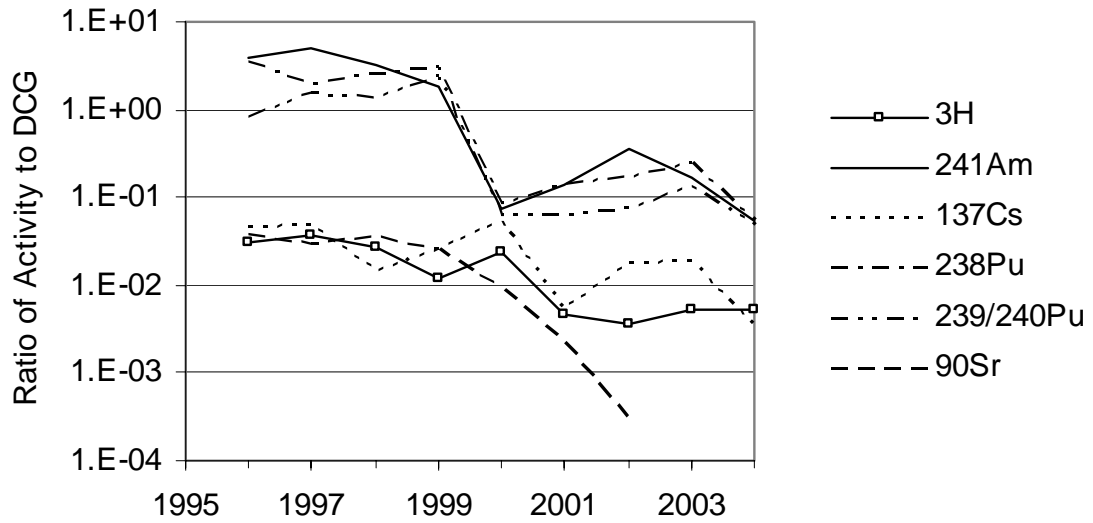
RLWTF Mean Annual Mineral Concentration Compared to Standard
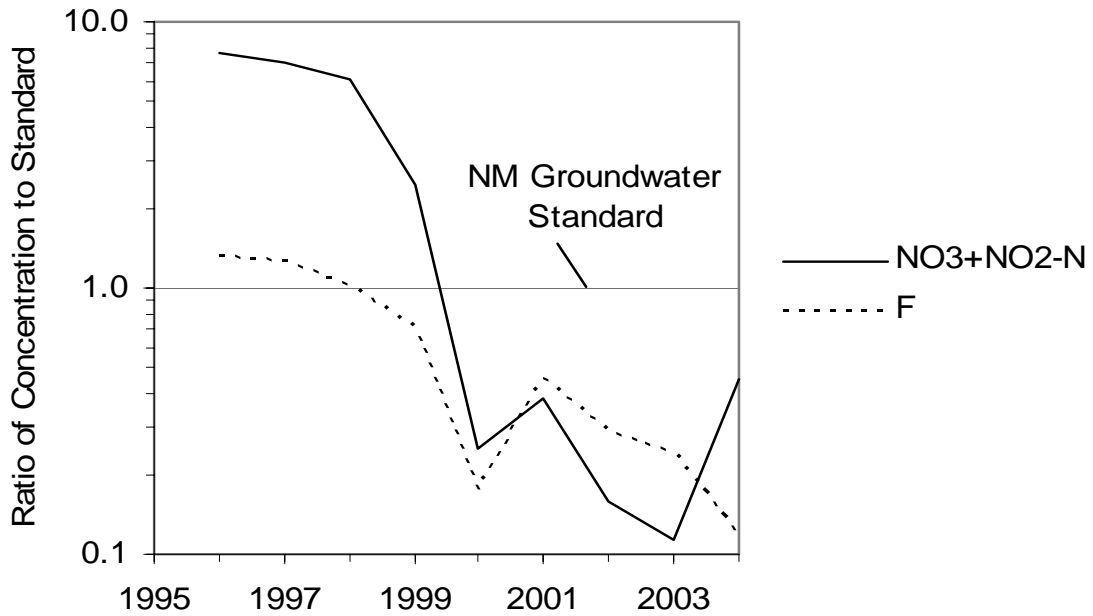
Figure 5-15. Ratio of 1996–2004 average annual radionuclide activity and mineral concentration in RLWTF discharges to the 100-mrem public dose DOE DCGs or New Mexico groundwater standards.

Fluoride in Mortandad Canyon Alluvial Groundwater 1999-2004

Nitrate in Mortandad Canyon Alluvial Groundwater in 1999-2004

Perchlorate in Mortandad Canyon Alluvial Groundwater 1999-2004

Figure 5-16. Fluoride, nitrate, and perchlorate in RLWTF effluent and Mortandad Canyon alluvial groundwater from 1999 through 2004.

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   c. Alluvial Groundwater. Radionuclide levels in Mortandad Canyon alluvial groundwater are, in general, highest nearest to the TA-50 RLWTF outfall at well MCO-3 and decrease down the canyon. Most radionuclides are adsorbed to sediment closer to the outfall. The levels of strontium-90 and gross beta usually exceed EPA drinking water criteria in many of the wells. In past years, the individual levels of strontium-90, plutonium-238, plutonium-239,240, and americium241 have exceeded the 4-mrem DOE drinking water DCGs, but have not recently exceeded the 100-mrem DOE DCGs for public dose for ingestion of environmental water. In 2004, total LANL-derived radioactivity exceeded 4 mrem in Mortandad Canyon alluvial groundwater samples from MCO-3 (the highest, at 2.14 times the 4-mrem DCGs), MCO-4B, MCO-5, and MCO-6 (Figure 5-10).

   In 2004, americium241 at MCO-3 was 47% of the 4-mrem DCG but was 13% of the DCG at MCO-4B and 13% to 20% of the DCG at MCO-5, MCO-6, and MCO-7. Gross beta values ranged from more than 90% to 300% of the EPA screening level in alluvial groundwater samples. Tritium was found at activities ranging from 12% to 20% of the MCL of 20,000 pCi/L. Plutonium-238 and plutonium-239,240 at MCO-3 were each at 35% of the 4-mrem DOE DCGs. Plutonium-238 was also found at MCO-5 at 2% of the 4-mrem DCGs. Strontium-90 at MCO-4B was 1.5 times the DOE DCG and 7.6 times the EPA MCL (Figure 5-9). strontium-90 activity at MCO-3, MCO-5, and MCO-6 also exceeded the DOE DCG and the EPA MCL.

   Under the Laboratory's groundwater discharge plan application for the RLWTF, ENV-WQH collected separate quarterly samples for nitrate, fluoride, perchlorate, and total dissolved solids during 2004 from four alluvial monitoring wells in Mortandad Canyon: MCO-3, MCO-4B, MCO-6, and MCO-7. Nitrate concentrations in Mortandad Canyon alluvial groundwater were below the NMWQCC groundwater nitrate standard of 10 mg/L (as nitrogen; Figure 5-16), and fluoride concentrations were below the NMWQCC groundwater standard of 1.6 mg/L. MCO-3 had nitrate (as nitrogen) at about 74% of the NMWQCC groundwater standard. All of the Mortandad Canyon alluvial groundwater samples had fluoride concentrations ranging from 60% to 90% of the New Mexico groundwater standard. As shown in Figure 5-16, the nitrate (as nitrogen) and fluoride concentrations of effluent discharge from the RLWTF after March 1999 have been less than the New Mexico groundwater standards.
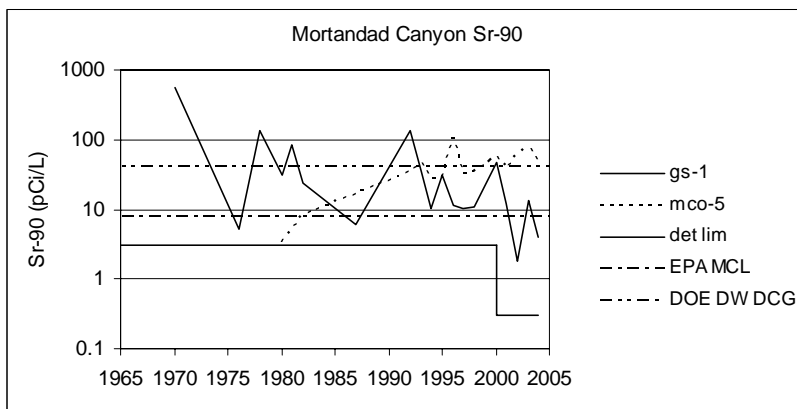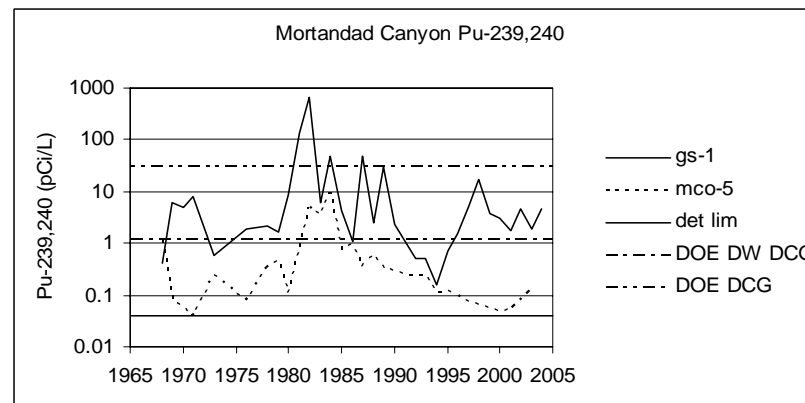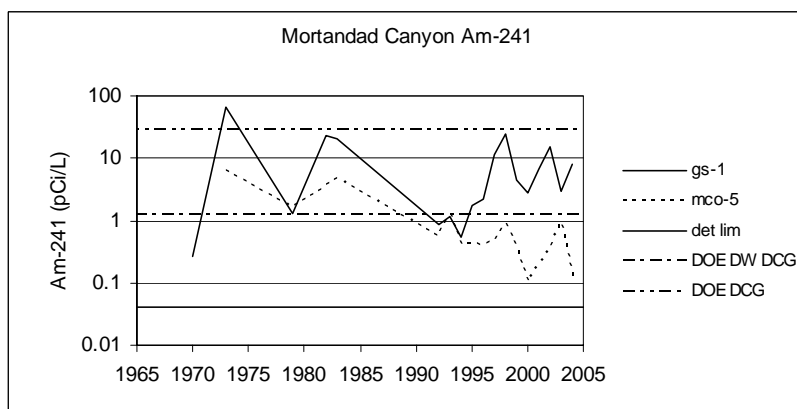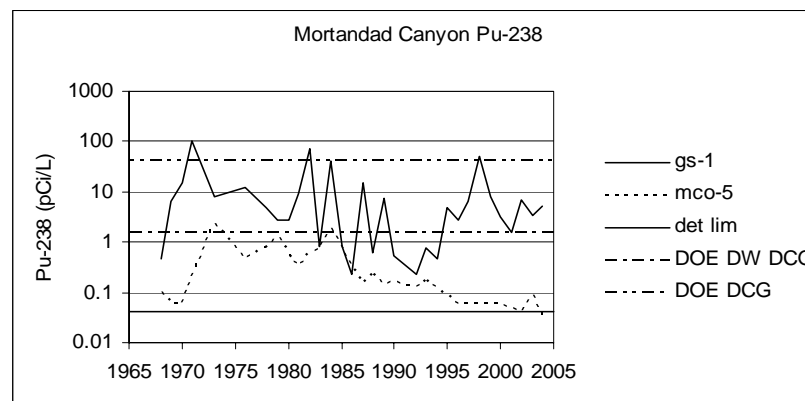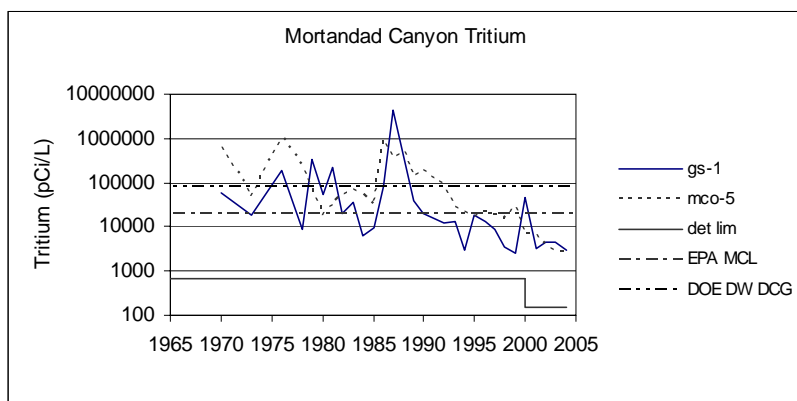
   Mortandad Canyon alluvial groundwater samples had the highest perchlorate concentrations found at LANL (Figures 5-11 and 5-16). Alluvial groundwater concentrations of perchlorate have dropped following the reduction of perchlorate in RLWTF effluent in March 2002, especially nearest the outfall. The recent concentrations at MCO-3 were up to 5 ppb. Perchlorate concentration generally increased downstream, from 8 to 43 ppb at MCO-4B, and 52 to 99 ppb at MCO-7. As with nitrate and fluoride, the decrease over time of perchlorate near the outfall and downstream indicates that the concentrations in alluvial groundwater are decreasing in response to improved effluent quality. For organic analyses, only dichlorobenzene[1,4-] and dichlorobenzene[1,3-] were found in samples from MCO-3 at values less than 1% of EPA MCLs.

   d. Long-Term Radioactivity Trends. Figure 5-17 depicts long-term trends of radionuclide concentrations in surface water and shallow perched alluvial groundwater in Mortandad Canyon downstream from the RLWTF outfall at TA-50. The figure shows only radionuclide detections. If more than one sample was collected in a year, the average value for the year is plotted. The surface water samples are from the station Mortandad Below Effluent Canyon (GS-1), a short distance downstream from the outfall. Radioactivity levels at this station vary daily depending on how soon individual samples are collected after a release from the RLWTF. These samples also vary in response to changing amounts of runoff from other sources in the drainage.
The groundwater samples are from observation well MCO-5 in the middle reach of the canyon. Groundwater radioactivity at MCO-5 is more stable than surface water sampled at station Mortandad Below Effluent Canyon because groundwater responds more slowly to variations in runoff water quality. Because of its strong adsorption to sediments, cesium-137 is not detected in groundwater samples.

   Chemical reactions such as adsorption do not delay tritium transport, so tritium activity is usually relatively uniform throughout the alluvial groundwater. Tritium activities within the Mortandad Canyon alluvial groundwater have been below the EPA MCL since 2001 (Figure 5-17). Average annual tritium activity in the RLWTF effluent dropped below 20,000 pCi/L in 2001, and tritium activity has dropped in surface water and alluvial groundwater since then.

Mortandad Canyon Tritium

Mortandad Canyon Am-241

Mortandad Canyon Sr-90

Mortandad Canyon Pu-238

Mortandad Canyon Pu-239,240

Figure 5-17. Average annual radioactivity in Mortandad Canyon surface water and alluvial groundwater.

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Before 1990, americium241 activity was not measured regularly at monitoring stations in Mortandad Canyon. For most years up to 1999, the americium241 activity of RLWTF discharges exceeded the 100-mrem DOE DCG for public dose of 30 pCi/L. In the last few years, americium241 in surface water nearest the outfall has been just below the 100-mrem DOE DCG, whereas in the groundwater it is closer to the 4-mrem DCG. americium241 in alluvial groundwater downstream at MCO-5 has been below the 4-mrem DOE DCG.

In 2004, strontium-90 was detected in surface water at Mortandad below Effluent Canyon and in all alluvial groundwater observation wells down to MCO-7. The strontium-90 activities remain at values in the range of the EPA drinking water standard (8 pCi/L) and the 4-mrem DOE DCG for drinking water (40 pCi/L). It appears that strontium-90 has been retained by cation exchange within the upstream portion of the alluvium. The level of strontium-90 has risen gradually at downstream wells MCO-5 and MCO-6 during the last 20 years, suggesting that the mass of the radionuclide is moving slowly downstream.

Both plutonium isotopes were detected at Mortandad below Effluent Canyon and at MCO-3, with only plutonium-238 detected at MCO-5 in 2004. Both isotopes have been historically detected at Mortandad below Effluent Canyon and at MCO-3 at levels near the 100-mrem DOE public dose DCGs (30 pCi/L for plutonium-239,240 and 40 pCi/L for plutonium-238), but the levels have decreased during the past few years. Values at other alluvial observation wells, except for MCO-4 and MCO-7.5, were near the detection limit in the 1990s. Plutonium has, in general, been detected in all alluvial observation wells in Mortandad Canyon but appears to be decreasing in activity at downstream locations.

e. Cañada del Buey. Water supply wells PM-4 and PM-5 are on the mesa top just south of Cañada del Buey. PM-4 did not operate much during 2004 and had no sample events. Analyses for some samples from PM-5 detected tritium, although reanalyses of those samples and results from other samples were nondetections. Six analyses for perchlorate in samples from PM-5 had an average concentration of 0.34 ppb, similar to earlier results and to other supply wells in northern New Mexico. No HE compounds were detected in samples from these wells.

No alluvial wells were sampled in Cañada del Buey in 2004 because of lack of water in the alluvium.

5. Pajarito Canyon (Includes Twomile and Threemile Canyons)

Pajarito Canyon has a drainage that extends into the Sierra de los Valles west of the Laboratory. In lower Pajarito Canyon near the eastern Laboratory boundary, saturated alluvium occurs but does not extend beyond that boundary. In the past, the Laboratory released wastewater into tributaries of Pajarito Canyon from several HE-processing sites at TA-9. Some firing sites border portions of Twomile and Threemile canyons. A nuclear materials experimental facility occupies the floor of Pajarito Canyon at TA-18. Waste management areas used for disposal of organic solvents and low-level radioactive waste occupy the mesa north of the lower part of the canyon.

In 2004, PM-2 did not have tritium detectable by the low-detection-limit method (MDA about 1 pCi/L). Six perchlorate analyses had an average concentration of 0.29 ppb, similar to prior data. No HE compounds were detected in the well.

Regional aquifer well R-22 lies just east of MDA G, the low-level radioactive waste management facility. In 2004, R-22 showed tritium at 2–3 pCi/L in the uppermost of five regional aquifer ports. These results are consistent with previous sampling observations. Prior sampling found tritium at 13 pCi/L in the deepest port, which was not sampled in 2004. Perchlorate was not detected in ports 1 and 4, and concentrations in ports 2 and 3 were 0.32 ppb and 0.21 ppb.

Of the seven sampled ports of monitoring well R-19, the upper port is dry, the second port is within an intermediate perched zone, and the remaining five ports are in the regional aquifer. The perchlorate concentration in the intermediate port was 0.30 ppb. Concentrations of perchlorate in the upper two regional aquifer ports were about 0.25 ppb, and 0.06 ppb were detected in the deepest regional aquifer port. These values indicate no influence of recent groundwater recharge on water samples, consistent with other R-19 data.

