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New Mexico's Right to Know: The Potential for Groundwater Contaminants from LANL to Reach the Rio Grande

Concerned Citizens for Nuclear Safety

George Rice

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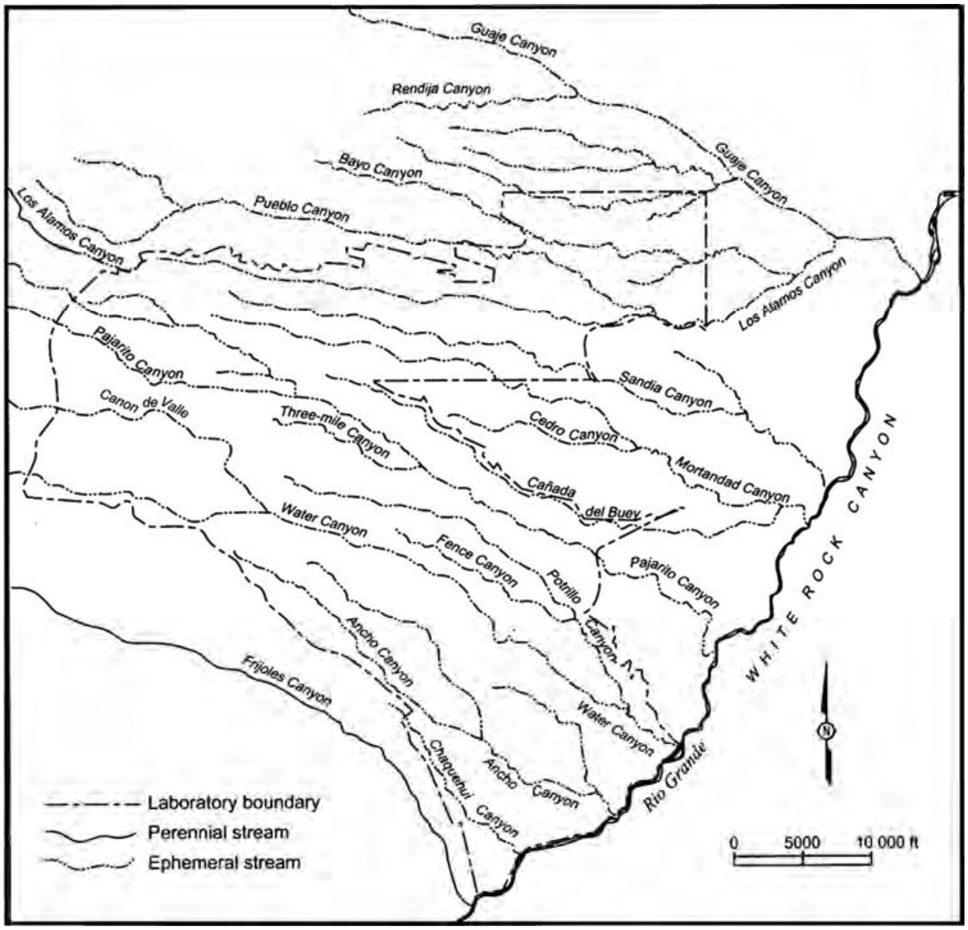
The Potential for Groundwater Contaminants from Los Alamos National Laboratory to Reach the Rio Grande



George Rice

Prepared for Concerned Citizens for Nuclear Safety

Second Technical Report
July 2004

On the Cover: Canyons traversing the Pajarito Plateau at Los Alamos National Laboratory.

Adapted from: Purtymun, W.D., 1995, *Geologic and Hydrologic Records of Observation Wells, Test Holes, Test Wells, Supply Wells, Springs, and Surface Water Stations in the Los Alamos Area,* LA-12883-MS, UC-903 and UC-940, January 1995.

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Executive Summary

Los Alamos National Laboratory (LANL) was established in 1943. It is located on the Pajarito Plateau in north central New Mexico, approximately 40 miles northwest of Santa Fe. The Pajarito Plateau consists of a series of east-west oriented canyons and mesas. It is bounded on the west by the Jemez Mountains and on the east by the Rio Grande.

LANL has discharged wastes from its industrial operations to the mesas and canyons of the plateau. Contaminants associated with LANL include americium-241, cesium-137, plutonium, strontium-90, tritium, chloride, nitrate, perchlorate and high explosives.

The uppermost geologic units of the plateau are volcanic rocks (Bandelier Tuffs). These are underlain by conglomerates, sandstones and basalts (Puye Formation and Cerros del Rio Basalts). The Puye Formation and Cerros del Rio Basalts are underlain by siltstones, sandstones and basalts (Santa Fe Group).

Groundwater at LANL occurs in four zones: 1) as shallow perched zones in tuff, 2) as shallow perched zones in canyon alluvium, 3) as intermediate perched zones in tuff, basalt and conglomerate and 4) in the regional aquifer. Water from the perched zones infiltrates to the underlying regional aquifer. The regional aquifer discharges to springs along the Rio Grande.

Contaminants from LANL have been found in perched zones in canyon alluvium, intermediate perched zones and the regional aquifer.

This report addresses two questions:

1. Is it possible for groundwater to transport contaminants from LANL to the Rio Grande during the 61 years LANL has existed?

2. If so, have contaminants from LANL reached the Rio Grande?

The answer to the first question is yes. Contaminants traveling along fast flow paths may reach the Rio Grande in less than 61 years.

The answer to the second question is also yes. LANL-derived contaminants have been detected in springs along the Rio Grande. High explosives have been found in Ancho Spring and Spring 6 and perchlorate has been found in Springs 4 and 4C.

Table of Contents

Figures

Tables

The Potential for Groundwater Contaminants from Los Alamos National Laboratory to Reach the Rio Grande

1.0 Introduction

This report addresses two questions:

- Is it possible for groundwater to transport contaminants from Los Alamos National Laboratory (LANL) to the Rio Grande during the 61 years LANL has existed?

- If so, have contaminants from LANL reached the Rio Grande?

In order for contaminants from LANL to reach the Rio Grande, three conditions must be satisfied.

1. Contaminants must have entered the groundwater.

2. Groundwater must flow toward the Rio Grande.

3. Groundwater, and the contaminants it transports, must be able to travel from contaminated areas at LANL to the Rio Grande in 61 years or less.[1]

If these conditions are satisfied, we can conclude it is possible for groundwater contaminants from LANL to reach the Rio Grande in the time available. In order to conclude that contaminants have reached the river, another condition must be satisfied:

4. Contaminants from LANL must be found in springs discharging to the Rio Grande.

Each of these conditions is examined below.

2.0 Physical Setting

LANL is located in north central New Mexico, approximately 40 miles northwest of Santa Fe (Figure 2-1).[2] It is on the Pajarito Plateau between the Rio Grande and the Jemez Mountains.[3] The Pajarito Plateau consists of a series of east-west oriented canyons and mesas (Figure 2-2).

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[1] LANL began operating in 1943. LANL, 2002b, pg. 3.

[2] Dale, 1998, pg. 1.

[3] LANL, 2002b, pg. 5.

The elevations of the mesas range from about 6,200 feet at the Rio Grande to about 7,800 feet along the flanks of the Jemez Mountains.[4]

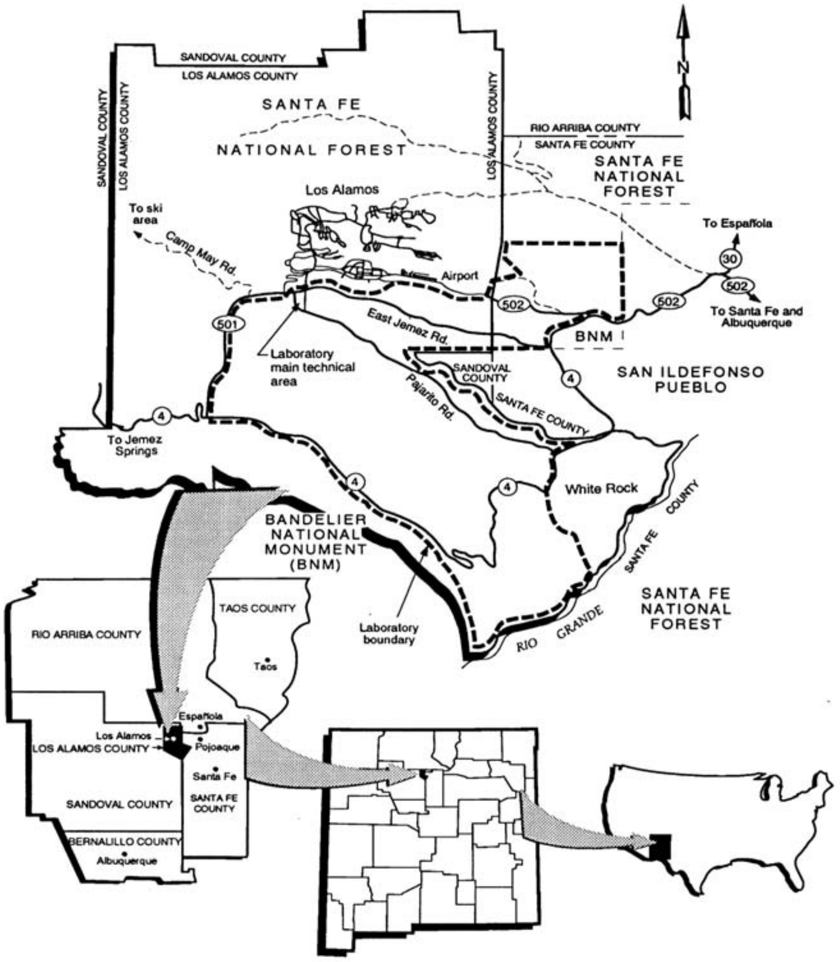

Figure 2-1
Location of Los Alamos National Laboratory

(Adapted from LANL 1992)

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[4] LANL, 2002b, pg. 5.