High concentrations of iron and manganese (in the range of EPA MCLs) in R-19 and R-22 are a temporary effect of well construction (Longmire 2002c, 2002d). Samples from two ports in R-19 found bromoform and phthalate compounds at low concentrations; the latter are common contaminants from sampling and analysis processes. In R-22, sampling for volatile organic compounds and semivolatile organic compounds again found isopropyl benzene, in port 1. This compound was found in port 1 during

the third and fourth characterization sampling rounds and in port 5 on the fourth round. Isopropyl benzene may be a temporary result of drilling fluids used (Longmire and Goff 2002). Phthalate compounds were also found in some samples.

ENV-WQH personnel sampled six springs in the Upper Pajarito Canyon drainage. TA-18 Spring is an alluvial spring, and PC, Homestead, Starmer, Keiling, and Bulldog Springs are fed by intermediate depth groundwater from within adjacent mesas. PC Spring lies west of LANL in the Sierra de los Valles, so likely reflects background conditions. These intermediate springs mainly issue along canyon sides above adjacent streams. No LANL-derived radioactivity was found in these spring samples. Four of the springs had perchlorate concentrations between 0.15 ppb and 0.25 ppb, but Keiling and Bulldog Springs had perchlorate concentrations of 0.86 ppb and 1.09 ppb. All of the springs showed some of the metals (aluminum, iron, manganese) reflecting high turbidity, and several had background selenium above the NM Wildlife Habitat standard. Three springs showed traces of acetone (no regulatory standard). Bulldog Spring samples contained HMX and RDX, the latter at 83% of the EPA tap water screening level of 6.1 µg/L (corresponding to 10^{-5} excess cancer risk).

No alluvial wells were sampled in Pajarito Canyon in 2004 because of lack of water in the alluvium.

### 6. Water Canyon (Includes Cañon de Valle, Potrillo and Fence, Indio Canyons)

Water Canyon and Cañon de Valle (a tributary) pass through the southern portion of LANL where the Laboratory conducts explosives development and testing. In the past, the Laboratory released wastewater into both canyons from several HE-processing sites in TA-16 and TA-9. In 1997, the Laboratory consolidated these individual NPDES outfalls into one outfall, the High Explosives Wastewater Treatment Facility. Alluvial groundwater in Cañon de Valle shows barium above 1 mg/L, the New Mexico groundwater standard (Figure 5-18), and RDX above 6.1 ppb, an EPA risk-based tap water screening level that corresponds to a 10^{-5} excess cancer risk. Intermediate perched groundwater in this area also shows RDX above 6.1 ppb (Figure 5-19). The Potrillo, Fence, and Indio canyon watersheds contain several open-burning/open-detonation and firing sites used for open-air testing of weapons systems.

R-25, located down-gradient from a former HE wastewater outfall, has four ports in a large intermediate perched zone and four in the regional aquifer (Broxton et al., 2002b). Port 5 at a depth of 1,309 ft is the uppermost regional aquifer port. The intermediate port at 1,063 ft only yielded water during the first of 4 characterization sampling events. The Laboratory completed installation of the well casing in May 1999, and installed the Westbay packer system in October 2000. During the intervening 17 months, the well casing stayed open, allowing commingling of water between the eight screens. This mixing of water from different groundwater zones temporarily obscured the original water quality differences between the zones. Several key constituents (tritium, chlorinated solvents, and HE compounds) apparently were introduced into regional aquifer screens during the 17 months before packer installation. Concentration histories now available for six or seven sampling episodes from the ports indicate that concentrations for these analytes have decreased or stabilized over time. These sampling results indicate that several of these constituents are present in the regional aquifer only at very low levels, if at all.

Four main constituents of concern were found in intermediate and regional aquifer samples at some time during sampling of R-25 (ESP 2002; Longmire 2005). Two constituents were the HE compounds RDX and TNT, and two were the organic chlorinated solvents tetrachloroethene (tetrachloroethylene, perchloroethylene or PERC) and trichloroethene (or trichloroethylene or TCE). Samples collected in 2004 from the uppermost intermediate port showed several of these constituents at concentrations near EPA MCLs or EPA Region VI tap water screening levels. None of the four compounds was detected in samples from the uppermost regional aquifer port in 2004.

Tritium histories for the ports indicate that tritium activities in the intermediate perched zone (ports at depths 754 ft to 1,192 ft) have stabilized at values ranging from 30 pCi/L to 55 pCi/L (ESP 2004). This result suggests that groundwater mixing during well construction no longer affects tritium activity in the groundwater surrounding these ports. The tritium activity in the uppermost regional port at 1,309 ft has stabilized at approximately 15 pCi/L, and activities in the deepest three regional aquifer ports have continued to fall toward background values. The tritium activity in the intermediate and uppermost regional ports show the effect of past recharge from surface water and the overlying intermediate perched groundwater, whereas deeper regional ports appear to be isolated from surface recharge originating near
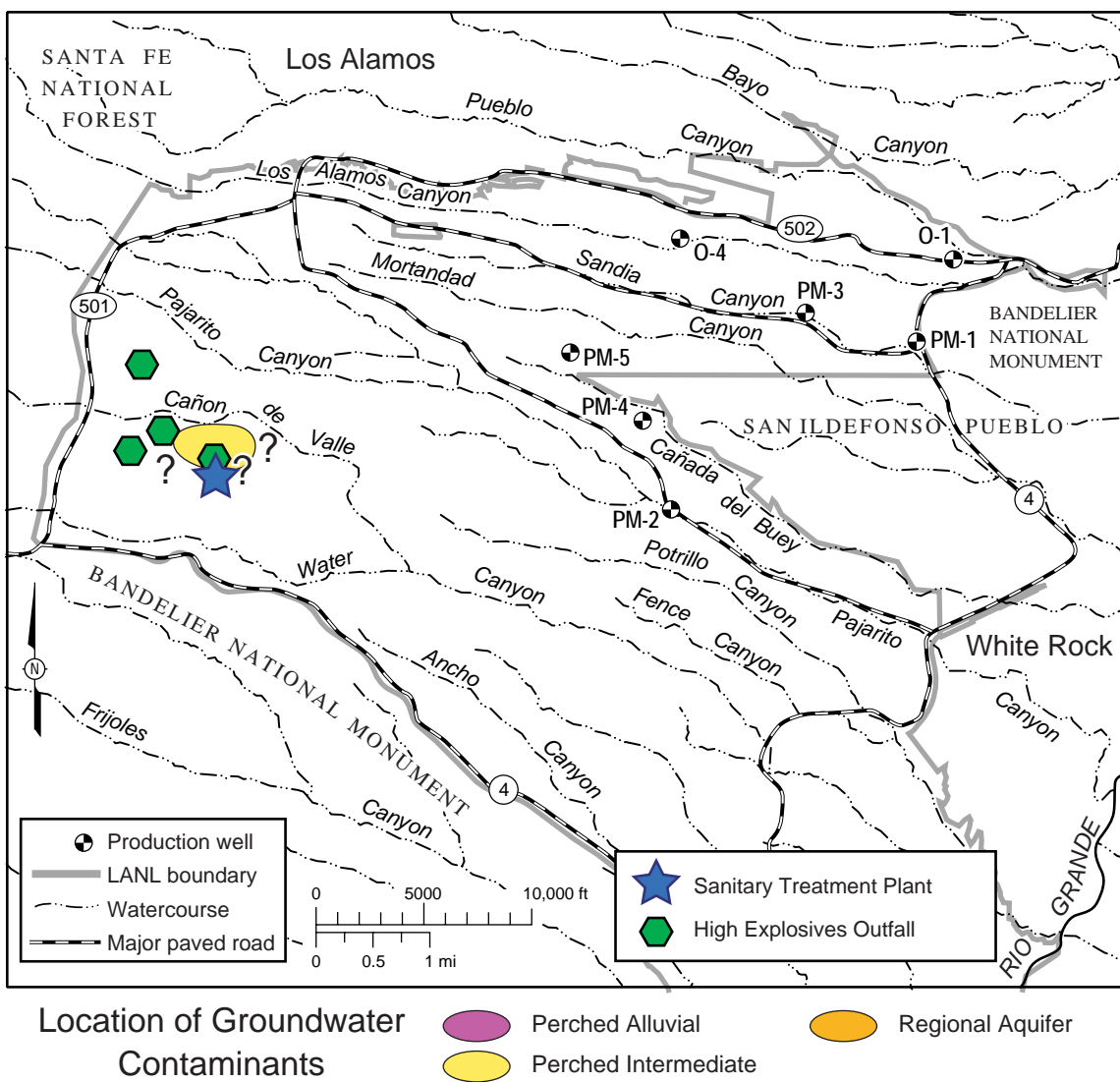
5. Groundwater Monitoring
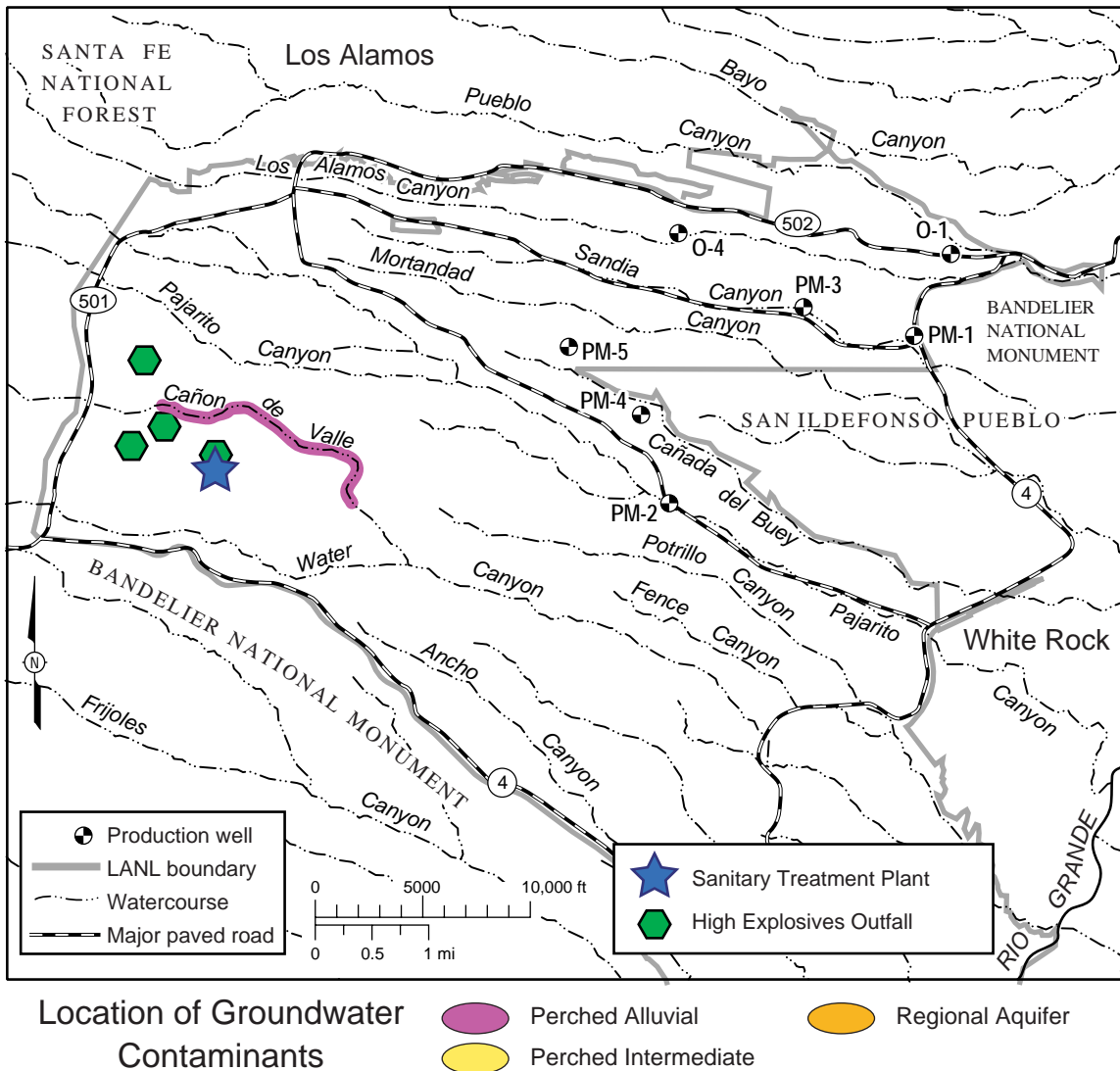
Figure 5-18. Location of groundwater contamination by RDX above the EPA Region VI screening level of 6.1 ppb and barium above the New Mexico groundwater standard of 1 mg/L in perched alluvial groundwater. This map is based on data obtained by the Environmental Restoration Project. Different colors indicate the affected groundwater zones.

this location. In 2004, R-25 samples showed 42 pCi/L of tritium at the uppermost intermediate port at 754 ft and about 16 pCi/L at 1303 ft in the uppermost regional aquifer port, in line with recent values.

RDX occurs in the upper port of the intermediate perched zone at an average concentration of 50 µg/L (44 µg/L in 2004), compared with an EPA tap water screening level of 6.1 µg/L. Concentrations of RDX at other ports have declined to about 1 µg/L or are nondetectable. The concentration histories suggest that RDX is present in large amounts only in perched intermediate groundwater near the upper port and was introduced into the other ports by groundwater mixing during well construction. No HE compounds were detected in the uppermost regional port in 2004. TNT concentration histories lead to a similar conclusion: TNT is present in the upper intermediate perched zone port at an average concentration of about 3 µg/L, compared with an EPA tap water screening level of 22.4 µg/L. Concentrations (where detected) in regional

Figure 5-19. Location of groundwater contamination by RDX above the EPA Region VI screening level of 6.1 ppb in perched intermediate groundwater. Maximum 2004 values for RDX in intermediate groundwater at well R-25 were seven times the 6.1 ppb EPA Region VI 10-5 excess cancer risk screening level. Different colors indicate the affected groundwater zones.

aquifer ports are steadily decreasing. HMX was also detected in the uppermost intermediate port, but at concentrations far below screening levels.

Two chlorinated solvents, PERC and TCE, were found in samples from several ports at R-25 throughout their sampling history. PERC and TCE were only found in the uppermost intermediate port in 2004, and not in the uppermost regional aquifer port. The analytical results for PERC and TCE indicate that the chlorinated solvents are present near or above screening levels and at 30% to 40% of the MCL. Both solvents have EPA MCLs of 5 µg/L.

The upper intermediate port at R-25 had perchlorate at about 0.6 ppb; none was detected at the top of the regional aquifer. Several R-25 ports have showed high levels of iron and manganese (relative to EPA MCLs), a temporary effect of well construction found in other recently drilled wells (Longmire 2002d). Nickel and chromium have occurred at levels above EPA MCLs, possibly another temporary effect of well construction.

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7. Ancho Canyon

Area AB at TA-49 was the site of underground nuclear weapons component testing from 1959 to 1961 (Purtymun and Stoker 1987; ESP 1988). The tests involved HEs and fissionable material insufficient to produce a nuclear reaction. In 1960, the US Geological Survey drilled three deep wells to monitor regional aquifer water quality. Perchlorate levels in the three wells ranged from 0.17 ppb to 0.25 ppb. Aluminum, iron, and manganese (related to aging well casings or to turbidity) often exceed regulatory standards in these wells. In 2004, only iron in DT-5A and manganese in DT-10 were at such levels. One PCB detection and several phthalate detections occurred in these wells in 2004 and are likely sampling or analytical artifacts.

8. White Rock Canyon Springs

The springs that issue along the Rio Grande in White Rock Canyon represent the principal discharge of regional aquifer groundwater that flows underneath the Laboratory (Purtymun et al., 1980). A few springs such as Spring 2B appear to represent discharge of perched groundwater; in the case of Spring 2B, it is supplied by municipal sanitary effluent discharge near White Rock. The springs serve as boundary monitoring points for evaluating the Laboratory's impact on the regional aquifer and the Rio Grande. Other than tritium near background or precipitation levels, the only radionuclide detection in White Rock Canyon springs was uranium in La Mesita Spring. Naturally occurring uranium is commonly detected in La Mesita Spring.

We were unable to sample a number of springs in 2004 because they lacked sufficient flow. Samples from several springs were analyzed using the low-detection-limit tritium method. Except where impacted by effluent discharge, activities of tritium in the regional aquifer in other parts of the Laboratory range from nondetection to between 1 and 3 pCi/L. Tritium concentrations in northern New Mexico surface water and rainwater range from 30 to 50 pCi/L. Rainfall around the Laboratory may have higher tritium activity because of atmospheric tritium releases (Adams et al., 1995). Most of the springs had tritium values ranging between nondetection (less than about 1 pCi/L) and 2 pCi/L. Three springs (Springs 2, 5A, and 6) had detections in some analyses or samples but not in duplicate samples or reanalyses: these values are near the detection limit. Three springs (4, 4B, and 4C) issue within a few hundred feet of each other near the Rio Grande. In 2002, Spring 4B had tritium values near 45 pCi/L, whereas the other two springs had tritium values near 10 pCi/L. Spring 4B has a low flow rate, and all the spring samples may be affected to some degree by rainfall. The largest spring in the area, Spring 4A, had a nondetect for tritium during 2002. The 2003 low-detection-limit tritium results for the springs were similar to earlier data; only Spring 4 was analyzed in 2004, and the result of near 10 pCi/L was similar to prior data.

Many of the springs were sampled for perchlorate in 2004. The results ranged from nondetection (<0.05 ppb) to 0.85 ppb. Of 41 analyses for 23 sampled springs, the average and standard deviation of the results (including detection limit for nondetections) were 0.39 ppb and 0.19 ppb. The perchlorate values found in the springs appear to relate to the geologic setting where they discharge. Most of the springs discharge from one of two geologic units: the Tesuque Formation and the Totavi Lentil (the lower part of the Puye Formation) (Purtymun et al., 1980). The Tesuque Formation consists of sandstones, siltstones, and interbedded basalts. The Totavi Lentil is a channel fill deposit made up of grain sizes ranging from gravel to boulders.

Purtymun (1980) divided the springs into four groups based on geologic unit and chemistry. Most of the sampled springs are in groups I and II. Group I springs discharge from the Totavi Lentil on the west side of the river. These springs follow the outcrop of the Totavi Lentil, increasing their elevation above the river in a downstream direction. In 2004, perchlorate concentrations for the group I springs (Sandia Spring, Spring 3 series, 4 series, Spring 5) averaged 0.47 ppb. Group II springs discharge from coarse-grained Tesuque Formation sediments on both sides of the river. For the group II springs (Springs 5A, 6, 6A, 8A, 9, 9A, Doe Spring), perchlorate concentrations averaged 0.27 ppb. Group III Springs 1 and 2 had 0.29 ppb and a nondetect, respectively. Other springs were quite variable, with group IV springs east of the river having a nondetect (Ancha Spring) and the highest value of 0.85 ppb (La Mesita Spring). Sacred Spring, north of Los Alamos Canyon, had 0.15 ppb.

Spring 2 contained fluoride at 74% of the New Mexico groundwater standard and arsenic at 50% of the EPA MCL of 50 ppb. The fluoride and arsenic occur naturally in springs and wells in the area. Spring 4A

had a high selenium value (compared with the New Mexico wildlife habitat surface water standard), but a duplicate filtered analysis and several unfiltered analyses did not find selenium at a detection limit of half that result value. A similar case applied to a selenium value at La Mesita Spring.

No organic compounds detections other than in QC samples or of common analytical or sampling-related contaminants were found in spring samples, supporting the conclusion that detections in prior years resulted from inadvertent sample or analytical contamination.

9. San Ildefonso Pueblo

The groundwater data for San Ildefonso Pueblo indicate the widespread presence of naturally occurring uranium at levels approaching the EPA MCL of 30 µg/L (effective 12/08/03). Naturally occurring uranium concentrations near the EPA MCL are prevalent in well water throughout the Pojoaque area and San Ildefonso Pueblo. The high gross alpha readings for these wells are related to uranium occurrence. In 2004, Westside Artesian well had the highest total uranium of 24 µg/L, and New Community well and Black Mesa well had 13.5 µg/L. These measurements are consistent with previous samples.

The U-234 value in Westside Artesian well exceeded half the 4-mrem DOE DCG for drinking water. The gross alpha values in these wells were below the EPA primary drinking water standard of 15 pCi/L.

Strontium-90 seemed to be detected in Westside Artesian Well, Pajarito Well Pump 1, and New Community Well, but was not found in a sample duplicate or a reanalysis, indicating the results were false positives.

Several of the San Ildefonso Pueblo wells have levels of sodium, chloride, fluoride, and total dissolved solids near or above New Mexico groundwater standards or EPA health advisory levels. Perchlorate concentrations in these wells ranged from not detected to 0.6 ppb.

The boron value in the Westside Artesian well was 220% of the NMWQCC groundwater standard of 750 µg/L. This value was similar to the values of past years. Boron in Pajarito Well Pump 1 was 140% of the NM standard. The J. Martinez House well had arsenic at about 22% of the EPA MCL of 50 ppb. Other than sample issues mentioned in the introduction, no organic compounds were found in San Ildefonso Pueblo well samples.

10. Buckman Well Field

In 2004, ENV-WQH sampled three wells in the City of Santa Fe's Buckman Field for radionuclides and general inorganic chemistry constituents, with two rounds of samples for strontium-90, perchlorate, tritium, and HEs.

One sample from Buckman well No. 2 contained about 18 µg/L of uranium compared with a prior value in 2003 of 111 µg/L and compared with the EPA MCL of 30 µg/L. Earlier values were in the range of the 2003 result (and much less than the 2002 value of 248 µg/L) obtained for that well. Buckman No. 1 had 6 µg/L of uranium and Buckman No. 8 had 16 µg/L.

The gross alpha levels in these wells are attributable to the presence of uranium and were near or above the EPA primary drinking-water standard of 15 pCi/L. The EPA MCL for gross alpha, however, does not include the contribution to gross alpha by radon or uranium. The U-234 values in Buckman well No. 2 and Buckman well No. 8 were about 40% to 50% of the 4-mrem drinking water DCG.

Generally, no tritium is detected in these wells at a detection limit of about 1 pCi/L. In 2004, one sample produced a detection, but a duplicate sample did not detect tritium, casting doubt on the detected result. Perchlorate concentrations in the Buckman wells ranged from 0.27 ppb to 0.43 ppb. Other than sample issues mentioned in the introduction, no organic compounds were found in the Buckman well samples. No HE compounds were detected in these well samples.

G. Unplanned Releases

1. Radioactive Liquid Materials

No unplanned radioactive liquid releases occurred in 2004.

2. Nonradioactive Liquid Materials

Seven unplanned releases of nonradioactive liquid took place in 2004. The following is a summary of these releases.

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- One bentonite drilling fluid release into Two Mile Canyon and Pajarito Canyon.

- Three unplanned petroleum product releases:

    1. TA-3-38

    2. TA-3-4100

    3. TA-60-1

- One unplanned mineral-oil-contaminated storm water release at TA-60-5 (Materials Recycling Facility).

- One unplanned release of untreated sanitary sewage from the TA-46 SWWS plant's collection system at TA-3-43 Manhole #616.

- One unplanned release of untreated sanitary sewage from a septic system at TA-40.

ENV-WQH investigated all unplanned releases of liquids as the NMWQCC Regulations 20.6.2.1204 New Mexico Administrative Code require. Upon cleanup, personnel from NMED and NMED DOB inspected the unplanned release sites to ensure adequate cleanup. The Laboratory is in the process of administratively closing out all releases for 2004 with NMED DOB. The Laboratory anticipates these unplanned release investigations will be closed out when NMED DOB personnel become available for final inspections.

H. Quality Assurance of Groundwater Sample Analyses at ENV-WQH

1. Introduction

ENV-WQH personnel conducted quality assurance (QA) activities in 2004 in accordance with DOE Order 414.1A, which prescribes a risk-based, graded approach to QA. This process promotes the selective application of QA and management controls based on the risk associated with each activity to maximize effective resource use.

The ENV-WQH Water Quality Database (http://wqdbworld.lanl.gov) contains all the water and sediment analytical data received from the analytical laboratory. None of the data are censored or removed. If analytical results are inconsistent with historic data, we investigate the laboratory records and the sample may be reanalyzed or the location resampled. Both the initial sample and the follow up sample or analyses are kept in the database and are available to the public. In some cases, comments are appended to the records to indicate existence of recognized analytical issues. The primary documentation of analytical issues for data from a given year is provided in this report.

All sampling was conducted using ENV-WQH standard operating procedures. Completed chain-of-custody forms serve as an analytical request form and include the requester or owner, sample number, program code, date and time of sample collection, total number of bottles, the list of analytes to be measured, and the bottle sizes and preservatives for each analysis required.

See Table S5-14 for the analytes, analytical methods, and detection limits used for analysis of surface water, sediment, and groundwater samples during 2004.

2. Analytical Laboratories

ENV-WQH is responsible for acquiring analytical services that support monitoring activities. The ENV-WQH Group Statement of Work (SOW) follows the National Nuclear Security Administration Service Center's Analytical Management Program's Model Statement of Work (Model SOW) for analytical services. The ENV-WQH SOW provides contract analytical laboratories the general QA guidelines specified in the Model SOW and also includes specific requirements and guidelines for analyzing surface water, groundwater, and sediment samples.

3. Analytical Quality Assurance Activities

ENV-WQH is responsible for verifying that analytical data used to support monitoring activities are defensible and of known quality. Analytical data packages undergo a rigorous review and validation process following the guidelines set in the DOE-AL Model standard operating procedure for Data

Validation, which includes review of the data quality and the documentation's correctness and completeness. Tables S5-5, S5-6, and S5-7 in the Data Supplement list qualifier and validation flag codes that accompany 2004 sediment and water data.

Analytical Quality Associates, Inc. (AQA) validated all of the 2004 data packages. Individual validation memos were issued for each analytical fraction for each data report. The average report had about five data validation memos. AQA issued a number of nonconformance reports (NCRs) for Data Validation Memos that had to be reissued (Table 5-2). Most of the NCRs were written in response to problems concerning minor documentation and typographical errors on individual memos. These reports were corrected and reissued. Associated sample results were generally not affected.

Table 5-2. Nonconformance Reports Issued by GEL Analytical Laboratory

NCR Issue	No. of Associated NCRs	Analyte	Corrective Action	Samples affected
Analytical Laboratory Cross-Contamination	1	All 2004 pesticide detections in water data	Commenced use of disposable glassware	all pesticide results unusable
Target analyte not in analytical laboratory spiking solution	1	Nitroglycerin	Analyte added to spiking solution	0
Data packages - unreadable pages, missing pages, etc.	108		Data packages corrected and re-issued	0

When documentation or contract-compliance problems are identified during data validation, the analytical services laboratory is contacted and attempts are made to resolve or clarify the problem. In 2004, this process required ENV-WQH's largest analytical services provider, General Engineering Laboratories, to issue about 110 package-specific NCRs. Most of the NCRs written in response to these problems concerned requests for clarification on data results and missing pages in data packages. GEL reissued corrected documents for all of the reports containing missing documentation or erroneous data. All NCRs were successfully closed.

Two NCRs involved analytical issues. In the first case, LANL discovered that due to pervasive analytical laboratory contamination, many 2004 LANL samples produced false positive results for pesticides. As a result, we view every 2004 detection of pesticides in LANL water and sediment samples as a false positive. As described in more detail below, the analytical laboratory has taken steps to address the issue.

In August 2004, several positive pesticide results, notably results for 4,4'-DDT and 4,4'-DDE, were identified in ENV-WQH samples. These results were supported by neither previous data nor process knowledge at LANL. Subsequent examination of the GEL's data revealed some glassware used in the process was only rinsed, with no further cleaning between uses, which meant that pesticide contamination could be transferred from one sample to another during the sample preparation.

In late September 2004, GEL initiated corrective action to address the identified process deficiency. GEL also made specific recommendations for disqualifying sample results that had clearly shown cross contamination. AQA reviewed GEL's findings and recommendations, concurred, and rejected the data in question as unusable.

AQA subsequently reviewed all the positive pesticide results for all pesticide analytes reported to all of GEL's clients during 2004 for samples extracted before they implemented the corrective action. In cases for which positive pesticide hits were clearly the result of cross contamination, additional data were qualified as unusable (approximately two-thirds of the pesticides originally reported as detected). Pesticides that were qualified as unusable included alpha-BHC, delta-BHC, Heptachlor, Heptachlor epoxide, Endrin, Endrin aldehyde, Dieldrin, Endosulfan II, Endosulfan sulfate, 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE. However, numerous positive hits remain for which no unequivocal evidence of contamination exists. These data remain unqualified, but are considered unusable because of the known process deficiency that existed at the time GEL performed the analyses.

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With four exceptions, groundwater pesticide samples were collected from late May through mid September of 2004. GEL initiated corrective actions in late September 2004 so the bulk of pesticide sample analyses are potentially affected. Apparently spurious pesticide detections occurred only in samples collected from late May through late June of 2004 and no pesticides were detected in any other samples.

The other NCR involved the use of an explosive spiking solution that included GEL's standard list of compounds. This solution did not include nitroglycerin, which was a requested groundwater analyte. GEL's corrective action was to add nitroglycerin to the standard spike solution to prevent future errors.

In addition to routine review of data packages, analytical laboratory oversight includes audits, site visits, and conference calls to review general laboratory quality practices. Problems identified during these processes normally require the laboratory to take a formal corrective action. All requested corrective actions for 2004 were completed.

4. Radiological Data

Negative values are sometimes reported in radiological measurements. Negative numbers occur because radiochemistry counting instrument backgrounds must be subtracted to obtain net counts. Because of slight background fluctuations, individual values for samples containing little or no activity can be positive or negative numbers. Although negative values do not represent a physical reality, we report them as they are received from the analytical laboratory as required by the "Environmental Regulation Guide for Radiological Effluent Monitoring and Environmental Surveillance" (DOE 1991).

The precision of radiological analytical results is reported as the one standard deviation (one sigma) total propagated uncertainty. ENV-WQH reports radiochemical detections as analytical results that are greater than both the sample-specific minimum detected activity and three times the reported uncertainty.

5. Nonradiological Data

Nonradiological results are reported at levels down to the laboratory-derived MDL. Data between the MDL and practical quantitation limit are qualified as estimated by the analytical laboratory. The analytical laboratory reports results below the MDL as nondetections.

A perennial issue is differing results of perchlorate by ion chromatography (EPA 314.0) and LC/MS/MS [SW-846 8321(M)]. Studies of chromatographs associated with low-level hits by ion chromatography are often ambiguous as to the definitive identification of perchlorate peaks in those chromatographs. LC/MS/MS has shown to be less sensitive to matrix effects and more reliable for low-level perchlorate analysis.

6. Detection-Limit Issues

The ENV-WQH Group SOW requires that analytical laboratories verify their calculated MDLs empirically. Federal regulations prescribe a process for determining analytical laboratory detection limits which uses standards based on deionized water. For analysis of environmental samples, these detection limits may not be achievable. The additional constituents present in natural water samples may lead to matrix interference in the analytical process, which decreases the method sensitivity. Comparison of results from these analyses to a detection limit based on deionized water will lead to additional false positive results for environmental samples. Empirical determination of detection limits using natural sample matrices produces a detection limit that is achievable for these samples.

7. Participation in Laboratory Intercomparison Studies

General Engineering Laboratories is required by the ENV-WQH SOW to participate in independent national performance evaluation programs. GEL participated in the EPA water supply and water pollution proficiency testing programs prior to their elimination. GEL does continue to participate in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) for radiochemistry, organic, and inorganic analyses.

Results for the MAPEP are categorized as (1) acceptable (result within the 2-sigma acceptance range), (2) acceptable with warning (result within the 3-sigma acceptance range), and (3) not acceptable (result outside the 3-sigma acceptance range). Participating analytical laboratories are required to initiate internal corrective actions when evaluation results are categorized as "not acceptable," and those corrective actions are spot-checked during various analytical laboratory oversight activities. A summary of performance

evaluation program deficiencies is shown in table 5-3. All other analytes not shown in the table were acceptable.

Table 5-3. Summary of Performance Evaluation Program Deficiencies for GEL Analytical Laboratory

	MAPEP-03-W11 (May 2004 Water Sample)	MAPEP-04-MaW12 (November 2004 Water sample)	MAPEP-04-MaS12 (November 2004 Soil sample)
diethylphthalate	Acceptable with warning		
benzo(a)anthracene	Acceptable with warning		
Chrysene	Acceptable with warning		
Fe-55		Result not acceptable	
Tc-99			Acceptable with warning
U-238			Acceptable with warning
Pu-239,240			Result not acceptable
U-234/235			Result not acceptable
antimony			Result not acceptable

8. Quality Control Samples

ENV-WQH submits quality control samples along with environmental samples so that we can detect possible field or analytical laboratory contamination and track analytical laboratory performance. Differences in analytical results between field duplicate samples, for example, may indicate that the samples were not uniform or that there was significant variation in analyses. Detection of analytes in deionized water field blanks could indicate contamination of our deionized water source or sample bottles, or contamination from the analytical laboratory. We evaluate the results from QC samples along with the environmental sample results in order to understand whether the results truly represent environmental measurements.

The required analytical laboratory batch QC is defined by the analytical method, the analytical SOW, and generally accepted laboratory practices. The laboratory batch QC is used in the data-validation process to evaluate the quality of individual analytical results, to evaluate the appropriateness of the analytical methodologies, and to measure the routine performance of the analytical laboratory.

In addition to batch QC performed by laboratories, we submitted field QC samples to test the overall sampling and analytical laboratory process, and to spot-check for analytical problems. These samples included equipment blanks, field blanks (deionized water), performance evaluation blanks (deionized water), and field trip blanks. Duplicate analyses of select samples were also conducted at the laboratory.

a. Equipment and Field Blanks. Equipment and field blanks were submitted for metals, organic, general inorganic, and radiochemistry analyses to monitor for contamination during sampling and decontamination of equipment.

b. Performance Evaluation Blanks. Performance evaluation blanks aid in the determination of false detections in associated environmental samples.

c. Field Trip Blanks. Trip blanks are helpful in identifying cross contamination at the analytical laboratory.

d. Field Duplicates. Field duplicates are split samples that provide information about field variation of sample results as well as analytical laboratory variation. Field duplicates can indicate sampling techniques with poor reproducibility.

e. Laboratory Duplicate Analyses. Laboratory duplicate samples are splits of samples processed and analyzed by the laboratory that provide information about the precision of the measurement system, including sample homogeneity, preparation, and analysis. Laboratory duplicates can indicate analytical techniques with poor reproducibility. Comparing laboratory duplicates can be used to evaluate the sampling

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system and general environmental homogeneity at the time of sampling. Duplicates are required as routine batch QC for general inorganic, metals, and radiochemistry.

On the whole, the equipment and field blanks and laboratory duplicates were satisfactory, indicating no significant handling issues from sampling and analyses. For results (organized by analytical suite) for equipment, field, and performance evaluation blanks, see Tables S5-15, S5-16, S5-17, and S5-18 in the Data Supplement, as well as earlier tables along with sample data. Detections in the blanks are highlighted in Tables S5-4, S5-9, S5-19, S5-20, S5-21, and S5-22. Table S5-1 lists the definitions of sample description codes used in the data tables.

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6. Watershed Monitoring

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A. Introduction

The Laboratory monitors surface water and stream sediments in northern New Mexico and southern Colorado to evaluate the potential environmental effects of Laboratory operations. The Laboratory analyzes samples for several parameters including radionuclides, high explosives, metals, a wide range of organic compounds, and (for surface water) general chemistry. In this chapter, we assess effects of Laboratory operations and evaluate any trends over time. We also compare the monitoring results with criteria established to protect human health and the aquatic environment.

B. Hydrologic Setting

Watersheds that drain Laboratory property are dry for most of the year. No perennial surface water extends completely across Laboratory land in any canyon. The canyons consist of over 85 miles of watercourses located within the Laboratory and Los Alamos Canyon upstream of the Laboratory. Of the 85 miles of watercourse, approximately 2 miles are naturally perennial, and approximately 3 miles are perennial waters created by effluent.

The remaining 80 or more miles of watercourse dry out for varying lengths of time. The driest segments may flow in response only to local precipitation or snowmelt, and the bed is always above the water table. The flow in these streams is considered "ephemeral." Other streams may sometimes have the water table higher than the streambed and/or extensive snow melt in the watershed and are said to be "intermittent." Intermittent streams may flow for several weeks to a year or longer. The distinction between intermittent and ephemeral streams is important because intermittent streams may flow long enough to develop relatively complex biological communities similar to perennial streams.

To aid in water quality interpretation, we divide stream flow into three types or matrices. Each of the three flow types might be collected at a single location within a time span of as little as a week, depending on weather conditions. At times, the flow might represent a combination of several of these flow types. The three types are

- base flow—persistent stream flow, but not necessarily perennial water. (This stream flow is present for periods of weeks or longer. The water source may be effluent discharge or shallow groundwater that discharges in canyons.)

- snowmelt—flowing water that is present because of melting snow. (This type of water often may be present for a week or more and in some years may not be present at all.)

- storm runoff—flowing water that is present in response to rainfall. (These flow events are generally very short lived, with flows lasting from less than an hour to—rarely—several days.)

Because snowmelt and base flow are present for extended periods of time, they pose similar potentially longer-term exposures, such as wildlife watering. While runoff may provide a short-term water source for wildlife, that water is a principal agent for moving Laboratory-derived constituents off-site and possibly into the Rio Grande.