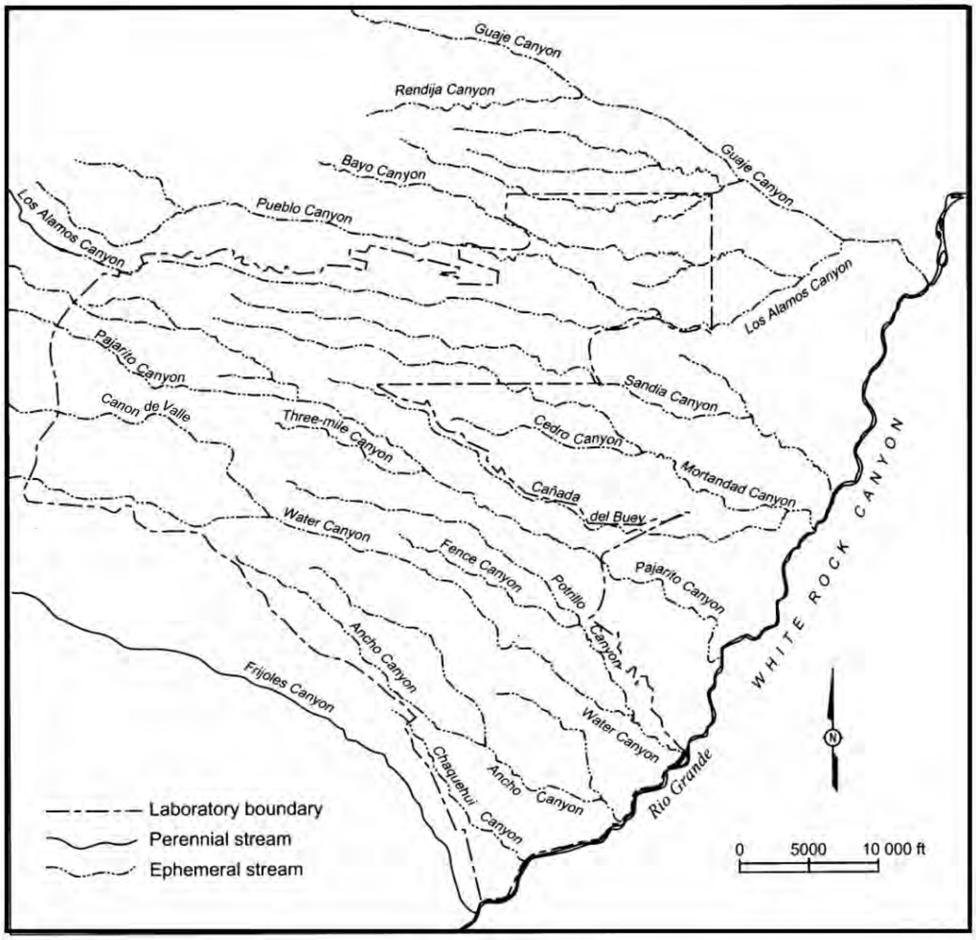

Figure 2-2
Canyons Traversing Pajarito Plateau
at Los Alamos National Laboratory
(Adapted from Purtymun, 1995)

All surface water on the Pajarito Plateau flows to the Rio Grande. Streams in the upper reaches of some canyons flow year-round due to the discharge of springs along the flanks of the Jemez Mountains (Guaje Canyon, Los Alamos Canyon, Pajarito Canyon, Cañon de Valle and Water Canyon).[5] However, surface flow is depleted by evapotranspiration and infiltration as the streams traverse the plateau, and most streams on LANL flow only intermittently.[6] Stream flow resulting from heavy storms and snowmelt is sufficient to reach the river several times a year.[7] Wastewater from sewage treatment plants and LANL industrial operations is discharged into some of the canyons.[8]

The uppermost rocks that form the plateau are the Bandelier Tuffs (Figure 2-3). These are volcanic rocks derived from the Jemez Mountains.[9] The Bandelier Tuffs are divided into two members, the Tshirege Member and the Otowi Member. The Tshirege is above the Otowi. These members are separated by the Cerro Toledo interval. The Guaje Pumice bed is at the base of the Otowi Member.[10] The tuffs are more than 1,000 feet thick near the Jemez Mountains and thin to a few hundred feet near the Rio Grande.[11]

The tuffs are underlain by the Puye Formation.[12] The upper portion of the Puye Formation is called the fanglomerate member.[13] This member is primarily composed of volcanic debris (e.g., tuff, rhyolite and pumice cobbles) in a matrix of clays and sands.[14] The lower portion of the Puye Formation is called the Totavi Lentil. This member is composed of cobbles, gravels and sands deposited by ancient streams.[15]

The Cerros del Rio Basalts are interbedded with the Puye Formation.[16] The basalts are a series of lava flows that originated east of the Rio Grande.[17] In the central portion of the Pajarito Plateau where LANL is located, the combined thickness of the conglomerate and basalts is greater than 1,000 feet.[18]

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[5] Purtymun, 1995, pg. 26.

[6] Purtymun, 1995, pg. 26. Several streams on LANL flow year-round due to spring discharge: the upper reaches of Pajarito Canyon and Cañon de Valle (S. Yanicak and M. Dale, NMED, personal communication, 2004) and the lower reaches of Pajarito Canyon and Ancho Canyon (Purtymun, 1995, pg. 26).

[7] Purtymun, 1995, pg. 26.

[8] Purtymun, 1995, pg. 26.

[9] LANL, 2002b, pg. 5.

[10] LANL, 2003b, pp. 4 -6.

[11] LANL, 2002b, pg. 5.

[12] Purtymun, 1995, pg. 5. The Puye Formation is also known as the Puye Conglomerate. A conglomerate is a rock composed of water worn fragments that have been cemented together. These are generally ancient stream deposits.

[13] A fanglomerate is a conglomerate that was originally deposited as an alluvial fan.

[14] Purtymun, 1995, pg. 14.

[15] Purtymun, 1995, pg. 14.

[16] LANL, 2003b, pp. 4 - 6.

[17] Purtymun, 1995, pg. 14.

[18] Stone and McLin, 2003, pp. 2, 24 and 28.

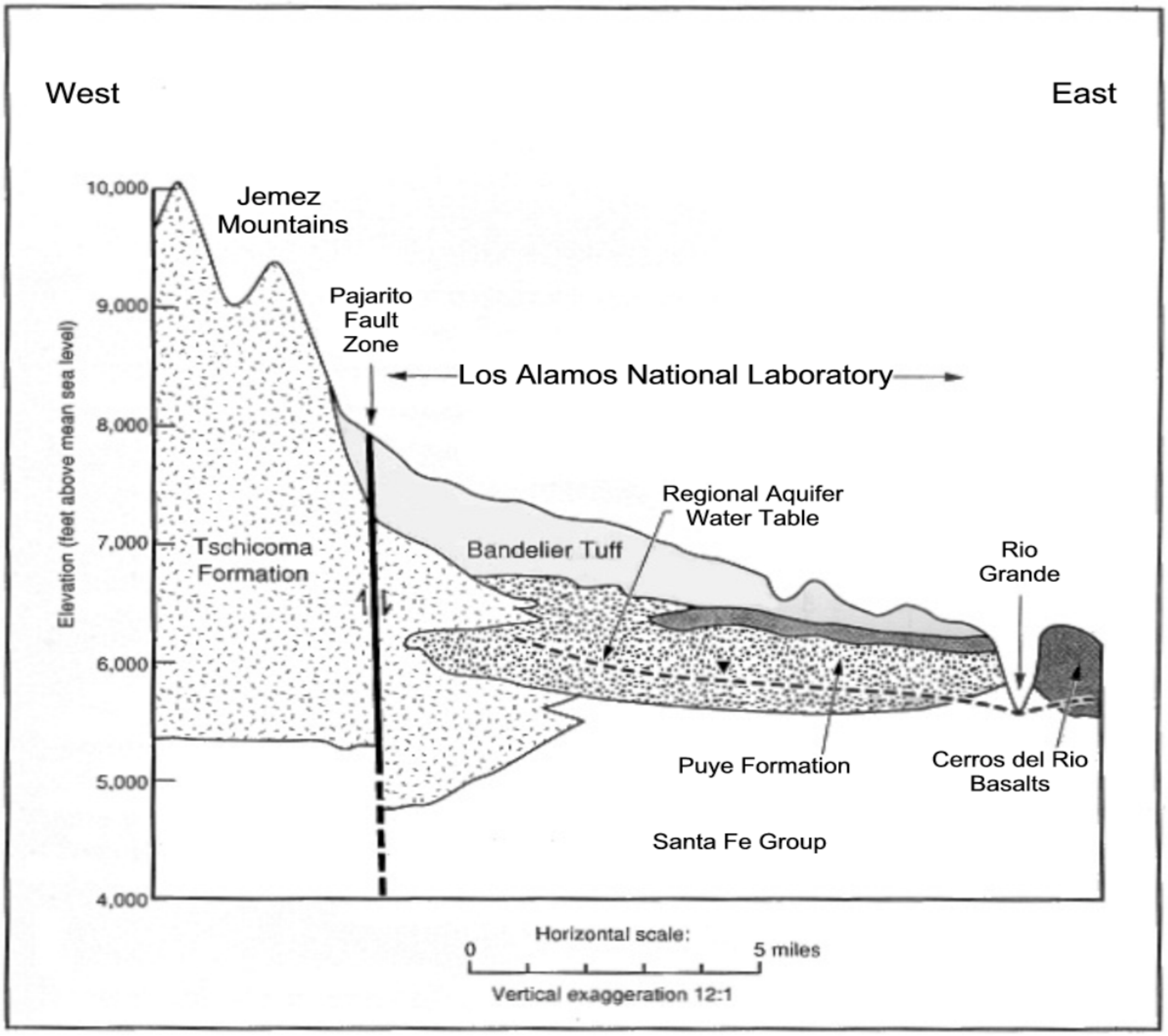

Figure 2-3
Generalized Geologic Cross-Section
of Pajarito Plateau

(Adapted from Robinson, 1998)

The Puye Formation and Cerros del Rio Basalts are underlain by the Santa Fe Group.[19] The Santa Fe Group is composed of three formations. These are, from shallowest to deepest, the Chaquehui Formation, the Chamita Formation and the Tesuque Formation. The Chaquehui Formation is a mixture of coarse sediments derived from the Jemez Mountains and from sources to the north and east of the Pajarito Plateau.[20] The Tesuque and Chamita Formations are composed of siltstones, sandstones and conglomerates.[21] The Santa Fe Group also contains interbedded basalt layers.[22] It is more than 3,000 feet thick.[23]

In the western portion of the Pajarito Plateau, where the majority of LANL operations are conducted, the Tschicoma Formation interfingers with the Puye Formation and the Santa Fe Group. The Tschicoma Formation consists of a series of lava flows derived from the Jemez Mountains. Beneath the Jemez Mountains this formation is at least 2,500 feet thick.[24]

The canyon bottoms are covered by alluvial deposits.[25] The alluvium is usually less than 20 feet thick and is absent in some areas.

3.0 Occurrence of Groundwater

Groundwater beneath the Pajarito Plateau occurs in four zones:

1. Shallow perched zones[26] in tuff
2. Shallow perched zones in canyon alluvium[27]
3. Intermediate perched zones within the tuffs, basalt and conglomerate[28]
4. In the regional aquifer (Figure 3-1)

The shallow tuff perched zones occur in the western and central portions of the plateau in the Tshirege Member of the Bandelier Tuffs.[29] These zones may be recharged from surface water infiltrating from streams west of LANL.[30] The water in this zone discharges to springs along canyons.[31]

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[19] Purtymun, 1995, pp. 4 and 5.
[20] Purtymun, 1995, pg. 11.
[21] Purtymun, 1995, pg. 6.
[22] Purtymun, 1995, pp. 253 - 266.
[23] LANL, 2002b, pg. 5.
[24] LANL, 2003b, pg. 4-4.
[25] LANL, 2003b, pg. 4-13. Alluvium is stream-deposited gravel, sand, silt and clay.
[26] Groundwater that occurs above a main aquifer is said to be perched. The strata immediately above and below a perched zone are unsaturated.
[27] LANL, 2003b, pg. 4-13.
[28] Stone and McLin, 2003, pp. 14 and 25; LANL, 2003b, pg. 4-13; Longmire, 2002a, pg. 3; and Gardner, et al., 1993, pp. 16 and 17.
[29] S. Yanicak and M. Dale, NMED, personal communication, 2004.
[30] Dale, et al., 1996, pg. 5.
[31] Purtymun, 1995, pg. 284; S. Yanicak and M. Dale, NMED, personal communication, 2004.