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None of the streams within Laboratory boundaries averages more than 1 cubic foot per second (cfs) of flow annually. It is unusual for the combined mean daily flow from all LANL canyons to be greater than 10 cfs. By comparison, flows in the Rio Grande commonly average approximately 800 to 1,000 cfs. Although most of the watercourses are dry throughout the year, occasional floods can redistribute sediment in a streambed to locations far downstream from where a release or spill occurs.

Precipitation was normal in 2004, following six consecutive years of below-average amounts. Total runoff volume at downstream gauges in 2004 was within pre Cerro Grande fire averages for the watersheds crossing current LANL lands. However, flow volumes in Pueblo Canyon remain more than 5 times higher than the pre Cerro Grande fire average (Gallaher and Koch 2005). Upper Pueblo Canyon has undergone significant urbanization since the Cerro Grande fire, and that may be a factor in the delayed recovery along with the post-fire effects. The largest peak runoff event for the year was recorded in Pueblo Canyon on July 24, 2004, at 504 cfs (Shaull et al., 2005).

C. Surface Water and Sediment Standards

Table 6-1 summarizes the standards used to evaluate the monitoring data. The suite of standards varies, depending on the stream flow conditions and established or potential uses. To evaluate Laboratory impacts, we compare analytical results for surface water and sediment samples with regulatory standards or with risk-based screening levels.

1. Radionuclides in Surface Water

The surface water within the Laboratory is not a source of municipal, industrial, or irrigation water, though wildlife does use the water. While direct use of the surface water is minimal within the Laboratory, stream flow may extend beyond the LANL boundaries where the potential is greater for more direct use of the water. Stream flows may extend onto San Ildefonso tribal land. Spring water is used traditionally and ceremonially by San Ildefonso tribal members, and uses may include ingestion or direct contact.

We compare concentrations of radionuclides in surface water with the 100-mrem DOE Derived Concentration Guides (DCGs) for public dose (DOE 1990). Although the DCGs primarily regulate radioactive liquid effluent discharges, we compare the quality of on-site surface waters with the DCGs as a benchmark to identify possible areas of concern. At the levels of radioactivity that are found in the environment, the predominant human health concern is long-term exposure. For protection of biota populations, we compare concentrations of radionuclides in surface water with the DOE Biota Dose Guidelines (BCGs; DOE 2002). The DCGs and BCGs are based on annual averages.

2. Gross Alpha in Surface Water

The New Mexico Water Quality Control Commission (NMWQCC 2002a) has promulgated radioactivity-related stream standards to protect livestock watering. Specific standards have been developed for Ra-226, plus Ra-228, tritium, and total gross alpha. Monitoring results of storm runoff after the Cerro Grande fire have shown widespread gross alpha activities greater than the wildlife habitat standard of 15 pCi/L. In response to these findings, the New Mexico Environment Department (NMED) designated several Los Alamos area drainages as water-quality impaired and added them to the federal Clean Water Act §303(d) List (NMED 2003a). The affected drainages noted with heightened gross alpha concentrations are Guaje Canyon, Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon, Pajarito Canyon, and Water Canyon. In the 2002 and 2003 surveillance reports, it was shown that the gross alpha activities generally correspond to the suspended sediment concentrations, and upstream concentrations were comparable to on-site concentrations and largely due to the natural radioactivity in the surface sediments. Although concentrations have progressively declined since the Cerro Grande fire, one-half of the surface water samples in 2004 contained gross alpha concentrations greater than the livestock standard. Because gross alpha is a general screening measurement that does not identify and quantify specific alpha emitters in the water, the gross alpha measurement is of limited value in assessing radiological hazards. Therefore, we do not discuss gross alpha results further in this report. Instead, we emphasize the concentrations measured for specific individual radionuclides identified in LANL waste streams (Watkins and Del Signore 2005) or known to be associated with the nuclear industry (Langmuir 1997). A listing of gross alpha concentrations measured in surface water is provided in Table S6-1.

Table 6-1. Application of Surface Water Standards and Sediment Screening Values to Monitoring Data.

Medium	Standard or DCG	Risk- or Dose- Based Screening Level	Reference	Location	Notes
Surface water					
Radio-nuclides	Derived Concentration Guides Biota Concentration Guides	New Mexico Radiation Protection Regulations	DOE Order 5400.5 20.3.4 NMAC	On-site and off-site	DCGs based on 100-mrem/year dose rate limit; surface waters are present sporadically or are not available for long-term access and do not provide persistent drinking water. BCGs based on 1 rad/day exposure limit for aquatic animals and terrestrial plants, and 0.1 rad/day for terrestrial animals. Comparison based on time-weighted average over the year per DOE Order 5400.5 and 20.3.4 NMAC.
Radio-nuclides	State stream standards		20.6.4 NMAC	On-site and off-site	Based on the protection of livestock watering for combined activity of Ra-226 and -228 and gross alpha. Standards are not specific about exposure duration or comparison criteria; for screening purposes, compare single sample results to standards.
Non-radio-nuclides	State water quality standards for surface and ground waters	EPA cancer risk 10^{-5} and HI=1 risk levels for NM toxic pollutants with no NM standard	20.6.2 NMAC	On-site and off-site	We compare average surface water concentrations for aquatic life chronic exposures. Individual results from all waters compared with livestock, wildlife, acute aquatic life standards, and human health persistent toxic standards. Comparisons with groundwater quality standards are used to determine potential for stream flows to impact underlying bodies.
Sediments					
Radio-nuclides		No standards; Screening levels	Environmental Remediation and Surveillance Program	On-site and off-site	Screening levels derived to determine if more detailed assessment is needed to evaluate impacts to the public; comparisons are made for residential or outdoor worker exposure parameters; based upon a dose rate limit 15 mrem/year. Recreational scenario should be optional for where residential use is impractical, e.g., many canyon bottoms.
Non-radio-nuclides		No standards; Screening levels cancer risk 10^{-5} and HI-1 risk levels for NM toxic pollutants with no NM standard	EPA Region VI	On-site and off-site	Screening levels derived to determine if more detailed assessment is needed to evaluate impacts to the public; comparisons may be made for residential or outdoor worker exposure parameters. Residential levels are appropriate for off-site areas with unrestricted land use; outdoor worker levels are appropriate for on-site areas with public access.

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3. Nonradioactive Constituents in Surface Water

We compare concentrations of nonradioactive constituents with the New Mexico Water Quality Control Commission (NMWQCC) General, Wildlife Habitat, Livestock Watering, and Human Health Standards (NMWQCC 2002a). Through 2004, the Laboratory canyons have not been classified with specific designated uses and, therefore, according to NMWQCC (2002a), by default are protected for the uses of livestock watering and wildlife habitat. In addition, the NMWQCC assigned criteria for persistent toxic substances to protect fish consumption by humans (also called human health standards) to all tributaries of waters with a designated fisheries use, regardless if those tributaries themselves have any fish or actually contribute significant flow to the receiving waters. The location of the upstream limits of these fish consumption standards has not been defined but is assumed to include all canyons and most drainages within the Laboratory boundaries. The standards protecting fish consumption require that all fish-consumption criteria be met at all points within all tributaries. Because Laboratory canyons drain to the Rio Grande, a designated fishery, we also screen the water quality data against the standards designed to protect the health of fish themselves and other aquatic organisms.

Given the short-term duration of the runoff events at LANL, we compare the results against the acute (short-term) aquatic life standards. Where perennial waters are found, we compare the results against both the acute and chronic (long-term) aquatic life standards. Surface water quality results are lastly compared with the NMWQCC groundwater standards to evaluate the potential for stream flows to impact underlying groundwater bodies (NMWQCC 2002b).

Evaluation of storm runoff results is complicated by several factors. Runoff events are short-lived, so they do not result in long-term exposure. The higher concentrations of many compounds found in runoff samples reflect constituents that are part of the large suspended sediment load of runoff, rather than dissolved constituents. We give consideration, therefore, to how much of the contaminant load is due to natural causes versus possible Laboratory-related causes. To evaluate storm runoff results, we developed preliminary threshold values for some metals and radioactivity parameters for the 2002 surveillance report (Gallaher et al., 2004). The thresholds are used to identify data that signify possible effects from Laboratory operations. A value is greater than the threshold if it is greater than the upper 95% prediction limit for concentrations measured at background locations in 2001 and 2002 samples. Alternatively, we can calculate the suspended sediment concentrations for metals and radioactivity in a water sample and screen against Pajarito Plateau background soils concentrations (Ryti et al., 1998). Above-background results merit further investigation to determine whether they are from Laboratory sources.

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We screen sediment results to screening action levels to identify concentrations of a constituent that may require further assessment (ER 2001). The Laboratory's Remediation Services Project uses residential screening action levels (SALs) to identify radionuclide activity levels of interest (ER 2001). Comparisons with SALs are used to readily distinguish the areas with most potential concern: concentrations below the SALs are not considered to be of concern to public health, whereas concentrations greater than the SALs would trigger the Laboratory's Remediation Services Project to perform more detailed investigations. Industrial worker screening levels for radionuclides (Perona et al., 1998) are applicable on Laboratory land because it is not available for residential development. This reflects the current land use status for the Laboratory. In the long term, it is possible that residential development patterns could change if Laboratory boundaries are modified.

Concentrations of nonradioactive compounds in sediments may be compared with residential and industrial outdoor worker soil-screening levels developed by Environmental Protection Agency (EPA) Region 6 (EPA 2003). All of these screening levels are conservative (protective) because they are calculated based on the assumption that humans will be continually exposed to the chemicals or radionuclides, which is not the case on LANL property. We can also compare sediment data with background levels of metals or background activities of radionuclides that are naturally occurring or result from atmospheric fallout (Ryti et al., 1998; McLin and Lyons 2002).

D. Sampling Locations and Data Analysis Methods

1. Regional Monitoring Locations

Regional base-flow and sediment-sampling stations (Figure 6-1) are located in northern New Mexico. Samples from regional stations provide a basis for estimating background concentrations of nonradioactive compounds and background activities of radionuclides that are naturally occurring or result from atmospheric fallout. We obtained regional sediment samples from stations on the Rio Grande and the Jemez River and from Abiquiu Reservoir on the Rio Chama. We were unable to collect samples from Cochiti Reservoir in 2004 because of the work restrictions imposed by the Laboratory stand-down. Sampling stations in the Rio Grande drainage system are located up to approximately 60 km upstream and downstream of the Laboratory.
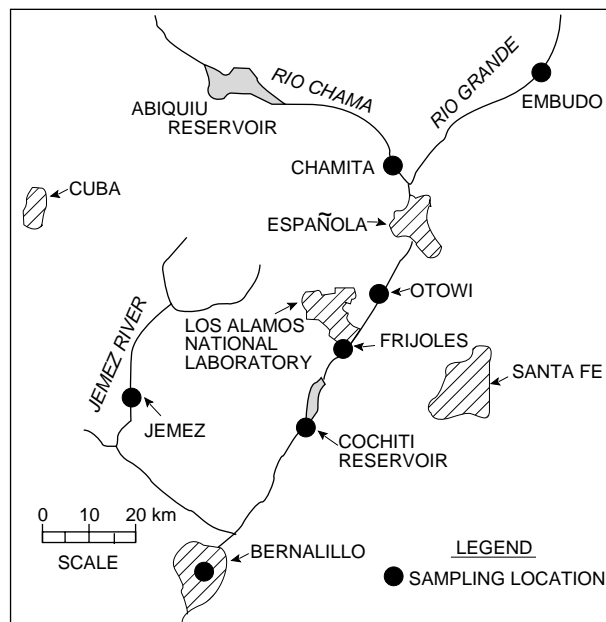
Figure 6-1. Regional base-flow and sediment-sampling locations.

2. On-Site and Perimeter Monitoring Locations

We sample surface water and sediments in all major canyons that cross Laboratory land, including those canyons with either persistent or brief flows. We sample stream sediments to evaluate any accumulation of undissolved contaminants in the aquatic environment (DOE 1991). During 2002, we reevaluated the locations of base-flow and sediment stations. In many cases, we consolidated station locations with nearby gauging stations to collect surface water and sediment samples at the same location. In other cases, sediment stations were adjusted to reflect current channel locations or to move the station above effects of disturbance by construction or post–Cerro Grande fire mitigation activity.

We collect base-flow samples from Pajarito Plateau stations within and near the Laboratory and snowmelt at upstream and downstream gauging stations at the Laboratory boundary. We collect base-flow grab samples annually from locations where effluent discharges or natural runoff maintains persistent stream flow (Figure 6-2).

After 1996, storm runoff samples are collected using stream-gauging stations with automated samplers (Figure 6-3). The stream-gauging stations collect samples when a significant rainfall causes flow in a monitored portion of a drainage. Many gauging stations are located where drainages cross the Laboratory's boundaries. We also sample storm runoff at several mesa-top sites that allow us to target specific industrial activities. These sites have negligible runoff from other sources.

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Sediment stations on the Pajarito Plateau (Figure 6-4) are located within approximately 4 km of Laboratory boundaries, with the majority located within Laboratory boundaries. Many of the sediment-sampling stations on the Pajarito Plateau are located within canyons to monitor sediment contamination in the active channel related to past and/or present effluent release sites. We sampled three major canyons (Pueblo, Los Alamos, and Mortandad) that have experienced past or present liquid radioactive releases from upstream of the Laboratory to their confluence with the Rio Grande.

We collected sediments from drainages downstream of two material disposal areas. Material Disposal Area G at Technical Area (TA)-54 is an active waste storage and disposal area. Nine sampling stations were established outside its perimeter fence in 1982 (Figure 6-5) to monitor possible transport of radionuclides from the area.

Area AB at TA-49 was the site of underground nuclear weapons testing from 1959 to 1961 (Purtymun and Stoker 1987; ESP 1988). The tests involved high explosives (HEs) and fissionable material insufficient to produce a nuclear reaction. We established 11 stations in 1972 to monitor surface sediments in drainages adjacent to Area AB (Figure 6-6).
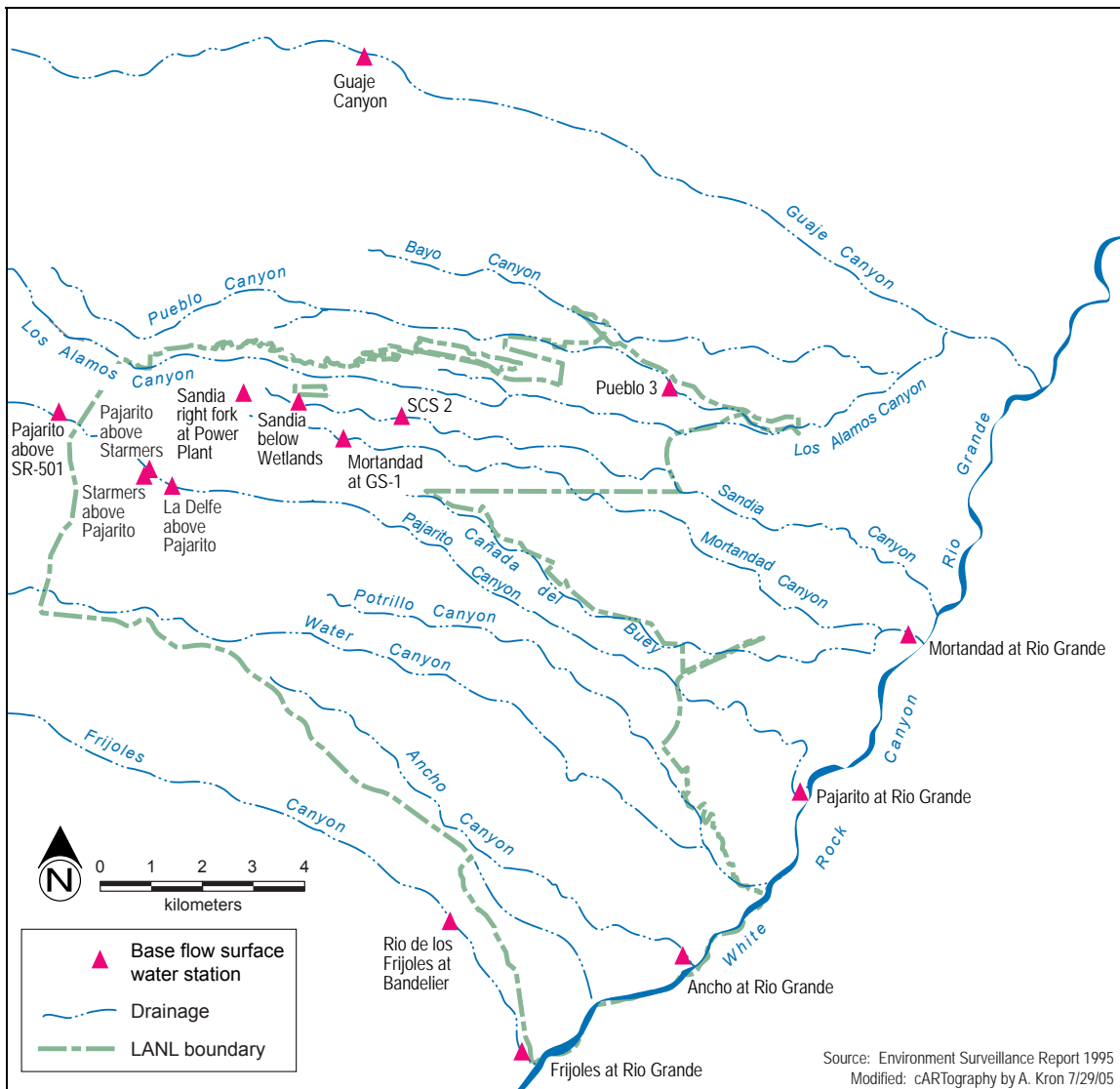
Figure 6-2. Base-flow sampling locations in the vicinity of Los Alamos National Laboratory.

Figure 6-3. Storm runoff sampling (gauging) stations in the vicinity of Los Alamos National Laboratory.

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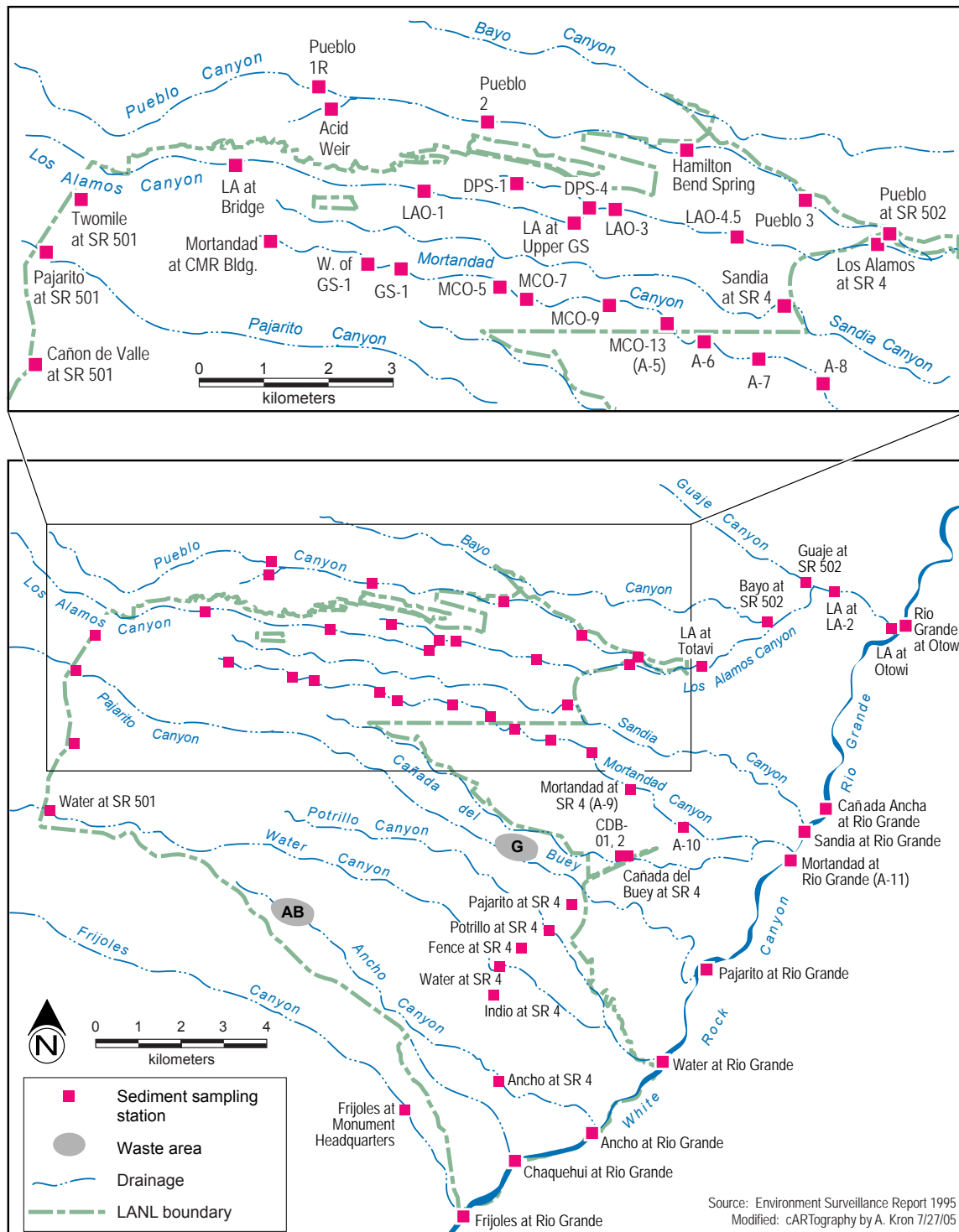
Figure 6-4. Sediment sampling locations in the vicinity of Los Alamos National Laboratory. Material disposal areas with multiple sampling locations are shown in Figures 6-5 and 6-6.
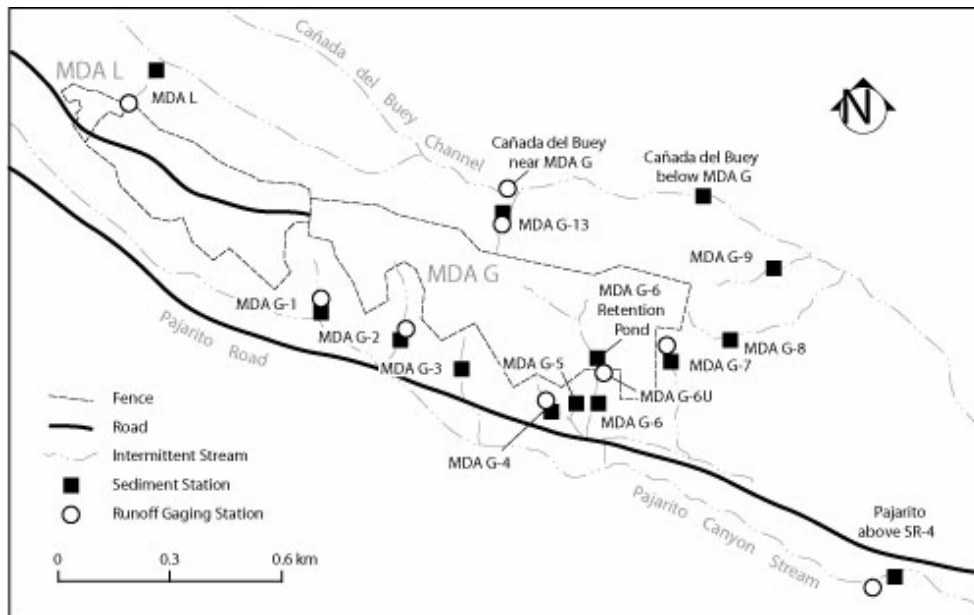
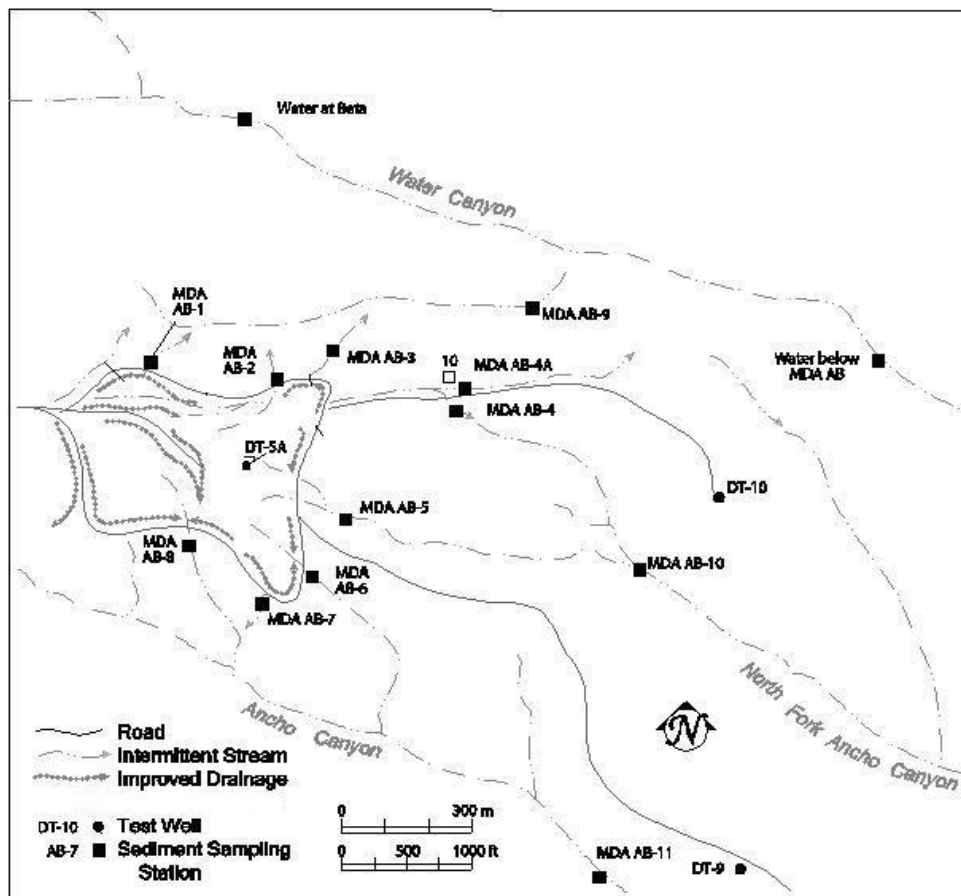**Figure 6-5.** Sediment and storm runoff sampling stations at TA-54, Area L, and Area G.

Figure 6-6. Sediment sampling stations at Area AB, TA-49.

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We also sample surface water and sediments at several locations on San Ildefonso Pueblo lands. DOE entered into a Memorandum of Understanding with the Pueblo and the Bureau of Indian Affairs in 1987 to conduct environmental sampling on pueblo land. The watershed drainages that pass through LANL onto the Pueblo are Los Alamos/Pueblo, Sandia, Mortandad, and Canada del Buey Canyons.

3. Sampling and Analysis Procedures

Our procedures for sampling and analysis depended on what types of samples were taken and where and how they were taken. We collect grab samples of base flow from free-flowing streams near the bank. We filter and preserve base flow grab samples in the field. The storm runoff (gauging) stations are equipped with automated samplers, which are activated during major flow events. We submit a time-weighted composite sample of the collected runoff water for chemical analysis. The analytical laboratory filters and preserves runoff samples, because filtering highly sediment-laden waters in the field is difficult.

We collect sediment samples from the main channels of flowing streams. To get samples from the beds of intermittently flowing streams, we use a disposable scoop to collect samples across the main channel to a depth of 20 mm.

4. Estimation of Annual Average Radioactivity in Surface Waters

In order to compare surface water sample results with the DOE DCGs and BCGs, we calculated the time-weighted average annual radioactivity in waters, focusing on the stream segments with relatively persistent waters—the perennial and intermittent stretches with more than 20 days of flow per year (Fisher 2003). Although none of these waters is used as a drinking water source, the persistent waters represent those with the greatest potential for human or biota exposure. Time-weighted average concentrations were calculated for the individual radionuclides of primary concern on the landscape at Los Alamos: americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, tritium, and several uranium isotopes. Concentrations measured during base-flow periods and during storm runoff periods were weighted proportionally after reviewing stream flow records (Shaull et al., 2005) to distinguish the flow regimes; periods with no flow were assigned concentrations of zero. This approach is consistent with DOE guidance (DOE 2003). For waters containing more than one radionuclide, a ratio for each radionuclide is calculated by dividing the concentration of each radionuclide divided by its particular DCG. To be consistent with DOE Order 5400.5, the sum of the ratios should not exceed 1.0. Because the calculations are often based on limited sample sets and hydrologic interpretation, these results should be viewed as approximations.

5. Contaminant Maps

We reviewed recent watershed monitoring results to develop a broad picture of key analytes that reflect possible effects from Laboratory operations. Most of the above-background results for surface water were found in storm runoff samples. We prepared a series of maps to show general patterns of where potential contamination from Laboratory operations was measured in surface water or sediment during 2004. To add confidence to the 2004 results, we also considered previous sampling results in the development of the maps. When the same pattern showed up in several samples within part of a canyon, we highlighted that area on the maps.

We prepared separate maps for sediments and for storm runoff, although they often show similar distribution for a constituent. Because of the lack of flow, storm runoff data are sparse in some parts of the Laboratory. The maps show analytes that are widely distributed, possibly affecting an entire watershed, and may not show localized contamination. The maps are presented later in this chapter.

The maps show contaminant distributions extrapolated beyond the area covered by monitoring locations. This extrapolation takes into account the location of contaminant sources and direction of sediment and surface water movement. Question marks on the maps indicate where contaminant extent is inferred, but not confirmed by monitoring coverage, or they indicate locations where analytical measurements suggest detections that are contradicted by other measurements. Along canyons, the extent of contamination lateral to the canyon is diagrammatic: contamination is quite narrow at the map scale.

E. 2004 Watershed Monitoring Data Tables

The Data Supplement contains tables of all the 2004 watershed-related surface water and sediment analytical results. Radiological results are presented in sequence for each of these media, followed by the results for major chemical quality analytes, trace metals and minor constituents, and organic compounds.

Surface water and sediment samples are annually analyzed for gross alpha, gross beta, and selected radionuclides (americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, uranium isotopes, and tritium). In 2004, we added cobalt-60, potassium-40, neptunium-237, radium-226, radium-228, and sodium-22 to our base list of radionuclides analyzed. Table S6-1 in the Data Supplement lists the results of radiochemical analyses of surface water for 2004. The tables also list the total propagated one-sigma analytical uncertainty and the analysis-specific minimum detectable activity where available. Uranium was analyzed by isotopic methods; from these values, specific activities for each isotope were used to calculate the total uranium concentration.

To emphasize values that are detections greater than DOE DCGs, Table S6-2 lists radionuclides detected in surface water at concentrations greater than the DCGs. Detections are defined as values that exceed both the analytical method detection limit (MDL) (where available) and three times the individual measurement uncertainty. The right-hand column of Table S6-2 show how the results compare with the DCGs.

Qualifier codes are shown in some tables because some analytical results that meet the detection criteria are not detections: in some cases, the analyte was found in the laboratory blank or was below the MDL, but the analytical result was reported as the minimum detectable activity. The tables show two categories of qualifier codes: those from the analytical laboratory and those from secondary validation. For an explanation of the qualifier codes, see Table S5-5 in the Data Supplement.

The results of radiochemical analyses of sediments appear in Table S6-8. Table S6-9 lists radiological detections for results that are higher than river or reservoir sediment background levels and identify values that are near or above SALs. Table S6-8 shows all tritium detections regardless of screening levels.

F. 2004 Watershed Monitoring Findings

The overall quality of most surface water in the Los Alamos area is very good, with very low levels of dissolved solutes. Of the more than 100 analytes tested in sediment and surface water within the Laboratory, most are at concentrations far below regulatory standards or risk-based advisory levels. However, nearly every major watershed shows indications of some effect from Laboratory operations, often for just a few analytes.

Although many of the above-background results in sediment and surface water are from the major liquid effluent discharges (Figure 5-4), other possible sources include isolated spills, photographic-processing facilities, highway runoff, and residual Cerro Grande ash (Gallaher and Koch 2005). At monitoring locations below other industrial or residential areas, particularly in the Los Alamos and Pueblo canyon watersheds, above-background contaminant levels reflect contributions from non-Laboratory sources, such as urban runoff.

1. Guaje Canyon (includes Rendija and Barrancas Canyons)

Guaje Canyon is a major tributary in the Los Alamos Canyon watershed that heads in the Sierra de los Valles and lies north of Laboratory land. The canyon has not received any effluents from LANL activities. Concentrations of metals, organics, and radionuclides in Guaje Canyon base flow and sediments were below regulatory limits or screening levels. Active channel sediments contained background ranges of metals and radionuclides.

2. Los Alamos Canyon (includes Bayo, Acid, Pueblo, and DP Canyon)

Los Alamos Canyon has a large drainage that heads in the Sierra de los Valles. The Laboratory has used the land in the Los Alamos Canyon watershed continuously since the mid-1940s, with operations conducted at some time in all of the subdrainages. Each of the canyons draining the watershed also receives urban runoff from the Los Alamos town site.

Past release of radioactive liquid effluents into Pueblo, DP, and Los Alamos Canyons has introduced americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, and tritium among other radionuclides, into canyon bottoms. Many of these radionuclides bind to stream sediments and persist at levels several orders of magnitude above worldwide fallout levels. Elevated levels of radioactivity can be

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found in those canyons in both surface waters and stream bottom sediments. We evaluated the significance of these heightened levels by comparing against DOE DCGs and BCGs for waters and against risk-based screening levels for sediments.

Table 6-2 and Figure 6-7 compare the annual average levels of radioactivity in persistent surface waters at Los Alamos against the DOE's 100-mrem DCGs (see section 6.D.4 for details of calculation). Table 6-2 also compares the average concentrations against the Biota Concentration Guides. Figures 6-8 through 6-10 compare radioactivity in stream sediments to background activities and screening levels.

Table 6-2. Estimated Annual Average Surface Water Concentrations of Radionuclides in Selected Canyons Compared with the DCGs and BCGs.

			Estimated 2004 Average Conc. (pCi/L)					
Radionuclide	DCG[a] (pCi/L)	BCGs[b] (pCi/L)	Lower Pueblo Canyon	DP Canyon below TA-21	LA Canyon between DP and SR-4	Mortandad Canyon below Effluent Canyon	Max Percent of DCG	Max Percent of BCG[b]
H-3	2000000	300000000	0.7	64	14	12600	0.6	0.004
Sr-90	1000	300	0.6	23	0.4	4	2	8
Cs-137	3000	20000*	0.02	1	0.4	42	1	0.2*
U-234	500	200	0.1	0.8	0.1	3	0.6	1
U-235,236	600	200	0.01	0.05	0.01	0.2	0.03	0.08
U-238	600	200	0.1	0.1	0.1	0.3	0.04	0.1
Pu-238	40	200	0.001	0.02	0.005	5	13	3
Pu-239,240	30	200	0.3	0.1	0.05	5	16	2
Am-241	30	400	0.01	0.2	0.07	8	27	2
	Sum of ratios to DCGs		0.011	0.04	0.005	0.6		
	Sum of ratios to BCGs		0.004	0.08	0.003	0.1		

[a]DCG = DOE 100-mrem Derived Concentration Guides for Public Exposures (DOE 1990)

[b]BCG = DOE Biota Concentration Guides (DOE 2002)

*The BCG for Cs is a site-specific modified BCG from McNaughton 2005

Individual storm runoff events in Pueblo Canyon sometimes contain plutonium-239,240 levels above the 100-mrem DOE DCG for public exposure (based on water ingestion). However, none of the individual radionuclides was greater than its associated 100-mrem DOE DCG on an annual average, and storm runoff is not a source of drinking water. The time weighted sum of ratios for 2004 (see section D4) was estimated to be lower than 0.05 in lower Pueblo Canyon, DP Canyon, and Los Alamos Canyon below DP Canyon (Figure 6-7, Table 6-2). This describes the upper-limit radionuclide concentrations that potentially could be ingested if a hypothetical person drank from the stream channel whenever flow was present.

There were insufficient data in 2004 to estimate the total inventory of radionuclides that were carried beyond the downstream boundary of the Laboratory via Los Alamos and Pueblo Canyons. The enhanced frequency of sampling conducted after the Cerro Grande fire allowed estimates to be made for the years 2000 through 2003 (Gallaher and Koch 2005). Over the four-year study period, it was estimated that plutonium-239,240 transport beyond the Laboratory's downstream boundary increased by as much as 50 to 80 times over that seen in the late 1990s.