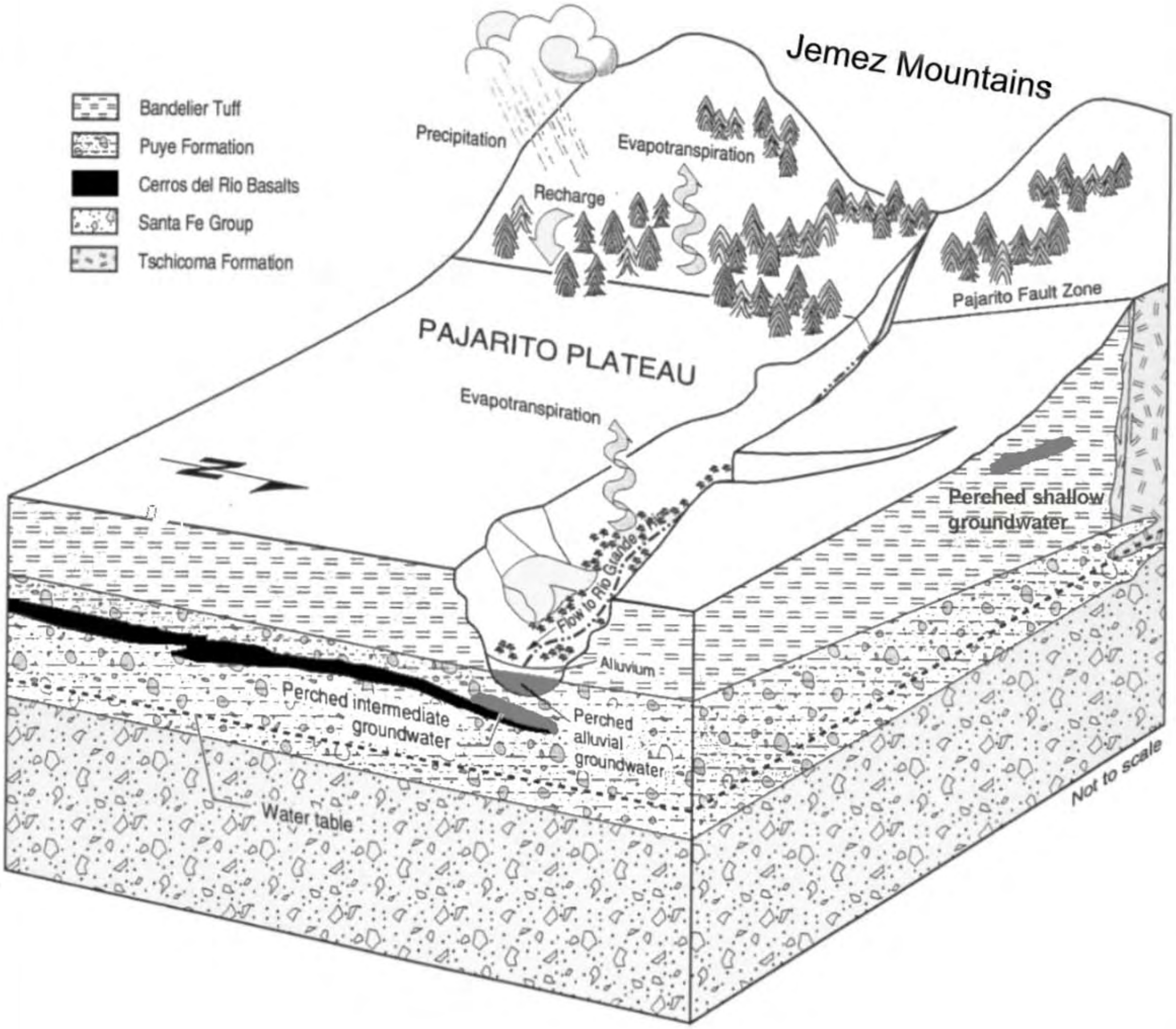

Figure 3-1
Occurrence of Groundwater
(Adapted from LANL, 1998b)

The perched alluvial zones occur in canyon bottoms of the plateau (e.g., Pueblo, Los Alamos, Mortandad and Pajarito).[32] The sources of perched water in the alluvium are natural spring flow and runoff and wastewater discharged from sewage treatment plants and industrial operations.[33] Water in the alluvium is discharged to the atmosphere (via evapo-transpiration), to streams in areas where the alluvium thins and to the intermediate perched or regional groundwater systems.[34]

Intermediate perched zones occur beneath the canyons (e.g., Pueblo, Los Alamos, Mortandad and Pajarito),[35] as well as beneath at least one of the mesas.[36] Depth to water ranges from about 125 feet to about 900 feet.[37, 38] The source of this perched water may be lateral flow from the Jemez Mountains or leakage from perched water in the overlying alluvium.[39] Intermediate perched water is found in the Otowi Member of the Bandelier Tuffs,[40] the Cerros del Rio Basalts[41] and the Puye Formation.[42] In some places two or more intermediate perched zones exist between land surface and the water table of the regional aquifer.[43] Intermediate perched groundwater discharges to springs and the regional aquifer.[44]

The regional aquifer exists beneath the entire plateau.[45] Depth to water ranges from about 1,200 feet near the Jemez Mountains to about 500 feet in the southeastern portion of LANL.[46, 47] Depending on location, the water table of the regional aquifer is found in the Cerros del Rio Basalts, the Puye Formation or the Santa Fe Group.[48] Groundwater in the regional aquifer generally flows from west to east, or from the Jemez Mountains toward the Rio Grande.[49] The sources of water in the regional aquifer are recharged along the Jemez Mountains[50] and leakage from overlying perched zones.[51] Water in the regional aquifer is

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[32] LANL, 2002a, pp. 181 - 183.
[33] Purtymun, 1995, pg. 26.
[34] LANL 2002a, pp. 19, 44 and 45.
[35] Purtymun, 1995, pg. 28; Longmire, 2002a, pg. 3; and Broxton, 2002, log of well R-32.
[36] Perched water has been found beneath the mesa between Threemile and Potrillo Canyons. In well R-19, a perched zone was found in the Puye Formation at a depth of about 900 feet (Longmire, 2002b, pg. 3).
[37] Gardner, et al., 1993, pg. 16.
[38] Longmire, 2002b, pg. 9.
[39] LANL, 2003b, pg. 3-2.
[40] LANL, 2002d, pg. 8.
[41] Stone and McLin, 2003, pg. 14.
[42] Stone and McLin, 2003, pg. 25.
[43] Stone and McLin, 2003, pp. 14 and 25; Broxton, et al., 2001a, pg. 26.
[44] LANL, 2002a, pp. 19 and 45.
[45] Stone, W., 2001a.
[46] Stone and McLin, 2003, pg. 32.
[47] Purtymun, 1995, pg. 29.
[48] Stone and McLin, 2003, pp. 2, 21, 24 and 28; and LANL, 2003b, pg. 1-11.
[49] Stone, 2001a.
[50] Purtymun, 1995, pg. 29.
[51] LANL, 2003b, pg. 3-3.

discharged through water supply wells on the plateau and along the Rio Grande[52] and to springs along the Rio Grande.[53]

3.1 Springs

There are many springs in the vicinity of LANL, both on the Pajarito Plateau and along the Rio Grande. This report focuses on the springs along the Rio Grande.

Over 20 springs have been identified along the Rio Grande below LANL (Figure 3-2). They emerge from the Totavi Lentil, the Chaquehui Formation and the Tesuque Formation.[54] The largest spring, 4A, discharges over 100 gallons per minute.[55] The total spring discharge along the 11-mile reach between Otowi and Frijoles Canyon is estimated to be 5,500 acre-feet/year.[56]

4.0 Background Groundwater Quality

Background groundwater quality is the quality of water that would exist if it were not affected by LANL operations.

Contaminants associated with operations at LANL include americium-241, cesium-137, plutonium, strontium-90, tritium, chloride, nitrate, perchlorate and high explosives.[57]

Unfortunately, there are few groundwater samples collected from locations on the Pajarito Plateau that might be considered background. Nearly all of the groundwater samples are from locations that are down gradient of LANL operations. Therefore, they may have been affected by LANL-derived contaminants.

Groundwater samples have been collected from only two locations that are not potentially down gradient from LANL operations, the spring at Water Canyon Gallery and American Spring. Water Canyon Gallery is hydraulically upgradient of LANL, approximately 3/4 mile west of the LANL boundary (Figure 5-2). This spring discharges from the shallow tuff perched zone at a rate of approximately 150 gallons per minute.[58]

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[52] Purtymun, 1995, pg. 30; and Vesselinov and Keating, 2002, pg. 18.
[53] LANL, 2002a, pg. 45.
[54] Purtymun, 1995, pp. 284 and 285.
[55] Purtymun, 1995, pp. 284.
[56] Purtymun, 1995, pg. 30.
[57] LANL, 1995a, pg. VI-13; LANL, 2002b, pg. 301; and LANL, *Information Sheet: 260 Outfall*, ER2002-0333, undated.
[58] Purtymun, 1995, pg. 284.

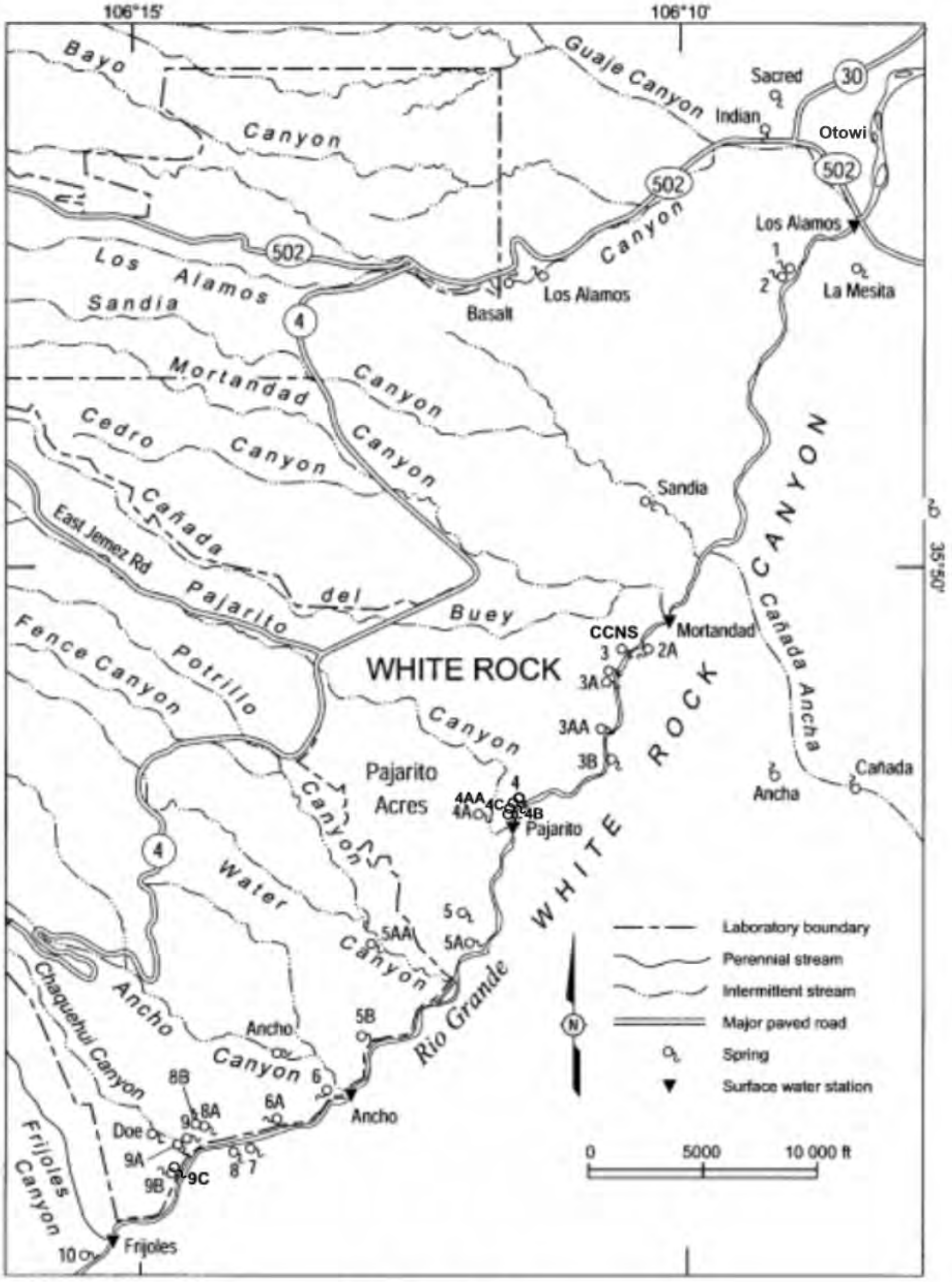

Figure 3-2
Springs
(Adapted from Purtymun, 1995)