Plutonium has moved down Pueblo Canyon, through Los Alamos Canyon, off-site across San Ildefonso Pueblo lands, and reaches the Rio Grande near the Otowi Bridge (Graf 1997; Reneau et al., 1998). Plutonium-239,240 contamination from the Acid Canyon discharge has been traced in stream sediments more than 55 km from the effluent source into lower Cochiti Reservoir (Gallaher and Efurd 2002).
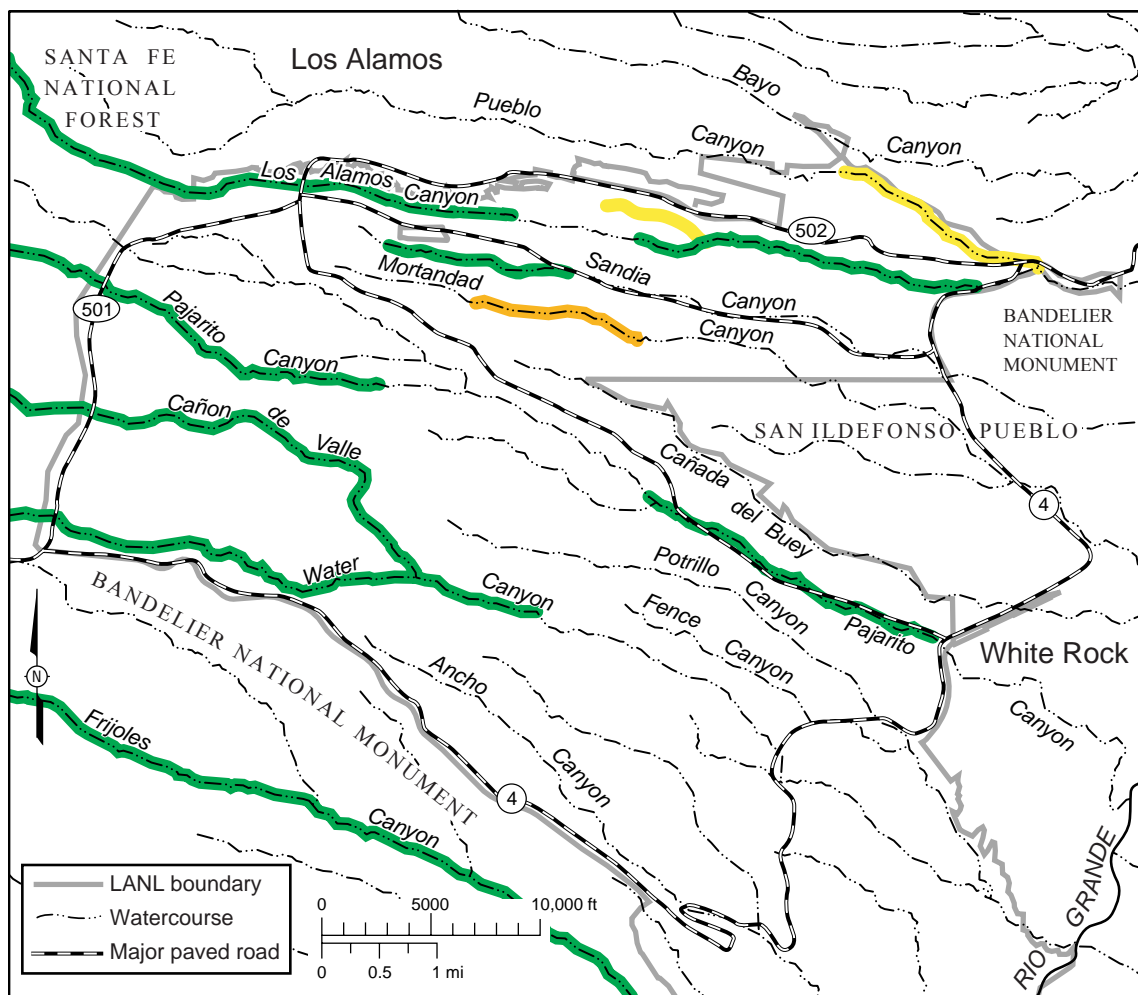
Figure 6-7. Annual average radioactivity in persistent surface waters compared with the DOE Derived Concentrations Guides (DGCs). Persistent waters include perennial and intermittent stream segments (Fisher 2003). The figure shows an integrated perspective of how the activities of a mixture of 9 key LANL radionuclides compare to the DCGs (see text for details).

Throughout the watershed, radionuclide concentrations in sediments remained below residential SALs. Plutonium-239,240 activities in lower Los Alamos Canyon ranged up to 0.5% of the SAL. Analysis of sediments from Pueblo and Los Alamos Canyons found no significant changes in radionuclide concentrations from the previous year. Temporary increases in plutonium-239,240 and cesium-137 concentrations after the Cerro Grande fire have fallen to near pre-fire levels (Figure 6-11). Over many decades, plutonium concentrations in Acid Canyon have declined moderately, whereas concentrations in lower Pueblo Canyon have risen slowly.
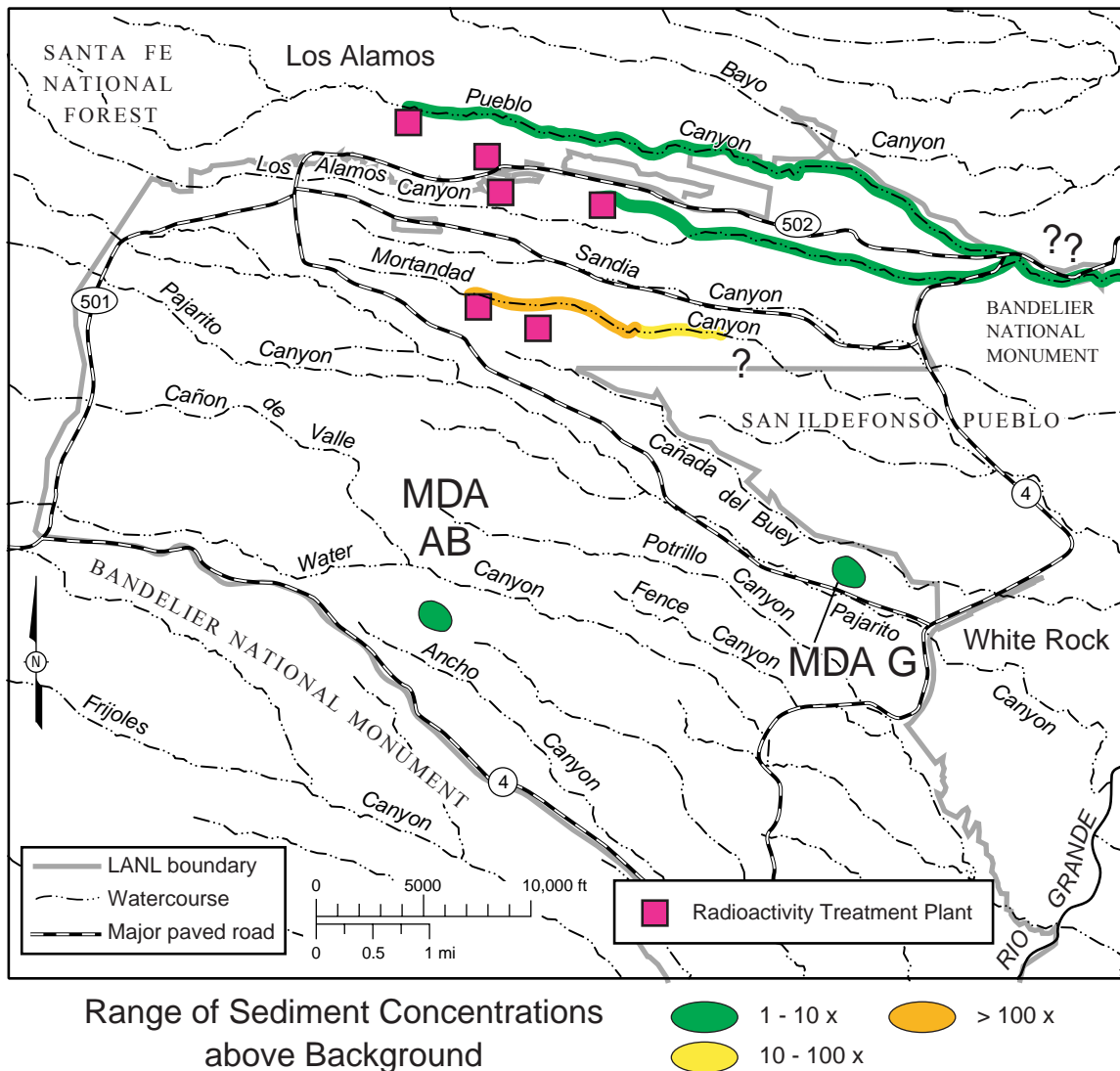
Figure 6-8. Location of the active stream channel sediment with Am-241 concentrations above the fallout levels derived from McLin and Lyons (2002). Different colors indicate the proportion of concentration to the fallout level. Shaded squares show locations of past or current radioactive effluent sources (see Chapter 5 in text). Question marks indicate where contaminant extent is uncertain. The highest value in 2004 was in Mortandad Canyon, at 160 times background, 31% of the residential SAL, and 22% of the industrial worker SAL.

Nonradiological constituents detected at significant concentrations in the Los Alamos Canyon watershed include polychlorinated biphenyls (PCBs), benzo(a)pyrene, mercury, copper, lead, and zinc. The PCB Aroclor-1260 was detected in a stormwater runoff sample in Los Alamos Canyon above DP at a concentration estimated to be 70 times greater than the New Mexico human health standard and 7 times the wildlife habitat standard (Figure 6-12). Analysis detected benzo(a)pyrene in sediment samples from Acid Canyon above Pueblo at 11 times the EPA residential soil-screening level and in a sediment sample from Los Alamos Canyon below DP Canyon at 22 times the residential screening level (Figure 6-13).
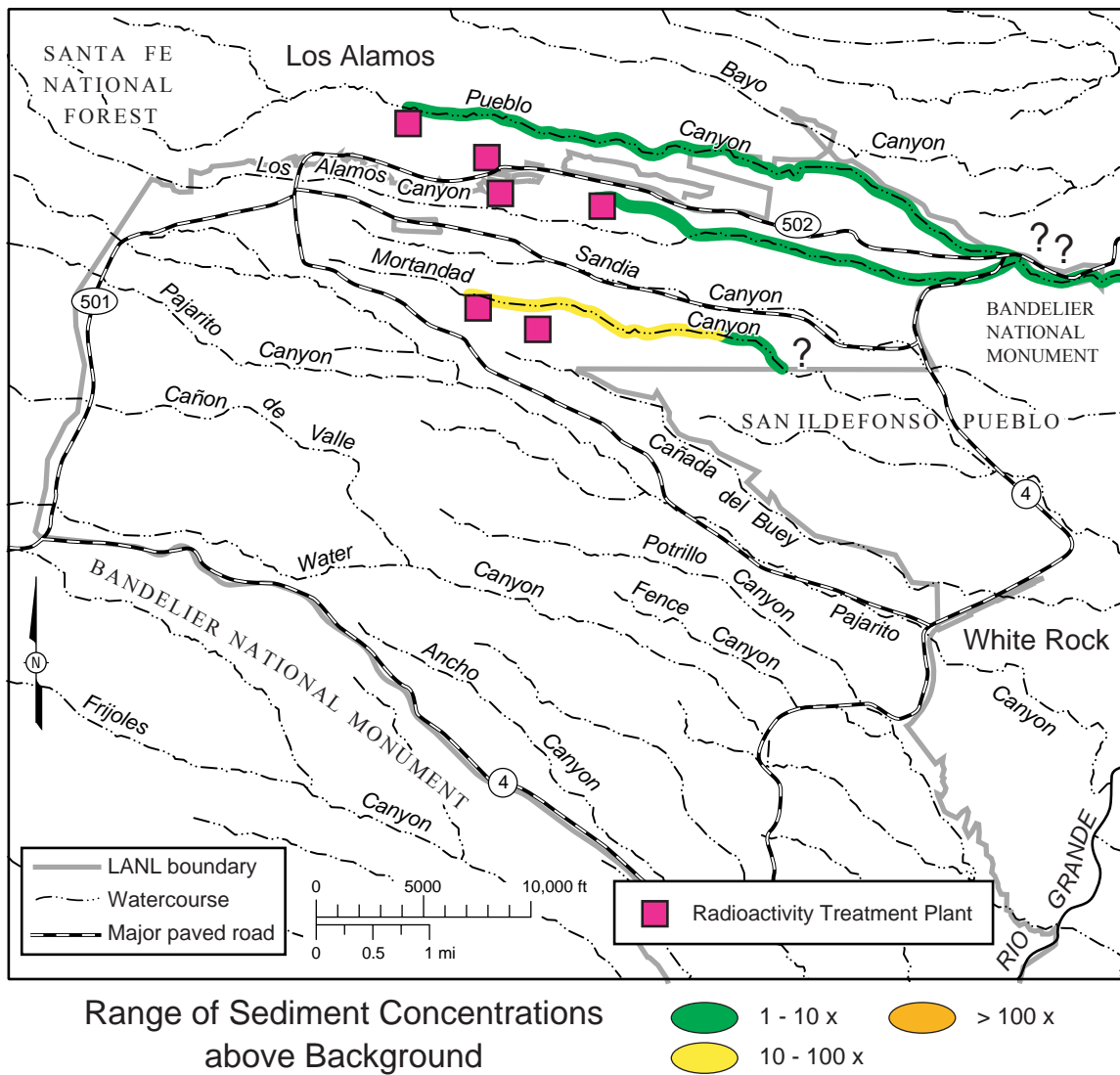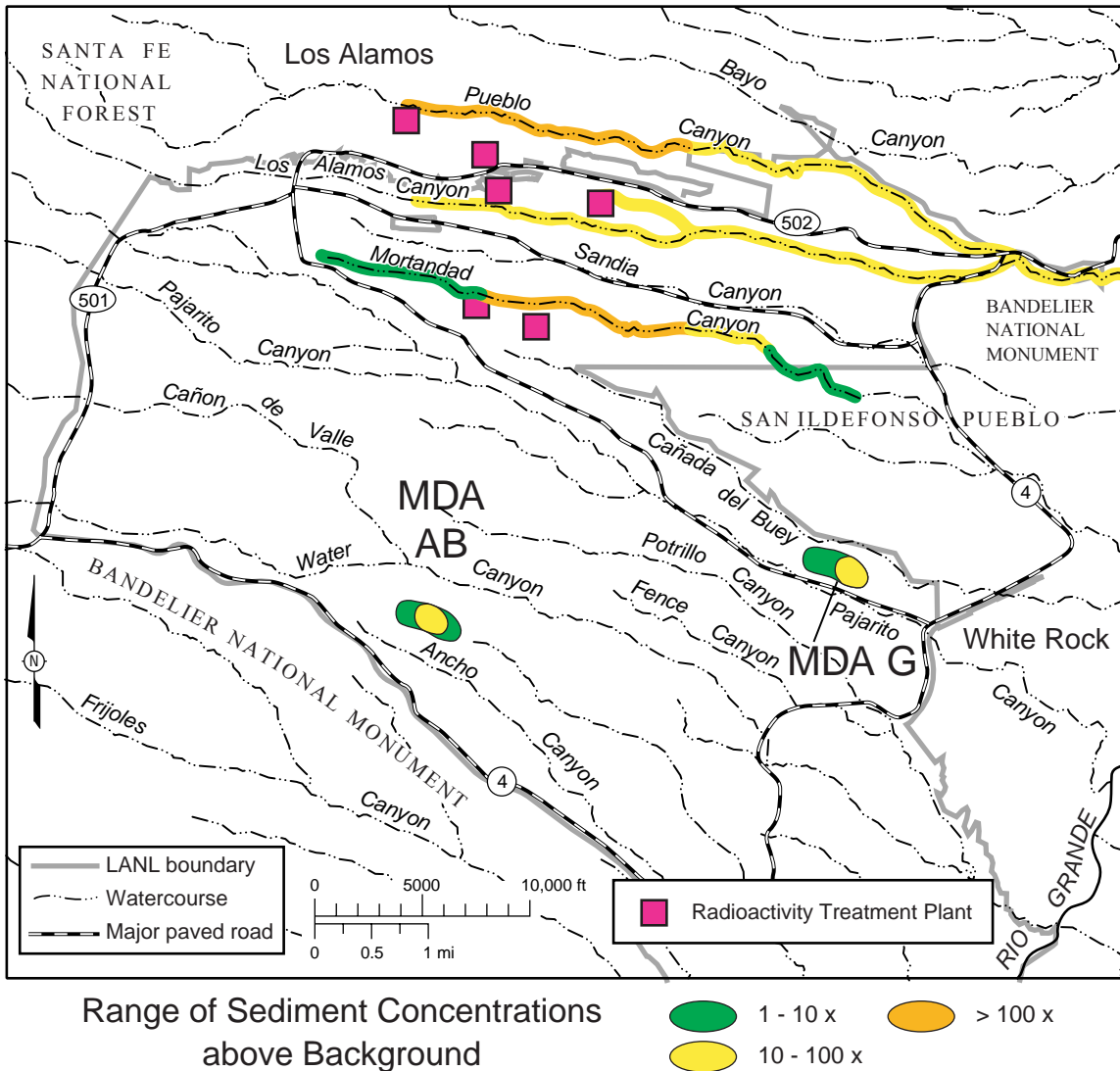
Figure 6-9. Location of the active stream channel sediment with cesium-137 activity above the fallout levels derived from McLin and Lyons (2002). Different colors indicate the proportion of concentration to the fallout level. Shaded squares show locations of past or current radioactive effluent sources (see Chapter 5 in text). Question marks indicate where contaminant extent is uncertain. The highest value in 2004 was in Mortandad Canyon, at 20 times background, 2.1 times the residential SAL, and 0.58 times the industrial worker SAL.

Environmental Remediation and Surveillance Program conducted detailed sediment investigations and concluded that the major source of benzo(a) pyrene in the drainage was urban runoff, rather than a Laboratory-related source (LANL 2004).

Mercury was detected in Los Alamos Canyon above DP Canyon slightly (1.5 times) above the wildlife habitat standard (Figure 6-14). LANL mercury and PCB sources are known to exist in the drainage system, and erosion control features have been installed near the sources to minimize downstream movement. Concentrations of copper, lead, and zinc were detected above the NM acute aquatic life standards (Figure 6-15). Elevated concentrations of these latter metals were found in DP Canyon above LANL facilities at TA-21 and are likely derived from urban runoff sources, rather than Laboratory operations.

Figure 6-10. Location of the active stream channel sediment with Pu-239,240 activity above the fallout levels derived from McLin and Lyons (2002). Different colors indicate the proportion of concentration to the fallout level. Shaded squares show locations of past or current radioactive effluent sources (see Chapter 5 in text). The highest value in 2004 was in Mortandad Canyon, at 758 times background, 22% of the residential SAL, and 16% of the industrial worker SAL.

3. Sandia Canyon

Sandia Canyon heads on the Pajarito Plateau within the Laboratory's TA-3 area and has a total drainage area of about 5.5 mi². This relatively small drainage extends eastward across the central part of the Laboratory and crosses San Ildefonso Pueblo land before joining the Rio Grande. Effluent discharges primarily from power plant blowdown supported perennial flow conditions along a 2-mile reach below TA-3. Only one day with flow was recorded at the Laboratory boundary in water year 2004 (Shaull et al., 2005). Monitoring results have consistently shown minimal off-site contamination from the Laboratory in Sandia Canyon.
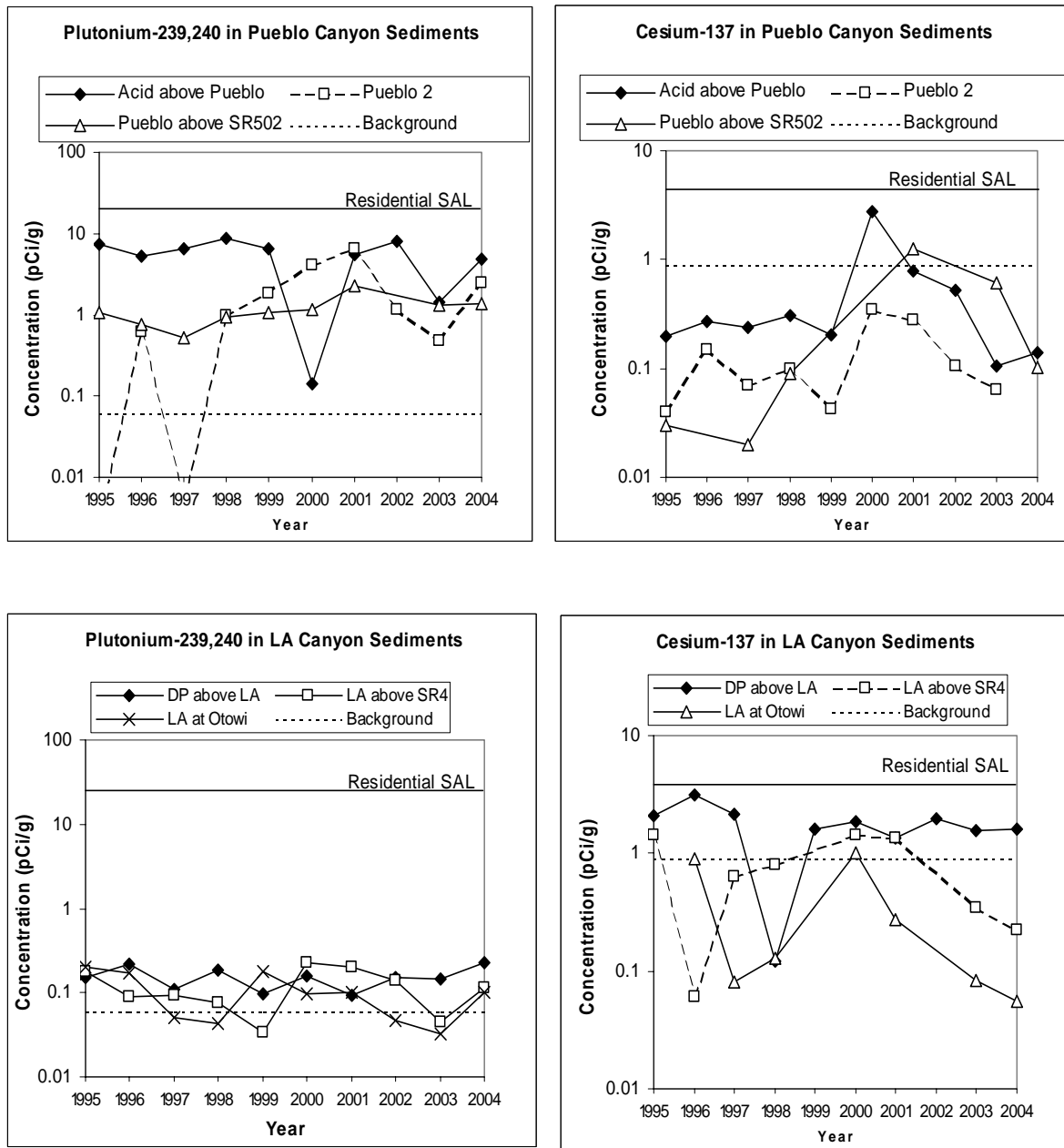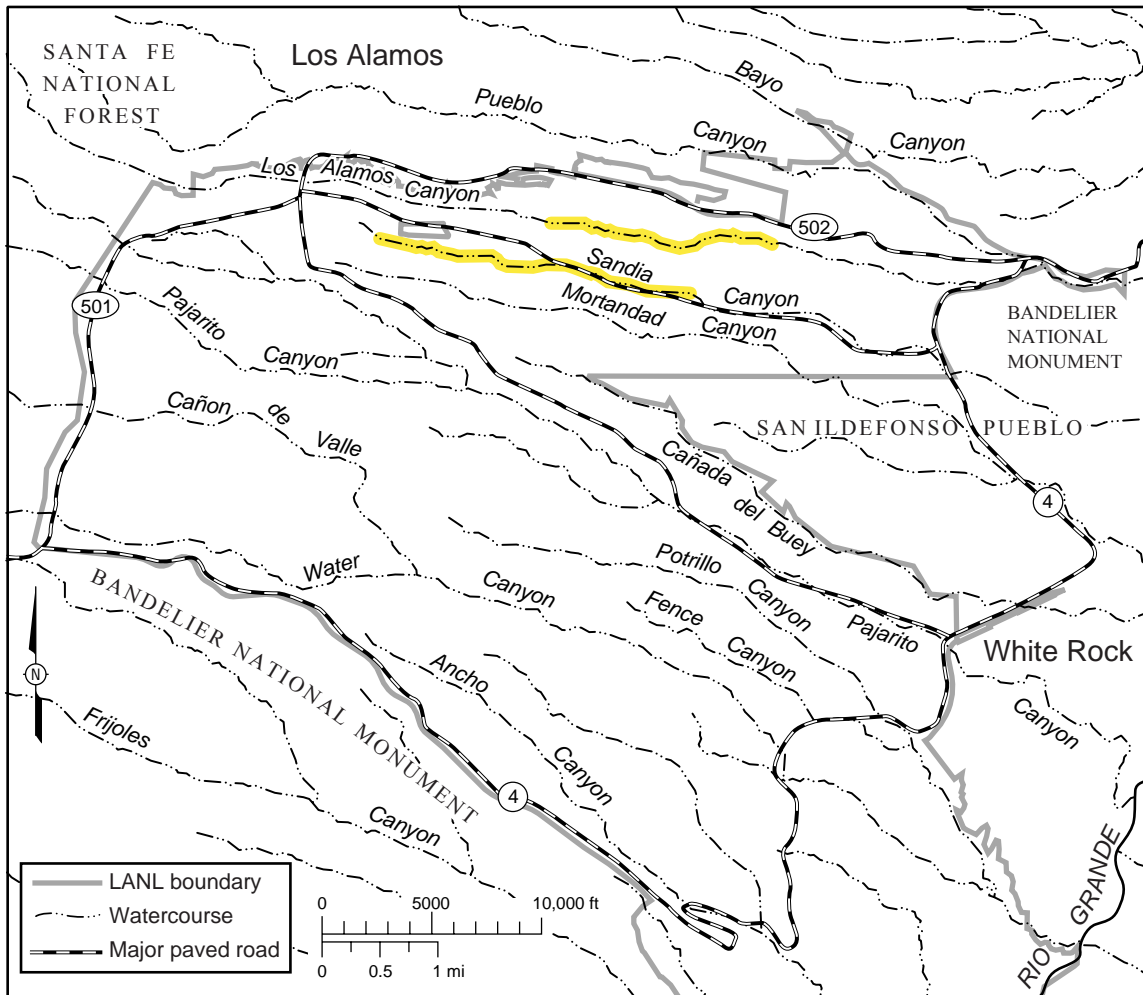
Figure 6-11. Long-term radioactivity trends in Los Alamos and Pueblo Canyon sediments. Note the logarithmic scale on the vertical axes of the graphs.

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**Range of Base Flow Concentrations
Compared to NM Wildlife Habitat Standard**

🟢 Detected but < Standard
🟡 Near or > Standard

Figure 6-12. Location of surface water with the total PCB detected or near the New Mexico Wildlife Habitat stream standard. Different colors indicate where PCBs was detected or was above the Human Health standard. The colors also reflect where the PCBs were above the New Mexico fish consumption/Human Health standard. The highest value in 2004 was in Sandia Canyon, at an estimated concentration 394 times the human health standard and 48 times the wildlife standard.
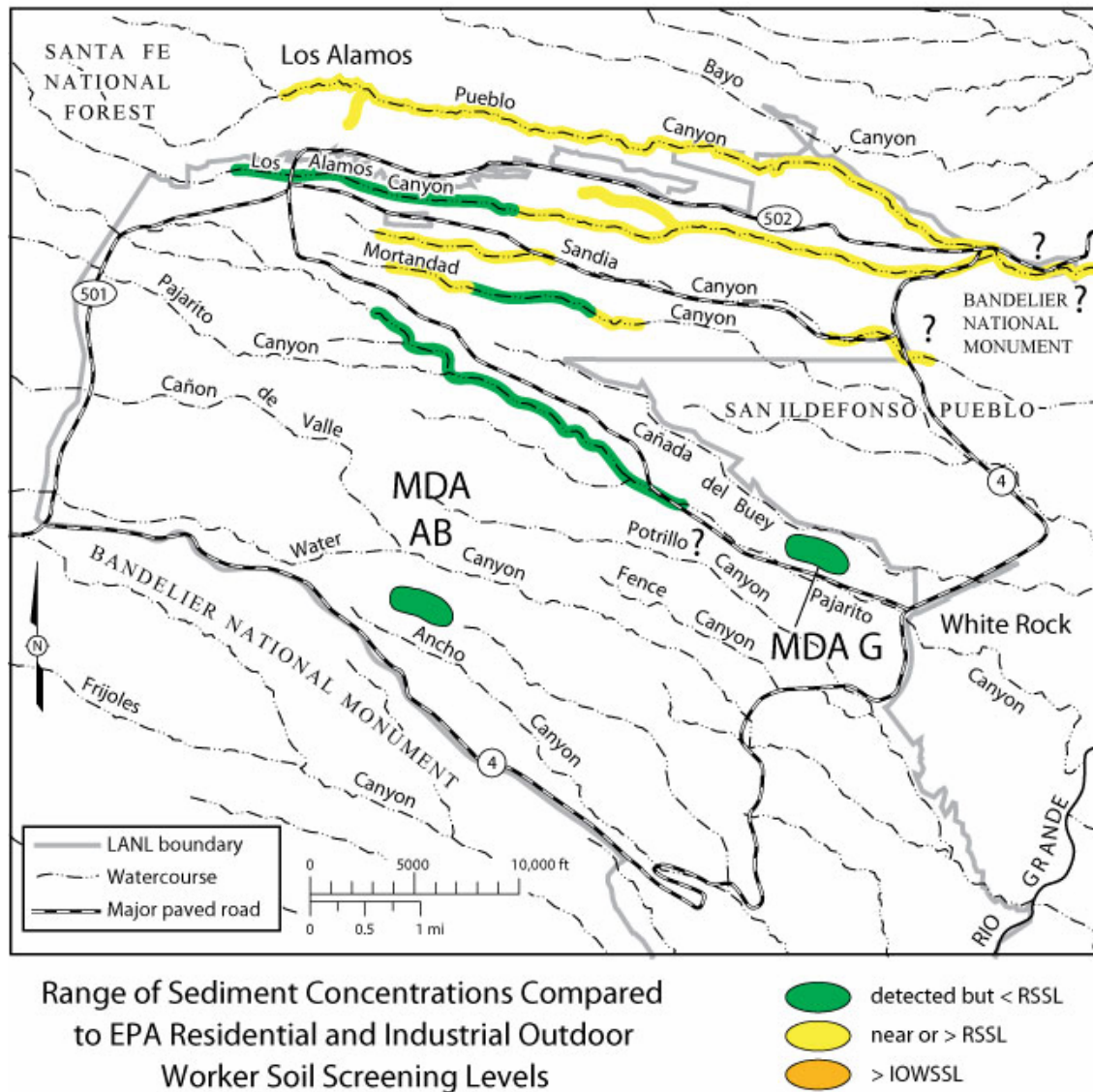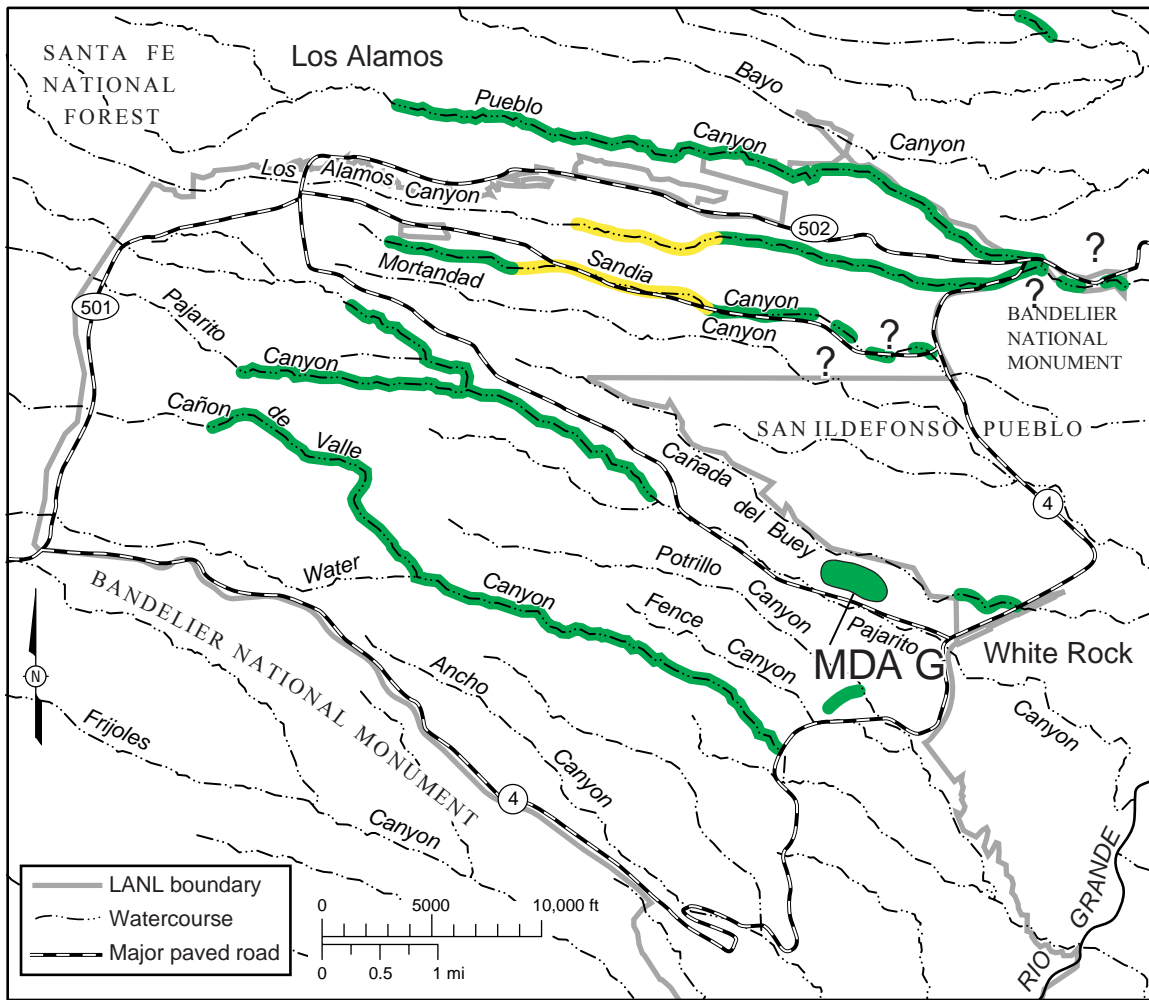
Figure 6-13. Location of sediment with benzo(a)pyrene, a polycyclic aromatic hydrocarbon, detected or above screening levels. Different colors indicate where polycyclic aromatic hydrocarbons are detected or are above the EPA Region 6 residential soil screening level. The highest value in 2004 was in Los Alamos Canyon, at 22 times the residential soil screening level and 5.6 times the industrial outdoor worker soil screening level.
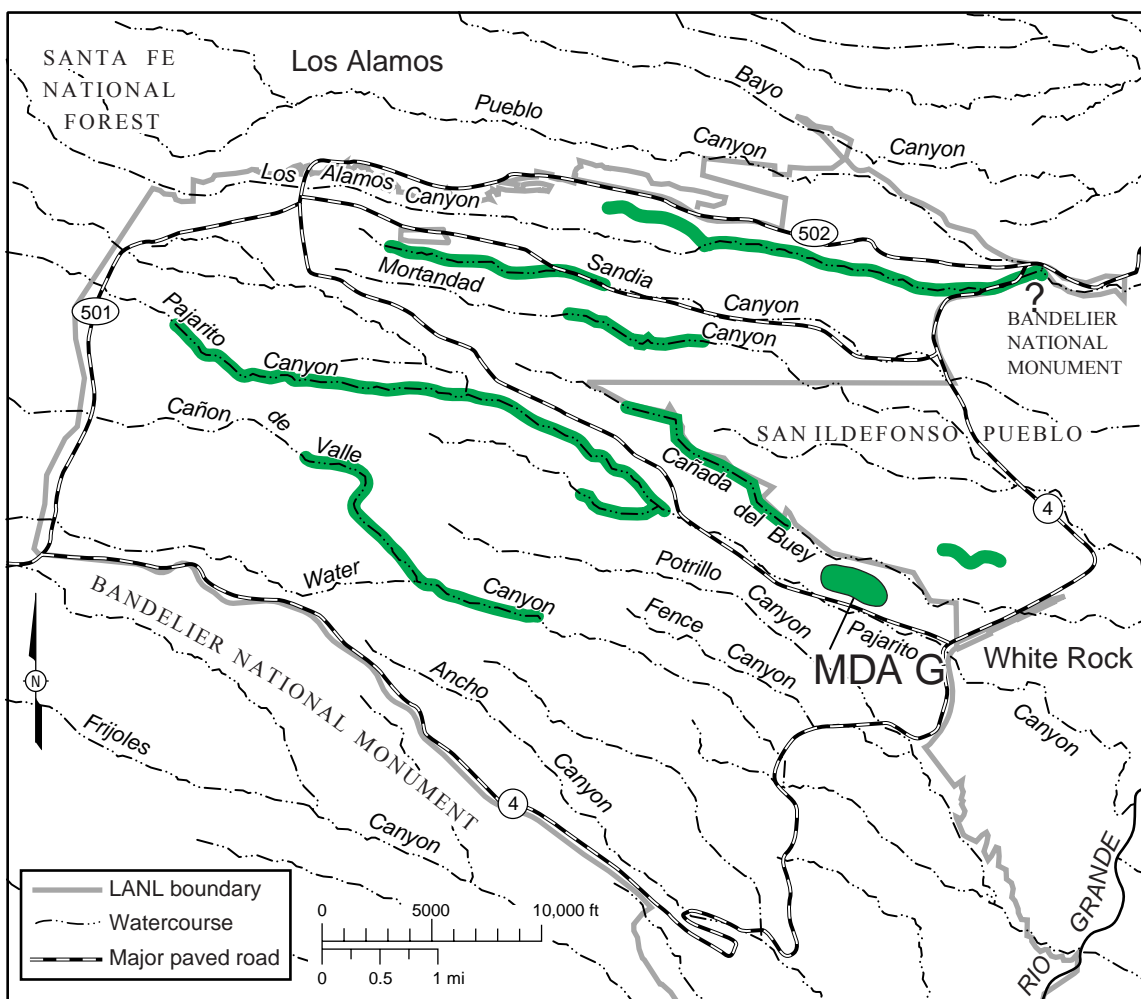
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Figure 6-14. Location of storm runoff with total mercury above the New Mexico Wildlife Habitat stream standard. Different colors indicate the proportion of concentration to the standard. The highest 2004 watercourse values were in Los Alamos Canyon at 1.5 times the standard and in Sandia Canyon at 1.2 of the standard.