The spring flow at Water Canyon Gallery emerges from a tunnel dug into the Bandelier Tuff. The tunnel is about 30 feet long and is framed with timbers and sheet metal to keep it from collapsing. Until 1989, the discharge was piped to LANL and used as a source of potable water.[59] The spring now discharges to Water Canyon, as it did before LANL was established.[60]

American Spring is also upgradient of LANL, approximately 1.5 miles west of the LANL boundary.[61] The spring discharges from the shallow tuff perched zone at a rate of approximately 5 gallons per minute.[62]

Table 4-1 presents a summary of concentrations of LANL-associated contaminants at Water Canyon Gallery and American Spring. Because the spring flow originates in the Bandelier Tuff, it may not be representative of background water quality in other geologic units.

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[59] LANL, 1995a, pg. 14.

[60] Purtymun, 1995, pg. 282; and S. Yanicak and M. Dale, NMED, personal communication, 2004.

[61] Purtymun, 1995, pg. 282.

[62] Purtymun, 1995, pg. 284.

Table 4-1
Background Groundwater Quality
Water Canyon Gallery and American Spring

Contaminant	Concentration Range[63]	Average Concentration	Number of Samples
Water Canyon Gallery[64]			
Americium-241	ND[65]	ND	8
Cesium-137	ND	ND	8
Plutonium-238	ND	ND	8
Plutonium-239/240	ND	ND	8
Strontium-90	ND	ND	8
Tritium[66]	13.9 pCi/L – 41.5 pCi/L	27.7 pCi/L	2
Chloride	1 mg/L – 12 mg/L	3.0 mg/L	8
Nitrate (as N)	0.15 mg/L – 0.97 mg/L	0.37 mg/L	8
Perchlorate	ND	ND	2
American Spring[67]			
Perchlorate	0.3 – 0.5 µg/L	0.4	2

5.0 Groundwater Contamination at LANL

This section examines the major areas of groundwater contamination at LANL. It does not address all groundwater contamination. The locations of wells and springs used in this section are shown in Figures 5-1 and 5-2.[68]

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[63] ND = not detected. mg/L = milligrams per liter (10^{-3} grams per liter). µg/L = micrograms per liter (10^{-6}grams per liter). pCi/L = picocuries per liter (10^{-12} curies per liter).

[64] Data Sources: LANL Environmental Surveillance Reports: 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2001. (LANL, 1994a, LANL, 1995a, LANL, 1996a, LANL, 1996b, LANL, 1997a, LANL, 1999b, LANL, 2000b, LANL, 2001a, LANL, 2002b), except as noted.

[65] LANL defines the detection of a radionuclide (e.g., strontium-90 and plutonium-238) as an analytical result that is 1) greater than or equal to three times the uncertainty associated with the analysis and 2) greater than the detection limit (LANL, 2002b, pg. 348). This definition is used throughout this report.

[66] Blake, 1995, pg. 28.

[67] Data source: NMED, 2004d.

[68] Most of the groundwater quality data used in this report was collected after 1992. It is likely that groundwater contamination in some areas was more severe in the past. For example, LANL stopped discharging untreated wastes to Pueblo Canyon in 1951 (LANL, 2002b, pg. 181). Contaminant concentrations in alluvial groundwater along the canyon have probably declined since the discharge of untreated effluents ceased.

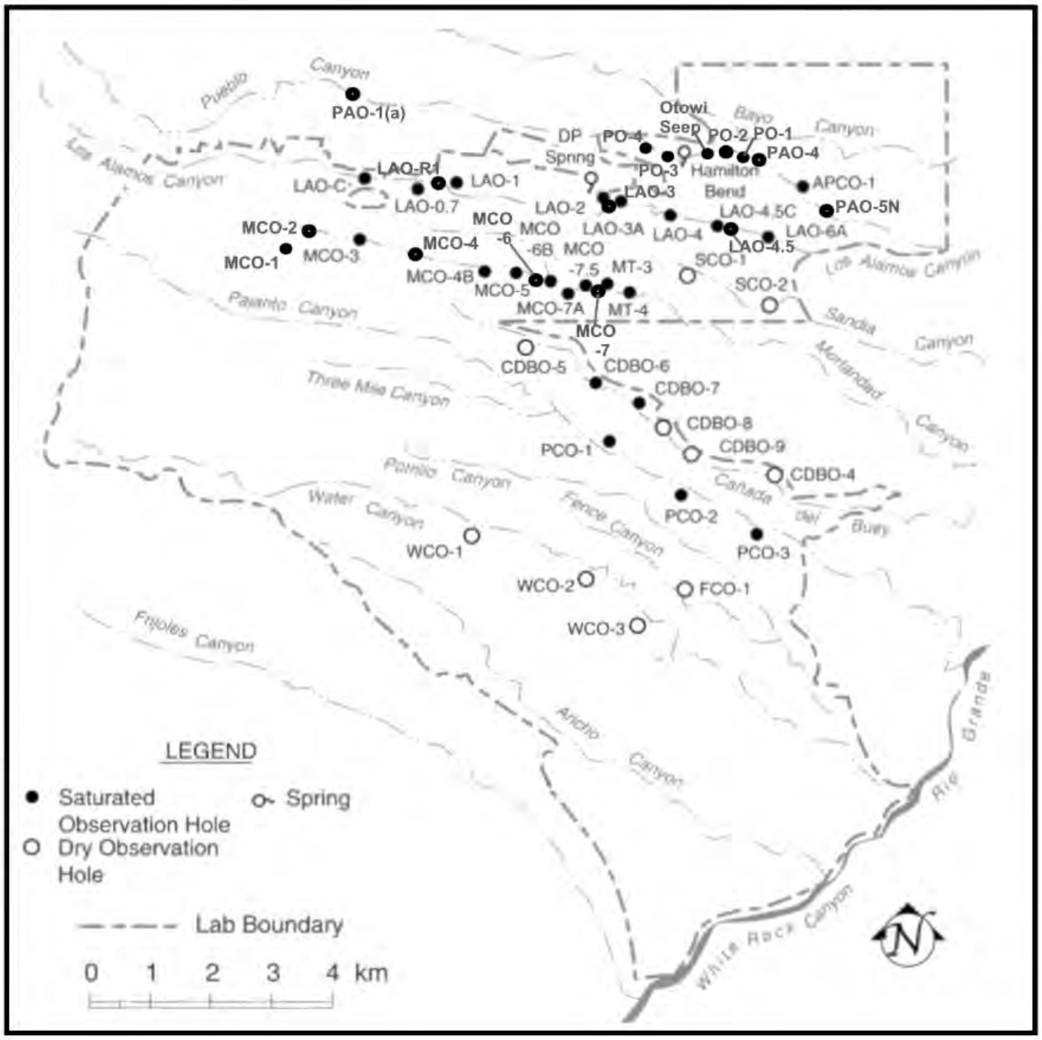

Figure 5-1
Wells and Springs in
Perched Alluvial Aquifers
(Adapted from LANL, 2002b)

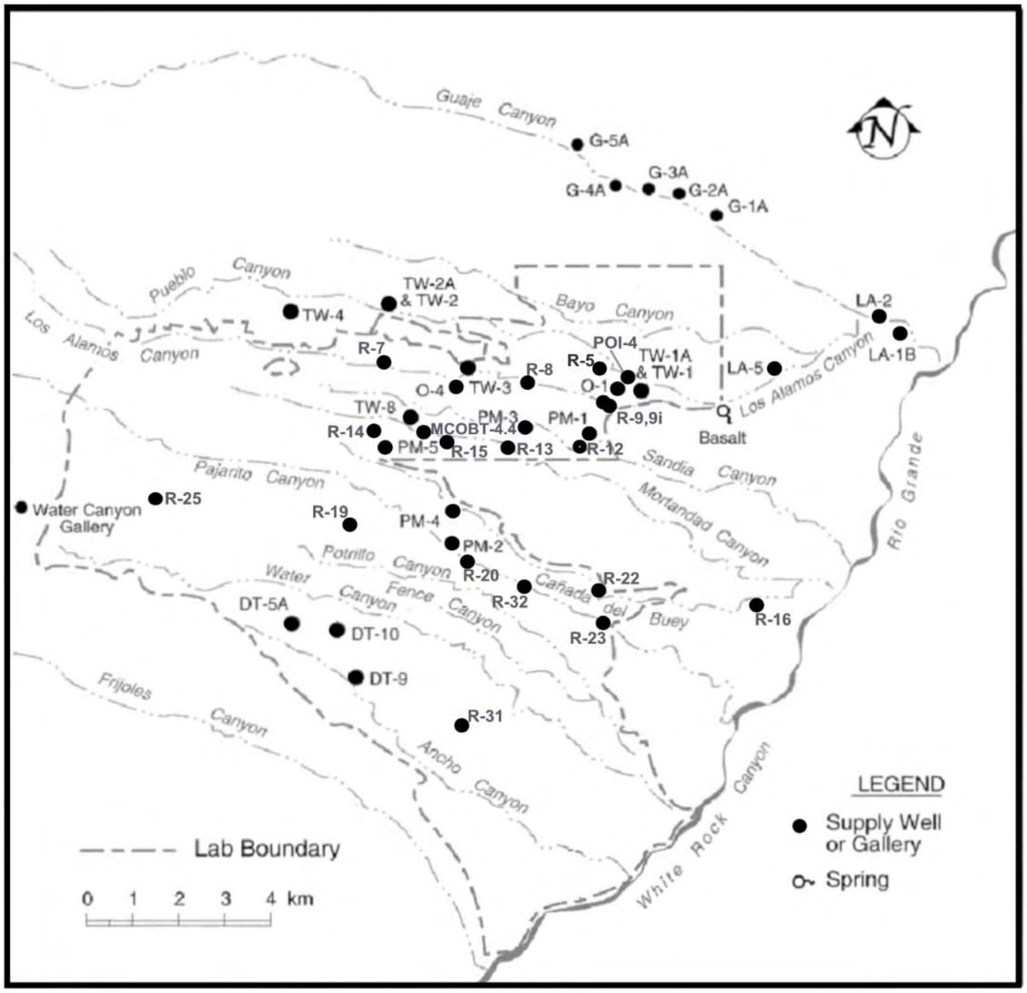

Figure 5-2
Wells and Springs in
Intermediate Zone and Regional Aquifer

(Adapted from LANL, 2002b)

Contaminated groundwater is known to exist in Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon and at Technical Area 16 (Figure 5-3). Groundwater quality at each of these areas is examined below.

It is important to note that detection of a contaminant associated with LANL operations does not necessarily mean that a sample contains LANL-derived contaminants. Some of the contaminants (e.g., tritium and nitrate) occur naturally. In addition, laboratory analytical methods used for some contaminants (e.g., perchlorate and strontium-90) are not always reliable.[69]

Discussions of tritium and perchlorate data at LANL are presented in Appendices A and B.

5.1 Pueblo Canyon

Untreated liquid wastes generated by the Manhattan Project were discharged to Acid Canyon, a tributary to Pueblo Canyon, between 1943 and 1951. A treatment plant was completed in 1951 and treated effluent was discharged between 1951 and 1964.[70] The wastes discharged to Acid Canyon were probably similar to those discharged by the Radioactive Liquid Waste Treatment Facility (RLWTF) at Technical Area 50 (TA-50) (see Section 5.3 on Mortandad Canyon below). The Los Alamos County Bayo Sewage Treatment Plant currently discharges effluent to Pueblo Canyon.[71]

The sediments in Acid and Pueblo Canyons contain americium-241, cesium-137 and plutonium[72] and are a potential source of radioactive contaminants found in the groundwater.

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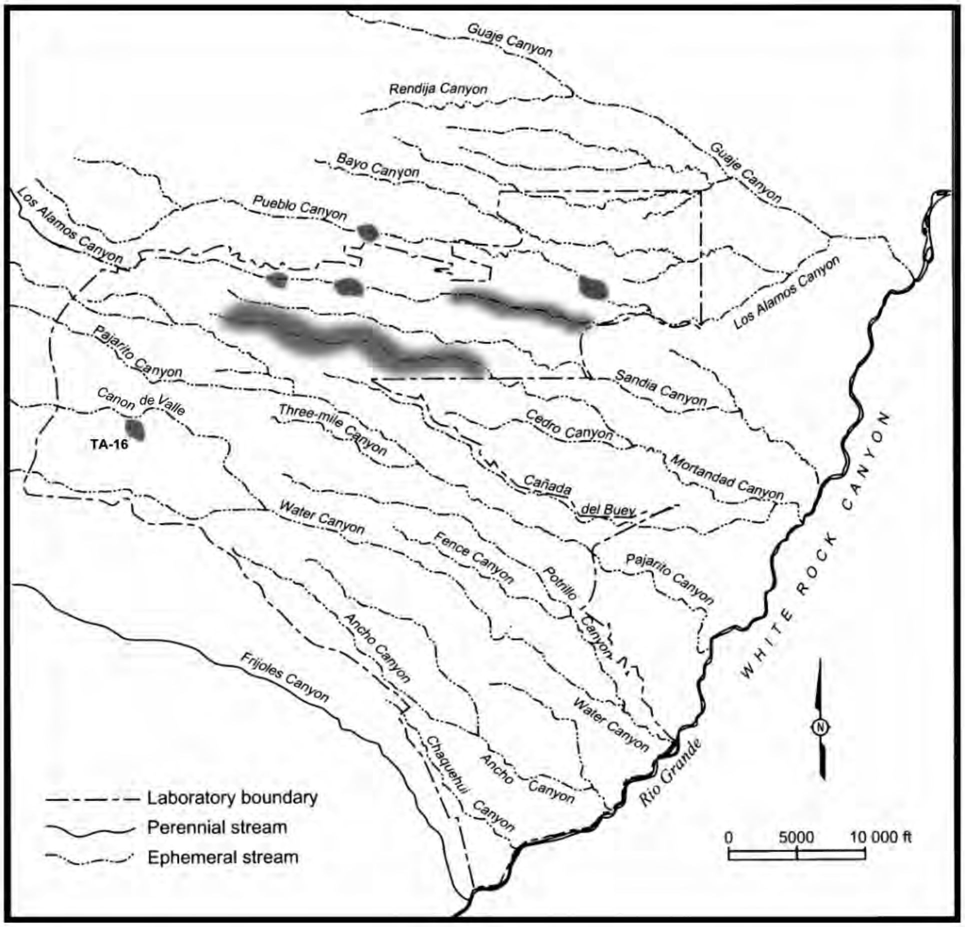
[69] It should also be noted that most of the radionuclide (americium, cesium, plutonium and strontium) analyses reported here are for unfiltered samples. Unfiltered water samples may contain fine sediments that also contain radionuclides. When these samples are analyzed, the result represents the sum of the radionuclides dissolved in the water and the radionuclides in the sediment. Thus, analyses of unfiltered samples may result in reported radionuclide concentrations that are too high. Where available, analyses of filtered samples are used. If an analysis of an unfiltered sample resulted in a higher concentration than the analysis of a filtered sample, the result from the unfiltered sample is given in the footnote. The use of unfiltered samples is appropriate when the purpose of sampling is to determine what people may be ingesting. But, when the purpose is to determine the concentrations of radionuclides being transported by groundwater, filtered samples are usually more appropriate. However, this may not apply to radionuclides that are transported on colloidal particles.

[70] LANL, 2002b, pg. 181.

[71] LANL, 2002b, pg. 181.

[72] LANL, 2002b, pp. 310, 311 and 405.



▨ Contamints detected in perched alluvial zone, perched intermediate zone, or regional aquifer. Based on detections of perchlorate, strontium-90 (alluvial wells only), tritium, and high explosives.

Figure 5-3
Contaminated Groundwater
(Adapted from Purtymun, 1995)

5.1.1 Pueblo Canyon Alluvial Perched Groundwater

Contaminants that have been detected in the alluvial aquifer include: americium-241, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride and nitrate (Table 5-1).

Water quality data are from wells APCO-1, PAO-1(a), PAO-4, PAO-5N, PO-1, PO-1A, PO-2, PO-3, PO-3B, PO-4A, PO-4B and from Hamilton Bend Spring and Otowi Seep.

Table 5-1
Contaminants Detected in Pueblo Canyon
Alluvial Perched Groundwater

Contaminant	Concentration Range	EPA MCL[73]	DOE DCG[74]
Americium-241	ND - 0.141[75] pCi/L	NA[76]	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND - 0.29[77]	NA	40 pCi/L
Plutonium-239/240	ND - 0.063[78] pCi/L	NA	30 pCi/L
Strontium-90	ND - 1.42[79] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND - 15,000 pCi/L[80]	20,000 pCi/L	2,000,000 pCi/L
Chloride	0.3 mg/L[81] - 1028[82] mg/L	NA	NA
Nitrate (as N)	ND - 245[83] mg/L	10 mg/L	NA
Perchlorate	ND	NA	NA

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[73] LANL, 2002b, pp. 341, 345 and 358. Environmental Protection Agency (EPA) Maximum Contaminant Limit (MCL): the regulatory standard established to protect human health.

[74] LANL, 2002b, pp. 341, 345 and 358. Department of Energy (DOE) Derived Concentration Guide (DCG) for water: the concentration of a radionuclide in water that, if consumed at a maximum rate of 730 liters per year, would give a dose of 100 millirem per year (LANL, 2002b, pg. 523).

[75] Well APCO-1, 1998, unfiltered sample (LANL, 1999b, pg. 192).

[76] NA = not applicable.

[77] Hamilton Bend Spring, unfiltered sample (NMED, 2004c)

[78] APCO-1, 1995, filtered sample (NMED, 2004c). Unfiltered sample: 7.55 pCi/L, Otowi Seep, 1963, analytical uncertainty not given (NMED, 2004c).

[79] Well APCO-1, 2001, filtered sample (LANL, 2002b, pg. 346). Unfiltered sample: 2,602 pCi/L, well PO-4A, 1961 (NMED, 2004c).

[80] Well PO-3B, 1971 (NMED, 2004c).

[81] Well PO-3B, 1960 (NMED, 2004c).

[82] Well PO-1A, 1957 (NMED, 2004c).

[83] Well PO-1A, 1957 (NMED, 2004c).

5.1.2 Pueblo Canyon Intermediate Perched Groundwater

Intermediate perched groundwater along Pueblo Canyon occurs in basalt and the Puye Formation.[84] Depth to water ranges from about 120 feet to about 390 feet.[85, 86] Contaminants that have been detected in the intermediate zone include: americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride and nitrate (Table 5-2).

Water quality data are from wells TW-1A, TW-2A, POI-4 and R-5.

Table 5-2
Contaminants Detected in Pueblo Canyon
Intermediate Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 0.065[87] pCi/L	NA[88]	30 pCi/L
Cesium-137	ND - 56[89] pCi/L	NA	3,000 pCi/L
Plutonium-238	ND - 0.032 pCi/L[90]	NA	40 pCi/L
Plutonium-239/240	ND - 4.22[91] pCi/L	NA	30 pCi/L
Strontium-90	ND - 3.3 pCi/L[92]	8 pCi/L	1,000 pCi/L
Tritium	ND - 19,900[93] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	0.4[94] mg/L - 508[95] mg/L	NA	NA
Nitrate (as N)	ND - 19.4[96] mg/L	10 mg/L	NA
Perchlorate	ND	NA	NA

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[84] Purtymun, 1995, pp. 220 and 221; LANL, 2002a, pg. 5.
[85] Purtymun, 1995, pg. 221.
[86] LANL, 2002a, pg. 3.
[87] Well TW-2A, 1995, not known if filtered (LANL 1996b, pg. 201). Unfiltered sample: 0.23 pCi/L, Well TW-2A, 1980 (NMED, 2004c).
[88] NA = not applicable.
[89] Well TW-1A, 1991, not known if filtered (LANL, 1996a, pg. 236).
[90] Well TW-1A, 1985, unfiltered sample (NMED, 2004c).
[91] Well TW-1A, 1964, unfiltered sample (NMED, 2004c).
[92] Well TW-1A, 1981, unfiltered sample (NMED, 2004c).
[93] Well TW-2A, 1979 (NMED, 2004c).
[94] Well TW-2A, 1960 (NMED, 2004c).
[95] Well TW-1A, 1957 (NMED, 2004c).
[96] Well TW-1A, 1994 (LANL, 1996a, pg. 240). Some nitrate may originate at the Bayo Sewage Treatment Plant (LANL, 1996a, pp. 267 - 268).

5.1.3 Pueblo Canyon Regional Aquifer Groundwater

Water in regional aquifer wells along Pueblo Canyon ranges in depth from about 580 feet to about 1,170 feet.[97] Contaminants detected in the regional aquifer include: americium-241, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride, nitrate and perchlorate (Table 5-3).

Water quality data are from wells O-1, TW-1, TW-2, TW-4 and R-5[98].