Figure 6-15. Location of storm runoff with dissolved copper above the New Mexico Acute Aquatic Life stream standard. Different colors indicate the proportion of concentration to the standard. The highest 2004 watercourse values were in Sandia Canyon at 12 times the standard and in Mortandad Canyon at 3.6 times the standard. Dissolved lead and zinc concentrations above the standard were detected in DP/Los Alamos and Sandia Canyons within the same shaded areas shown for copper. The highest dissolved lead and dissolved zinc concentrations were measured in Sandia Canyon at 2 and 9 times the standard, respectively.

The upper portion of the canyon contains some of the highest PCB concentrations of any watercourse within the Laboratory boundaries. Three samples collected below the Sandia Canyon wetland contained Aroclors 1254 and 1260 concentrations greater than the New Mexico stream standards for fish consumption/human health and wildlife protection by up to 350 and 35 times, respectively. The Aroclor 1260 was also detected above state fish consumption/human health and wildlife standards in a runoff sample collected above the firing range that is located approximately two miles upstream of the Laboratory eastern boundary. The human health standards protect people from ingesting contamination through fish consumption, but there are no fish in Sandia Canyon. Further, flows from the canyon have little probability of reaching the Rio Grande. Sediment samples collected in the upper portion of Sandia Canyon contained

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PCB concentrations more than one-half the EPA residential soil screening level. Downstream sediment concentrations of PCBs decline quickly and are near background (fallout) ranges at the LANL downstream boundary. PCB concentrations at Sandia below the wetlands in 2004 were approximately one-fourth those measured in 2002 (Figure 6-16). PCB concentrations at the other canyon stations were consistent with previous years.

Along an approximately two-mile segment below TA-3 are found above-background concentrations of chromium, copper, mercury, and zinc in surface water and sediments. Storm runoff occasionally contains concentrations above regulatory standards. Measurements in 2004 found dissolved concentrations of copper and lead above the acute aquatic life standard by 2 to 9 times and total mercury concentrations above the wildlife habitat standard by 2 times (Figures 6-14 and 6-15).

Last year's report described the detection of perchlorate in a January base-flow sample taken below the power plant, at a concentration of 18.5 μg/L. The Water Quality and Hydrology Group (ENV-WQH) collected subsequent samples in March 2003 of outfalls 001 (power plant) and 03A027 (cooling tower) discharging to Sandia Canyon that did not detect perchlorate using EPA Method 314 at a detection limit of 4 μg/L. Analyses of Sandia Canyon base flow in 2004 detected perchlorate concentrations of 0.5 to 0.7 μg/L using the more-sensitive LC/MS/MS method at a detection limit of 0.05 μg/L.

Sandia Canyon Below Wetlands
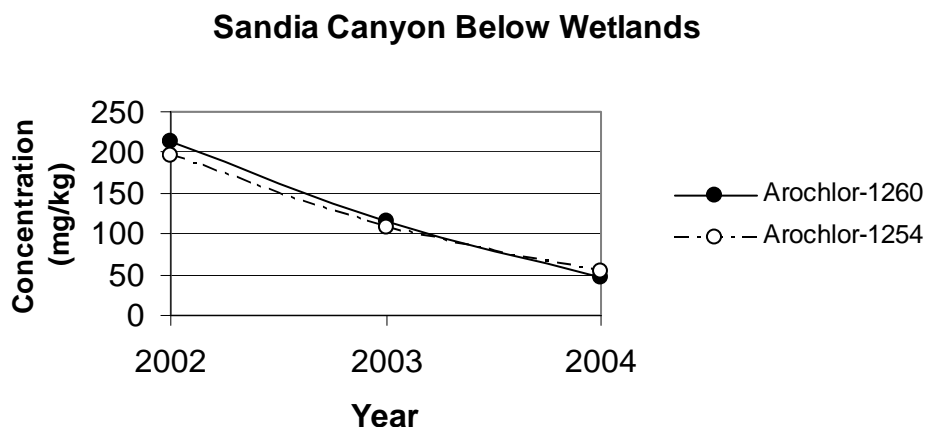
Figure 6-16. Recent trends of PCB concentrations in stream sediments at the Sandia Below Wetlands station.

4. Mortandad Canyon (includes Ten Site Canyon and Cañada del Buey)

Mortandad Canyon heads on the Pajarito Plateau near the main Laboratory complex at TA-3. The canyon crosses San Ildefonso Pueblo land before joining the Rio Grande.

One Mortandad Canyon stormwater runoff sample collected below the Radioactive Liquid Waste Treatment Facility (RLWTF) effluent discharge point contained americium-241 concentration 1.4 times greater than the DOE 100-mrem DCG for public dose. When considered together with analyses of base flow, the annual time-weighted average of americium-241 is below its DCG. When the mixture of radionuclides is considered (see discussion in D.4), the waters also are below the 100-mrem DCG (time weighted sum of ratios is 60% of DCG). Effluent discharges from the RLWTF during 2004 were well below the DCG (17% of DCG; Watkins and del Signore 2005). Stream flow in Mortandad Canyon does not extend off-site and is not used as a drinking water supply.

Despite the history of extensive releases into the Mortandad Canyon watershed, radioactivity in sediments is only slightly elevated above background levels at the Laboratory's eastern boundary, downstream of the effluent discharges. Americium-241, cesium-137, and plutonium-239,240 concentrations in sediments at the boundary are orders of magnitude lower than at upstream stations closer to the RLWTF discharge (Figures 6-8 through 6-10). The absence of stream flow near the Laboratory boundary is the main reason for the drop-off in sediment radioactivity downstream. Cesium-137 concentrations in active channel sediment upstream of the sediment traps were greater than residential

SALs (ER 2001) by up to two times (Figure 6-17). The sediment traps are located approximately 2 miles upstream of the Laboratory's eastern boundary. At the boundary, the cesium-137 concentrations were within background ranges.

Analysis detected dissolved copper concentrations above the New Mexico Acute Aquatic Life stream standard by 2 to 4 times in base-flow and runoff samples collected at the Mortandad below Effluent Canyon station. Benzo(a)pyrene was detected in a sediment sample at the same location at 2.1 times the EPA residential soil-screening level (Figure 6-13). As discussed in detail in the 2002 and 2003 reports, potential sources are many and include road runoff, the Cerro Grande fire, and industrial sources.

Radioactivity in sediment around Area G and in Cañada del Buey was generally consistent in 2004 with previous years. Upward trends of plutonium-239,240 and other radionuclides were noted in the previous 2003 ESR report at sediment sampling stations G-7 and G-8, which are both located along the eastern portion of Area G (Figure 6-18). Radioactivity at these sediment stations returned in 2004 to within typical ranges measured in the late 1990s for those sites. Plutonium-239,240 concentrations in Cañada del Buey were within or slightly elevated above background levels (Ryti et al. 1998).

a. Long-Term Trends. Figure 6-17 shows activities of plutonium-238, plutonium-239,240, and cesium-137 at four sediment stations in Mortandad Canyon. All of the stations are located below the RLWTF discharge. The stations MCO-9.5 and the LANL boundary are located below the sediment traps. For the plots discussed in this section, we describe only detections of a particular radionuclide in sediments; samples without such detections are not included.

Radioactivity levels in sediments just below the RLWTF have not changed appreciably in the past decade, but recent monitoring results show that the levels near the Laboratory boundary are higher than previously recognized before 2001. The plots show that plutonium and cesium activities at MCO-8.5 and -9.5 increased significantly in 2001; relocating the sampling stations to the active channel caused this increase.

5. Pajarito Canyon (includes Two Mile and Three Mile Canyons)

Pajarito Canyon heads on the flanks of the Sierra de los Valles on US Forest Service lands. The canyon crosses the south-central part of the Laboratory before entering Los Alamos County lands in White Rock.

Consistent with past years, we found americium-241, plutonium-238, and plutonium-239,240 at concentrations greater than background in sediments from channels draining Area G. Concentrations of these radionuclides were commonly 5 to 10 times background. While present at elevated concentrations, all of the radionuclides were at levels below residential SALs.

We detected dissolved copper concentrations greater than the New Mexico Acute Aquatic Life standard in channels throughout the Pajarito Canyon watershed, including Starmers, Three Mile, Two Mile, and Pajarito Canyons (Figure 6-15). Review of sediment data from the drainage does not indicate a Laboratory source for the copper. All 2004 sediment results from the drainage were within background concentrations (Ryti et al. 1998), except for at one location at the Laboratory's eastern boundary (Pajarito above State Road 4).

A sediment sample from Pajarito Canyon SR 4 contained many metals and radionuclides elevated two to five times above background. Cesium-137 concentrations were 4 times above background and 68% of the residential SAL. The 2004 results indicate a source(s) other than Area G because cesium-137 is not substantially elevated in sediments around Area G. The sample station was relocated in 2002. Previously the station was below SR-4 where flow is rapid and little sediment accumulates; the relocated station is in a depositional area upstream of the berm formed by SR-4. The higher analyte levels may be related to the finer texture of sediment that accumulates above the highway. Some of the elevated constituents (for example, cesium-137, barium, and manganese) also were found at high concentrations in post–Cerro Grande fire runoff samples (Gallaher and Koch 2005). Because the station is now located where sediment accumulates, both Cerro Grande fire-related and Laboratory-derived constituents are probably present.

Concentrations of organic compounds in sediments from Pajarito Canyon are low and far below EPA residential soil screening levels, with one exception. Benzo(a)pyrene was reported at 1.5 times the residential soil screening level in a sample from Pajarito above TA-18. Low levels of PCBs were detected at levels below the EPA residential soil-screening level in Pajarito Canyon sediments. Around Area G, PCBs concentrations reported in sediments at stations G-6 and G-7 were near the analytical detection limit. PCBs were not detected in stormwater runoff samples collected around Area G.
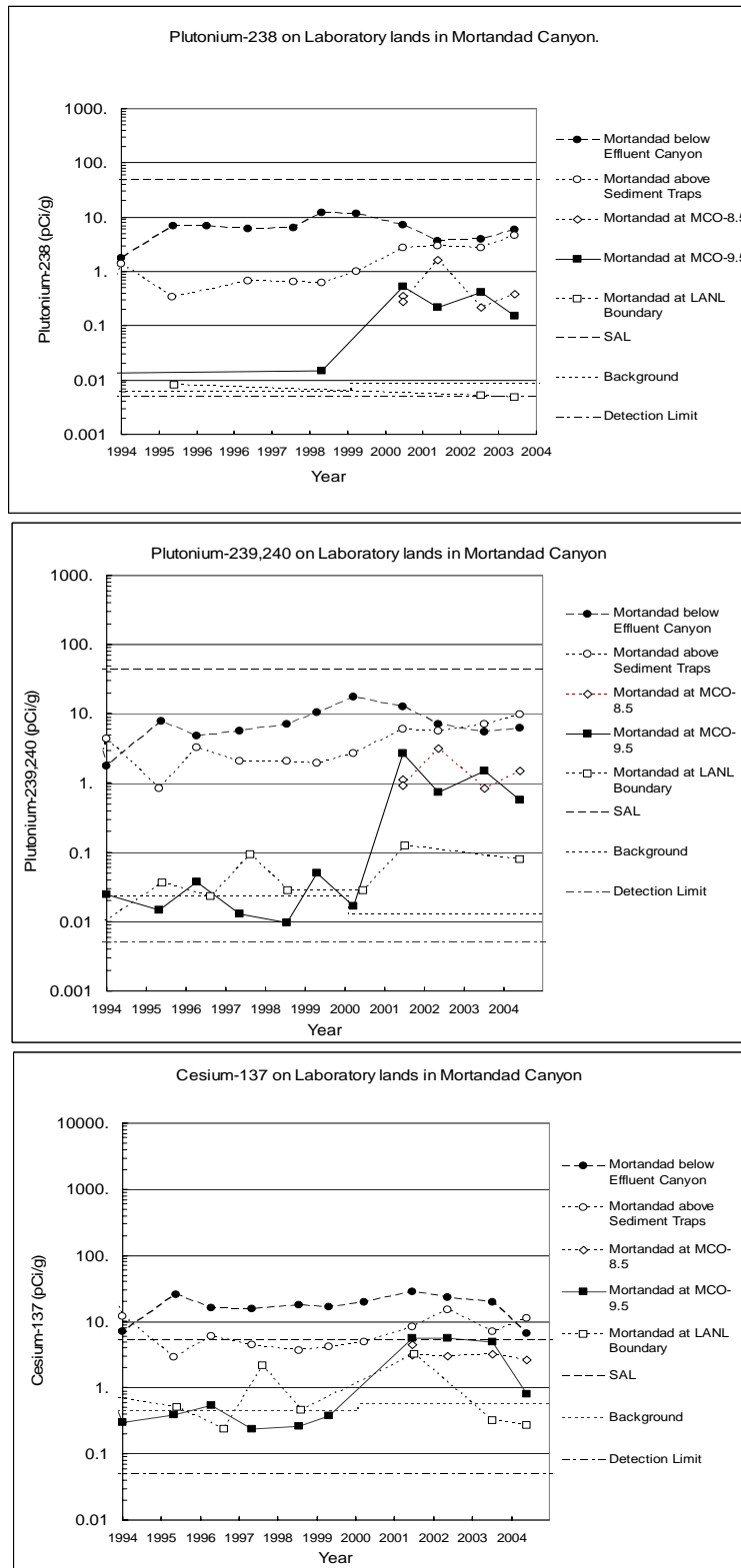
Figure 6-17. Long-term radioactivity trends in Mortandad Canyon sediments. Note the logarithmic scale on vertical axes of the graphs.
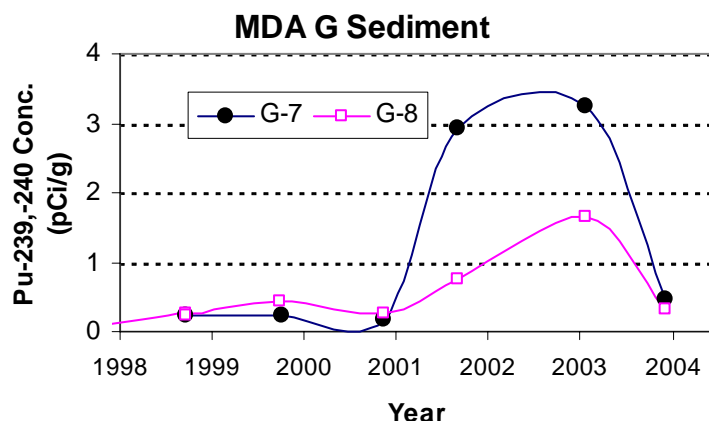
MDA G Sediment

Figure 6-18. Recent trends of Pu-239,240 activities at Material Disposal Area G sediment stations G-7 and G-8.

6. Water Canyon (includes Cañon de Valle, Potrillo, Fence, and Indio Canyons)

Water Canyon heads on the flanks of the Sierra de los Valles on US Forest Service land and extends across the Laboratory to the Rio Grande. Water Canyon and its tributary Cañon de Valle pass through the southern portion of the Laboratory where explosives development and testing historically and currently take place. Elevated concentrations of barium, HMX, and RDX have been previously measured in sediment and surface water. In 2004, dissolved barium was present in base flow at up to 85% of the New Mexico groundwater standard, and RDX occasionally is present in surface water above the 6.1-ppb EPA Tap Water Health Advisory in Cañon de Valle. Average concentrations for barium and RDX for 2004 are below these regulatory reference levels. The Laboratory's Remediation Services Project is investigating this area extensively in support of a Resource Conservation and Recovery Act Corrective Measures Study.

Area AB at TA-49 was the site of underground nuclear-weapons testing from 1959 to 1961 (Purtymun and Stoker 1987; ESP 1988). These tests involved HEs and fissionable material insufficient to produce a nuclear reaction. Area AB drains into Ancho and Water Canyons. Legacy surface contamination is responsible for the above-background concentrations of plutonium and americium present in the sediments downstream of this site. However, the site of highest surface contamination at Area AB drains north to Water Canyon, but no above-background plutonium extends more than 110 yards beyond Area AB.

G. Special Study of PCBs in the Los Alamos Area using Congener Analyses

PCBs are typically not detectable in Los Alamos surface waters when analyzed using standard EPA analytical methods, except in an occasional runoff sample from Los Alamos or Sandia Canyons. This presents an incomplete picture of PCB concentrations in surface waters, however, because the detection limits of the standard analytical methods are many orders of magnitude greater than regulatory limits prescribed by the New Mexico human health stream standard of 0.0017 μg/L. Starting in 2000 through 2003, the NMED and LANL have analyzed selected surface waters and sediments in the vicinity of the Laboratory using a much more sensitive nonstandard procedure, the EPA Method 1668 for the analysis of PCB congeners. Because the results from this special study have not been discussed in previous ESR reports, we include a brief summary here of the findings.

The congener analyses showed that stormwater runoff in northern New Mexico often contained detectable PCB concentrations, above the NMWQCC human health standard of 1.7 ng/L. Concentrations greater than the human health standard were found in Pajarito Plateau samples and in Rio Grande samples, both above and below the Laboratory.

On the Pajarito Plateau, stormwater runoff in every watershed tested contained total PCB concentrations greater than the human health standard: Pueblo Canyon (822 ng/L maximum), Los Alamos Canyon (125 ng/L), Sandia Canyon (253 ng/L), Pajarito Canyon (298 ng/L), and Water Canyon (121 ng/L). Depending on the location, Laboratory sources, urban runoff, and atmospheric deposition may contribute to the

contaminant load. For example, immediately below a urbanized area that drains into the north tributary of Pueblo Canyon, NMED measured a PCB concentration of 521 ng/L, indicating a significant urban source.

PCB concentrations measured in the Rio Grande were substantially lower than measured on the Pajarito Plateau, with a maximum concentration of 12.8 ng/L measured at the confluence with Ancho Canyon. Concentrations upstream of the Laboratory were generally comparable to those below.

The special study indicated that PCBs are commonly present in stormwater runoff at concentrations greater than the NMWQCC human health standard. This is a widespread and regional problem. Drainages within the Laboratory boundaries as well as drainages removed from Laboratory influences likely contain elevated PCB concentrations. Impacts to the Rio Grande from Pajarito Plateau drainages appear to be slight, with concentrations measured above the Laboratory comparable to those below.

Detailed results from the congener analyses are available in the following references: NMED (2003b), Mullen and Koch (2004), and Gallaher and Koch (2004).

H. Quality Assurance

To process watershed samples, we used the same quality assurance (QA) protocols and analytical laboratories described in Chapter 5. QA performance for the year is also described in Chapter 5.

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