Table 5-3
Contaminants Detected in Pueblo Canyon
Regional Aquifer

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 0.052[99] pCi/L	NA	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	0.136 pCi/L[100]	NA	40 pCi/L
Plutonium-239/240	ND - 0.063[101] pCi/L	NA	30 pCi/L
Strontium-90	ND - 6.6[102] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND – 1,100[103] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	ND - 55.9[104] mg/L	NA	NA
Nitrate (as N)	ND - 122[105] mg/L	10 mg/L	NA
Perchlorate	ND - 5.85[106] mg/L	NA	NA

5.2 Los Alamos Canyon

Both treated and untreated wastes were discharged to Los Alamos Canyon during the Manhattan Project.[107] Between 1952 and 1986, treated industrial effluent was discharged to

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[97] Purtymun, 1995, pp. 219 and 267.

[98] Well R-5 is completed in both the intermediate perched zone and the regional aquifer (LANL, 2003d, pg. 4).

[99] Well TW-1, 2000, unfiltered sample (LANL, 2001b, pg. 329).

[100] Well O-1, 2000, unfiltered sample.

[101] Well TW-4, 1993, not known if filtered (LANL, 1995a, pg. VII-9).

[102] Well TW-4, 1994, not known if filtered (LANL, 1996a, pp. 232 and 233).

[103] Well TW-1, 1992 (NMED, 2004c).

[104] Well TW-2, 1996 (LANL, 1997a, pg. 189).

[105] Well TW-1, 1952 (NMED, 2004c).

[106] LANL, 2002b, pg. 359. This value is the highest of four undisputed perchlorate detections for well O-1 in 2001. There were 43 total perchlorate analyses for well O-1 in 2001. Up to 40 pCi/L of tritium has been found in well O-1 (LANL, 2002b, pg. 352). This indicates that at least a portion of the water in this well was recharged since LANL began operating.

[107] LANL, 2002b, pg. 182.

DP Canyon, a tributary to Los Alamos Canyon.[108] The wastes discharged to Los Alamos Canyon were probably similar to those discharged by the RLWTF at TA-50 (see Section 5.3 on Mortandad Canyon below).

In January 1993, the Omega West reactor was discovered to be leaking tritium into Los Alamos Canyon.[109] The leakage rate was estimated to be three gallons per hour.[110] The tritium concentration of the leakage was probably greater than 100,000 pCi/L.[111] The reactor may have been leaking since it began operating in 1956.[112]

The sediments in Los Alamos Canyon contain above background concentrations of americium-241, cesium-137 and plutonium.[113] These sediments are a potential source of the radioactive contaminants found in groundwater.

5.2.1 Los Alamos Canyon Alluvial Perched Groundwater

Contaminants detected in the alluvial aquifer include: americium-241, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride and nitrate (Table 5-4).

Water quality data are from wells LAO-C, LAO-0.7, LAO-1, LAO-2, LAO-3, LAO-3A, LAO-4, LAO-4.5 LAO-4.5C, LAO-6, LAO-6A, LAOR-1, LAUZ-2 and DP Spring.

Table 5-4
Contaminants Detected in Los Alamos Canyon
Alluvial Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 0.509[114] pCi/L	NA[115]	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND - 0.105[116] pCi/L	NA	40 pCi/L
Plutonium-239/240	ND - 0.049[117] pCi/L	NA	30 pCi/L

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[108] LANL, 2002b, pg. 182. In the late 1960s, tritium concentrations in DP Canyon surface water ranged from 170,000 pCi/L to 4,860,000 pCi/L (LANL, 1995a, pg. VII-42).

[109] LANL, 1995a, pg. VII-40.

[110] LANL, 1995a, pg. VII-40.

[111] Based on concentration of tritium that leaked into the basement of the reactor building during high stream flows: 100,000 pCi/L - 120,000 pCi/L (LANL, 1995a, pg. VII-45).

[112] LANL, 1995a, pg. VII-45.

[113] LANL, 1999b, pg. 184.

[114] Well LAO-3, 1995, sample filtered (NMED, 2004b).

[115] NA = not applicable.

[116] Well LAO-4.5C, 1995, sample filtered (NMED, 2004b). Unfiltered sample: 0.46 pCi/L, well LAO-1, 1972 (NMED, 2004b).

[117] Well LAO-6, 1995, sample filtered (NMED, 2004b). Unfiltered sample: 10.4 pCi/L, well LAO-4, 1982 (NMED, 2004b).

Strontium-90	ND - 68.8[118] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND - 280,000 pCi/L[119]	20,000 pCi/L	2,000,000 pCi/L
Chloride	15.8[120] mg/L - 147[121] mg/L	NA	NA
Nitrate (as N)	ND - 63.7[122] mg/L	10 mg/L	NA
Perchlorate	ND	NA	NA

5.2.2 Los Alamos Canyon Intermediate Perched Groundwater

Intermediate perched groundwater along Los Alamos Canyon occurs in basalt[123] and the Puye Formation.[124] Depth to water ranges from about 180 feet to about 360 feet.[125, 126] Contaminants detected in the intermediate zone include: americium-241, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride and nitrate (Table 5-5).

Water quality data are from wells LAOIA-1.1,[127] R-7, R-9i, Basalt Spring and Los Alamos Spring.

Table 5-5
Contaminants Detected in Los Alamos Canyon
Intermediate Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 0.049[128] pCi/L	NA	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND - 0.2[129] pCi/L	NA	40 pCi/L
Plutonium-239/ 240	ND - 5.55[130] pCi/L	NA	30 pCi/L
Strontium-90	ND - 0.88[131] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND - 2,300[132] pCi/L	20,000 pCi/L	2,000,000 pCi/L

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[118] DP Spring, 1998, sample filtered, (LANL, 1999b, pg. 193). Unfiltered sample: 1,080 pCi/L, DP Canyon, no date given, (LANL, 1998c).
[119] Well LAO-2, 1970 (NMED, 2004b).
[120] Well LAO-4, 1996 (LANL, 1997a, pg. 192).
[121] Well LAO-C, 1981 (NMED, 2004b).
[122] Well LAO-3, 1972 (NMED, 2004b).
[123] Longmire, 2002c, pg. 3.
[124] LANL, 2002a, pg. 5.
[125] Longmire, 2002c, pg. 3.
[126] LANL, 2002a, pg. 5.
[127] LANL, 1996a, pg. 260.
[128] Well R-9i, 2000, filtered sample (Longmire, 2002c, pg. A-35). Unfiltered sample: 1.2 pCi/L, Basalt Spring, 1980 (NMED, 2004b).
[129] Los Alamos Spring, 1973, unfiltered sample, (NMED, 2004b).
[130] Basalt Spring, 1962, unfiltered sample (NMED, 2004b).
[131] Basalt Spring, 2000, filtered sample (LANL, 2001b, pg. 332).
[132] Basalt Spring, 1975 (NMED, 2004b).

Chloride	0.3[133] mg/L - 46[134] mg/L	NA	NA
Nitrate (as N)	ND - 16.2[135] mg/L	10 mg/L	NA
Perchlorate	ND	NA	NA

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[133] Basalt Spring, 1960 (NMED, 2004b).
[134] Basalt Spring, 1998 (LANL, 1999b, pg. 200).
[135] Basalt Spring, 2000 (LANL, 2001b, pg. 341).

5.2.3 Los Alamos Canyon Regional Aquifer Groundwater

Water in regional aquifer wells along Los Alamos Canyon ranges in depth from about 690 feet to about 900 feet.[136, 137] Contaminants detected in the regional aquifer include: americium-241, plutonium-238, plutonium-239/240, strontium-90, chloride and nitrate (Table 5-6).

Water quality data are from wells O-4, TW-3, LA-1A, LA-1B, LA-2, LA-3, LA-4, LA-5, LA-6, R-7, R-8, R-9, Otowi House Well, Sacred Spring and Indian Spring.

Table 5-6
Contaminants Detected in Los Alamos Canyon Regional Aquifer

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 1[138] pCi/L	NA	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND - 0.223[139] pCi/L	NA	40 pCi/L
Plutonium-239/240	ND - 0.14[140] pCi/L	NA	30 pCi/L
Strontium-90	ND - 35.1[141] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND – 2,811[142] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	0.1[143] mg/L - 56.3[144] mg/L	NA	NA
Nitrate (as N)	ND - 10.8[145] mg/L	10 mg/L	NA
Perchlorate	ND	NA	NA

5.3 Mortandad Canyon

The Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50 has discharged wastes to Mortandad Canyon since 1963.[146] The facility currently discharges approximately 10,000

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[136] Longmire, 2002c, pg. 4.
[137] LANL, 2002c, pg. 33.
[138] Well LA-1B, 1973, unfiltered sample (NMED, 2004b).
[139] Well TW-3, 1973, unfiltered sample (NMED, 2004b).
[140] Well LA-3, 1968, unfiltered sample (NMED, 2004b).
[141] Well TW-3, 1994, unfiltered sample (LANL, 1996a, pg. 233).
[142] Well LA-5, 1974 (NMED, 2004b). A tritium value of 3,800 pCi/L was measured in a sample collected from Sacred Spring in 1995 (LANL, 1996b, pg. 274). However, a duplicate sample analyzed by the University of Miami Tritium Laboratory yielded a value of 3.42 pCi/L (LANL, 1996b, pg. 274). The value obtained by the University of Miami is believed to be more accurate (LANL, 1996b, pg. 176). See Appendix A for a discussion of tritium analyses.
[143] Well TW-3, 1960, (NMED, 2004b).
[144] Otowi House Well, 1997, (NMED, 2004b).
[145] Otowi House Well, 1994, (NMED, 2004b).
[146] LANL, 2002b, pg. 182.

gallons per day.[147] The recent character of these wastes is shown in Tables 5-7 and 5-8.[148] Maximum historical contaminant concentrations are given in Table 5-9.

Table 5-7
Average Concentrations of Contaminants in
Discharges from the RLWTF at TA-50, 1992 - 1993[149]

Contaminant	1992	1993
Chloride	59 mg/L	63 mg/L
Nitrate (as N)	204 mg/L	360 mg/L

Table 5-8
Average Concentrations of Contaminants in
Discharges from the RLWTF at TA-50, 1999 - 2001[150]

Contaminant	1999	2000	2001
Americium-241	55.0 pCi/L	2.25 pCi/L	4.11 pCi/L
Cesium-137	76.9 pCi/L	166.7 pCi/L	15.7 pCi/L
Plutonium-238	121.3 pCi/L	3.39 pCi/L	5.46 pCi/L
Plutonium-239/240	70.0 pCi/L	1.86 pCi/L	1.79 pCi/L
Strontium-90	18.2 pCi/L	17.8 pCi/L	2.91 pCi/L
Tritium	24,252 pCi/L	48,713 pCi/L	9,297 pCi/L
Nitrate (as N)	24.2 mg/L	2.50 mg/L	3.86 mg/L
Perchlorate	not analyzed	254 µg/L	169 µg/L

Table 5-9
Maximum Historical Concentrations of Contaminants in
Discharges from the RLWTF at TA-50[151]

Contaminant	Concentration
Americium-241	1,000pCi/L
Cesium-137	7,900 pCi/L
Plutonium-238	500 pCi/L
Plutonium-239/240	1,000 pCi/L

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[147] Figure for 2001 (LANL, 2002b, pg. 301). The maximum discharge of about 43,000 gallons per day occurred in 1968 (LANL, 1998a, pg. 15).

[148] LANL has upgraded the treatment facility and the effluent concentrations of most contaminants have been significantly reduced. For reductions in concentrations of tritium, americium-241, plutonium-239/240, see LANL, 1998a, pp. 18, 19 and 21, respectively. Since March 2002 the perchlorate concentration has been reduced to less than 1 µg/L (LANL, 2003c, pg. 16).

[149] LANL, 1995a, pg. VI-13.

[150] LANL, 2002b, pg. 301.

[151] LANL, 1997b, except as noted. (S. Yanicak, NMED, 2004).

Tritium	4,688,000[152] pCi/L
Chloride	180 mg/L
Nitrate (as N)	490 mg/L

The sediments in Mortandad Canyon contain above background concentrations of tritium, americium-241, cesium-137, strontium-90 and plutonium.[153] These sediments are a potential source of the radioactive contaminants found in groundwater.

5.3.1 Mortandad Canyon Alluvial Perched Groundwater

Contaminants detected in the alluvial aquifer include: americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, chloride, nitrate and perchlorate (Table 5-10).

Water quality data are from wells MCO-1, MCO-2, MCO-3, MCO-4, MCO-4B, MCO-5, MCO-6.0, MCO-6B, MCO-6.5A, MCO-6.5B, MCO-7, MCO-7A, MCO-7.5, MT-3 and MT-4.

Table 5-10
Contaminants Detected in Mortandad Canyon
Alluvial Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND - 0.369[154] pCi/L	NA	30 pCi/L
Cesium-137	ND - 11.4[155] pCi/L	NA	3,000 pCi/L
Plutonium-238	ND - 76.3[156] pCi/L	NA	40 pCi/L
Plutonium-239/240	ND - 14.0[157] pCi/L	NA	30 pCi/L
Strontium-90	ND - 84[158] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	130[159] pCi/L - 111,200[160] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	ND - 294[161] mg/L	NA	NA

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[152] Rogers, 1998, page 21.
[153] LANL, 2002b, pp. 313 and 314.
[154] Well MCO-6, 1995, filtered sample (NMED, 2004d). Unfiltered sample: 56 pCi/L, well MCO-3, 1973 (NMED, 2004d).
[155] Well MCO-4, 1993, not known whether sample filtered (LANL, 1995a, pg. VII-11).
[156] Well MCO-4, 1976, sampled filtered (NMED, 2004d). Unfiltered sample: 123 pCi/L, well MCO-3, 1982 (NMED, 2004d).
[157] MCO-4, 1976, sample filtered (NMED, 2004d). Unfiltered sample: 1,493 pCi/L, well MCO-3, 1982 (NMED, 2004d).
[158] Well MCO-4b, 1995, sample filtered (NMED, 2004d). Unfiltered sample: 412 pCi/L, well MCO-3, 1971 (NMED, 2004d).
[159] Well MCO-2, 2000 (LANL, 2001b, pg. 325).
[160] Well MCO-6.0, 1992 (LANL, 1994a, pg. VII-9).

Nitrate (as N)	ND - 364[162] mg/L	10 mg/L	NA
Perchlorate	ND - 400[163] µg/L	NA	NA

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[161] Well MCO-3, 1989 (NMED, 2004d).
[162] Well MCO-3, 1981 (NMED, 2004d).
[163] Well MCO-6, 2000 (LANL, 2001b, pg. 356).

5.3.2 Mortandad Canyon Intermediate Perched Groundwater

Intermediate perched groundwater along Mortandad Canyon occurs in basalt[164] and the Puye Formation.[165] Depth to water ranges from about 490 feet to about 650 feet.[166, 167] Contaminants detected in the intermediate zone include: tritium, chloride, nitrate and perchlorate (Table 5-11).

Water quality data are from wells MCOBT-4.4 and R-15.

Table 5-11
Contaminants Detected in Mortandad Canyon
Intermediate Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND	NA	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND	NA	40 pCi/L
Plutonium-239/240	ND	NA	30 pCi/L
Strontium-90	ND	8 pCi/L	1,000 pCi/L
Tritium	3,960[168] pCi/L - 16,828[169] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	11.5[170] mg/L - 17[171] mg/L	NA	NA
Nitrate (as N)	ND - 13.2[172] mg/L	10 mg/L	NA
Perchlorate	12[173] µg/L - 179[174] µg/L (1,662[175] µg/L)	NA	NA

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[164] LANL, 2003h.
[165] LANL, 2003h.
[166] LANL, 2003h.
[167] LANL, 2003h.
[168] Well R-15, 1999 (LANL, 2001c, pg. 65), average of two values.
[169] Well MCOBT-4.4, 2003 (M. Dale, NMED, personal communication, 2004).
[170] Well R-15, 1999 (LANL, 2001c, pg. 61).
[171] Longmire, 2003a.
[172] Well MCOBT-4.4, 2002 (Nylander, 2003a).
[173] Well R-15, 1999 (LANL, 2001c, pg. 61).
[174] Well MCOBT-4.4, 2002 (Nylander, 2003b). Up to 14,900 pCi/L of tritium has been found in MCOBT-4.4. This indicates that the water has been affected by LANL operations.
[175] Perchlorate extracted from pore water near bottom of intermediate perched zone at well R-15 (LANL, 2001c, pg. 56).

5.3.3 Mortandad Canyon Regional Aquifer Groundwater

Water in regional aquifer wells in Mortandad Canyon ranges in depth from about 830 feet to about 1,180 feet.[176, 177] Contaminants detected in the regional aquifer include: plutonium-238, plutonium-239/240, strontium-90, tritium, chloride, nitrate and perchlorate (Table 5-12).

Water quality data are from wells TW-8, R-14 and R-15.[178]

Table 5-12
Contaminants Detected in Mortandad Canyon
Regional Aquifer

Contaminant	Concentration Range	EPA MCL	DOE DCG
Americium-241	ND	NA	30 pCi/L
Cesium-137	ND	NA	3,000 pCi/L
Plutonium-238	ND - 0.025 pCi/L[179]	NA	40 pCi/L
Plutonium-239/240	ND - 0.188[180] pCi/L	NA	30 pCi/L
Strontium-90	ND - 9.4[181] pCi/L	8 pCi/L	1,000 pCi/L
Tritium	ND - 89[182] pCi/L	20,000 pCi/L	2,000,000 pCi/L
Chloride	ND - 10[183] mg/L	NA	NA
Nitrate (as N)	ND - 5.10[184] mg/L	10 mg/L	NA
Perchlorate	ND - 4.19[185] µg/L	NA	NA

5.4 Technical Area 16

Technical Area 16 (TA-16) sits on a mesa in the southwestern corner of LANL. High explosives have been manufactured and tested at TA-16 since the 1940s.[186] Soils, surface water and groundwater at TA-16 are contaminated with the high explosives RDX, HMX and

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[176] LANL, 2003f, pg. 4.
[177] LANL, 2003g, pg. 5.
[178] Water quality data from R-13 were not used because samples may contain water from overlying units or drilling fluids.
[179] Well TW-8, 1974, sample unfiltered, analytical uncertainty not given (NMED, 2004d).
[180] Well TW-8, 1994, sample unfiltered (NMED, 2004d).
[181] Well TW-8, 1976, sample unfiltered (NMED, 2004d).
[182] Well TW-8, 1993 (LANL, 1995a, pg. VII-33).
[183] Well TW-8, 1976 (NMED, 2004d).
[184] Well TW-8, 1994 (LANL, 1996a, pg. 238).
[185] Well R-15, 2001 (Longmire, 2002a, pg. 7). Up to 3.29 pCi/L of tritium has been found in well R-15 (Longmire, 2002a, pg. 8). This indicates that at least a portion of the water in this well was recharged since LANL began operating.
[186] LANL, Environmental Restoration Project, *Monitoring Well R-25*, Rev. 3-3-99, pg. 4.

TNT.[187] Springs that discharge from the flanks of the mesa are also contaminated with high explosives.[188]

One deep well, R-25, has been installed at TA-16.[189] It is completed in both the intermediate perched zone and the regional aquifer.[190] The perched zone is about 750 feet deep and over 400 feet thick. It begins in the Otowi Member of the Bandelier Tuff and ends in the Puye Formation.[191] Water in the regional aquifer is about 1,290 feet deep.[192] High explosives and tritium have been found in both the intermediate perched zone and the regional aquifer (Tables 5-13 and 5-14).

Table 5-13
Contaminants Detected at TA-16, Well R-25
Intermediate Perched Groundwater

Contaminant	Concentration Range	EPA MCL	DOE DCG
RDX	30[193] µg/L - 84[194] µg/L	0.61[195] µg/L	NA
HMX	4.5[196] µg/L - 12[197] µg/L	1,800[198] µg/L	NA
TNT	1.1[199] µg/L - 19[200] µg/L	2.2[201] µg/L	NA
Tritium	38.3[202] pCi/L - 81.4[203] pCi/L	20,000 pCi/L	2,000,000 pCi/L

Table 5-14
Contaminants Detected at TA-16, Well R-25
Regional Aquifer

Contaminant	Concentration Range	EPA MCL	DOE DCG
RDX	ND - 62[204] µg/L	0.61[205] µg/L	NA

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[187] LANL, *Information Sheet: 260 Outfall*, ER 2002-0333, undated.
[188] RDX and HMX have been detected in Martin, Fish Ladder and SWSC Springs (Newman, et al., 2001; and LANL, 2004a).
[189] LANL, 2002a, pg. 4.
[190] LANL, 2002d, pg. 8.
[191] LANL, 2002d, pg. 8.
[192] LANL, 2002d, pg. 8.
[193] LANL, 2002a, pg. 47.
[194] LANL, 2002d, pg. 59.
[195] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).
[196] LANL, 2002a, pg. 47.
[197] LANL, 2002d, pg. 59.
[198] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).
[199] LANL, 2002a, pg. 47.
[200] LANL, 2002d, pg. 59.
[201] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).
[202] LANL, 2002a, pg. 47.
[203] LANL, 2002d, pg. 64.
[204] LANL, 2002d, page 59.

HMX	ND - 9.7[206] μg/L	1,800[207] μg/L	NA
TNT	ND - 7.1[208] μg/L	2.2[209] μg/L	NA
Tritium	1.02[210] pCi/L - 72.8[211] pCi/L	20,000 pCi/L	2,000,000 pCi/L

The tritium values in the intermediate zone and the regional aquifer indicate that at least a portion of the water in these zones was recharged since LANL began operating.

5.5 Conclusion

Contaminants from LANL have entered groundwater at LANL. LANL-derived contamination is demonstrated by the presence of the following contaminants:

Perched Alluvial Groundwater

- Tritium in Pueblo Canyon
- Tritium in Los Alamos Canyon
- Tritium and perchlorate in Mortandad Canyon

Perched Intermediate Groundwater

- Tritium in Pueblo Canyon
- Tritium and perchlorate in Mortandad Canyon
- Explosives at TA-16

Regional Aquifer

- Perchlorate in Pueblo Canyon
- Perchlorate in Mortandad Canyon
- Explosives at TA-16

The first condition listed in Section 1.0 is satisfied. Contaminants from LANL have entered the groundwater.

6.0 Groundwater Flow Directions at LANL

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[205] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).

[206] LANL, 2002d, pg. 59.

[207] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).

[208] LANL, 2002d, pg. 59.

[209] EPA health advisory (HA) limit for drinking water (LANL, 2002d, pg. 58).

[210] LANL, 2002d, pg. 64.

[211] LANL, 2002d, pg. 64.

Groundwater generally flows down the hydraulic gradient.[212] Where it has been measured, the hydraulic gradient slopes toward the Rio Grande.[213] Therefore, groundwater flows toward the river.

Figure 6-1 shows water level contours for the regional aquifer.

6.1 Conclusion

The second condition listed in Section 1.0 is satisfied. Groundwater from LANL flows toward the Rio Grande.

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[212] The hydraulic gradient is the slope of the water table or, if the aquifer is confined, the slope of the potentiometric surface. The steeper the gradient, the faster the groundwater flow rate.

[213] Purtymun, 1995, pp. 27 - 30. Note: hydraulic gradients in many areas, particularly in the shallow tuff and intermediate zones, are not well known due to a lack of monitor wells.

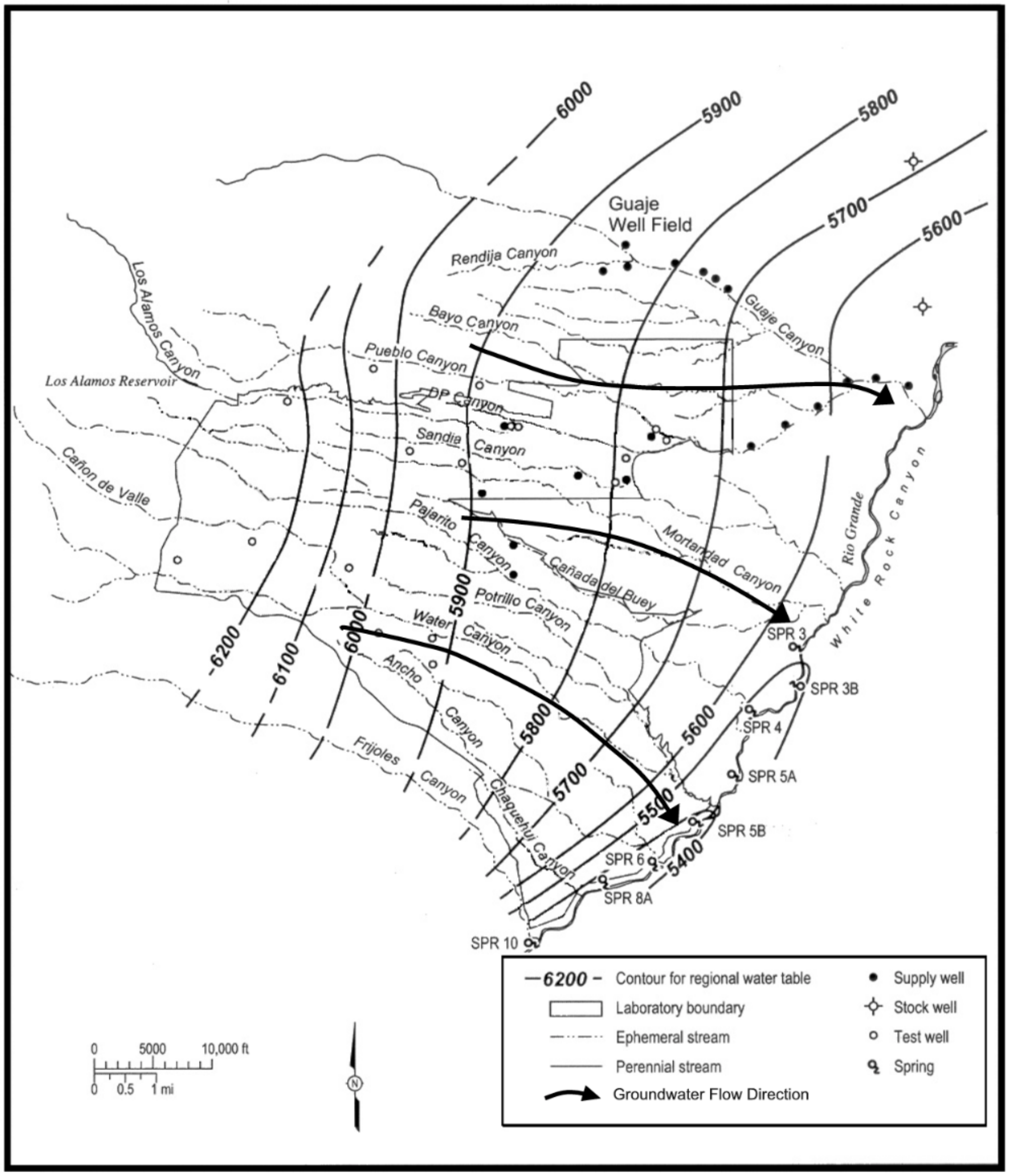

Figure 6-1
Water Level Contours, Regional Aquifer

(Adapted from Longmire, 2002b)

7.0 Groundwater Flow Rates and Contaminant Transport

Two questions are addressed here. First, is it possible for groundwater to travel from contaminated areas at LANL to the river in the 61 years since LANL has existed? Second, can contaminants being transported by the groundwater also reach the river in 61 years?

7.1 Groundwater Flow Rates

Groundwater flow rates are controlled by three parameters:

1. hydraulic conductivity[214]
2. hydraulic gradient
3. porosity

The groundwater flow rate is calculated with Darcy’s Law:[215]

$$\mathbf{q = K\ (\bullet h/\bullet L)/n}$$

Where:

q = groundwater flow rate
K = hydraulic conductivity
$\bullet h/\bullet L$ = hydraulic gradient
n = porosity

The horizontal hydraulic gradient within the regional aquifer ranges from 0.01 to 0.03.[216]

Estimates of hydraulic conductivities and porosities for geologic units underlying the Pajarito Plateau are presented in Tables 7-1 and 7-2.

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[214] Hydraulic conductivity is a measure of the ability of water to flow through an aquifer. The higher the hydraulic conductivity, the more rapidly water can flow.

[215] Freeze and Cherry, 1979, pg. 71.

[216] Stone, 2001a; and LANL, 2002a, pg. 37.

Table 7-1
Saturated Hydraulic Conductivities of Geologic Units at LANL

Geologic Unit	Hydraulic Conductivity (ft/day)[217]			Source of Data[218]
	Range	Arithmetic Mean	Geometric Mean	
Cerros del Rio Basalts	0.04 - 37.1	10.8	1.5	1, 2, 3
Puye Formation[219]	0.1 - 17.6	2.1	0.6	1
Totavi Lentil	0.7 - 32.3	12.6	4.7	1
Santa Fe Group	0.4 - 24.0	3.4	1.4	1

Table 7-2
Porosities of Geologic Units at LANL

Geologic Unit	Porosity	Source of Data[220]
Cerros del Rio Basalts	0.0001 - 0.05	1, 2
Puye Formation	0.01 - 0.25	2, 3, 4
Totavi Lentil	0.20 - 0.30	2, 3
Santa Fe Group	0.25 - 0.30	2, 3

The hydraulic conductivities within each unit are highly variable. Therefore, groundwater and contaminant flow rates within each geologic unit also will be highly variable. Some groundwater will flow through relatively fast flow paths and some will flow through relatively slow flow paths.

When estimating how quickly a contaminant may travel between two points, the faster flow paths should be considered.

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[217] Where more than one value was reported for the same interval in a well, the values were averaged. Thus, only one value per interval was used to calculate the means. Where results of slug/injection tests and pump tests were both reported, the pump test results were used.

[218]
1 = LANL, 2003b, pp. 4-17 through 4-19
2 = Stone and McLin, 2003
3 = Broxton, et al., 2001b, pg. 7

[219] For well R-19, LANL has reported several values of hydraulic conductivity for the same interval in the Puye Formation (screen 7). The values 0.6 ft/day and 19.6 ft/day are reported in LANL 2002a, pp. 41 and 88. Values of 0.60 ft/day and 0.73 ft/day are reported in LANL, 2003b, pg. 4-18. The reason for the discrepancy is not known. The average of the most recent (lower) reported values was used in the table above.

[220]
1 = LANL, 2003a, pg. J-3
2 = Vesselinov and Keating, 2002, pg. 26
3 = LANL, 2003b, pg. 5-3
4 = LANL, 2002a, pp. 39 - 40

High-range estimates of groundwater flow rates are presented in Table 7-3. They are based on the data presented above and on estimates given in Purtymun, 1995.

Table 7-3
High-Range Estimates
of Groundwater Flow Rates at LANL

Geologic Unit	Hydraulic Conductivity (ft/day)	Hydraulic Gradient	Porosity	Flow Rate (ft/day)	Flow Rate (ft/yr)	Flow Rate (mi/yr)
Cerros del Rio Basalts[221]	35	0.01	0.01	35	13,000	2.5
Puye Formation	15	0.01	0.20	0.75	275	0.05
Totavi Lentil	30	0.01	0.25	1.2	440	0.08
Santa Fe Group	20	0.01	0.25	0.8	290	0.05
Alluvial Perched[222]	NA	NA	NA	40	15,000	2.8
Intermediate Perched[223]	NA	NA	NA	60	22,000	4.1

Clearly, groundwater in some units travels rapidly. If the fast flow paths within these units extended all the way to the river, groundwater from LANL could reach the Rio Grande in a few years. For example, the distance from TA-50 in Mortandad Canyon to the Rio Grande is about eight miles.[224] Groundwater flowing at a rate of 2.5 miles per year would reach the river in less than four years.

However, flow paths in some units do not extend all the way to the river. The saturated alluvium in Mortandad Canyon extends only about two miles down stream from TA-50,[225] six miles short of the Rio Grande. The extent of water in the intermediate perched zones is not well known. In some places it may be confined to small pools that extend only a few hundred feet. In other places, water in the intermediate zone may extend for miles.[226]

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[221] The hydraulic conductivity and porosity are assumed to represent the properties of fractured basalt.

[222] Purtymun estimated groundwater flow rates in the alluvium along Mortandad Canyon to range from 7 ft/day to 60 ft/day (Purtymun, 1995, pg. 26). Estimates of hydraulic conductivity and porosity were not provided.

[223] Purtymun estimated groundwater flow rates in the intermediate perched system at Pueblo Canyon to be 60 ft/day. The perched zone is in the Puye Formation and Cerros del Rio Basalts. Estimates of hydraulic conductivity and porosity were not provided (Purtymun, 1995, pp. 28 - 29).

[224] LANL, 2002b, pg. 399.

[225] LANL, 2002b, pg. 182.

[226] The intermediate perched zone beneath Pueblo and Los Alamos Canyons appears to extend at least two miles (Purtymun, 1995, pg. 29).

There are probably many flow paths from contaminated areas to the Rio Grande. They probably consist of a number of segments. Some are probably fast and some are probably slow.

The following is a hypothetical fast flow path from TA-50 in Mortandad Canyon to Spring 3 on the Rio Grande, a distance of approximately eight miles (Figure 7-1):

1. Discharged from TA-50, flow begins as surface water along the canyon bottom
2. Surface water infiltrates the alluvium and flows through the alluvial perched zone
3. Leaks from the alluvium, through Otowi Member of Bandelier Tuff, down to the intermediate perched zone
4. Flows through basalt in intermediate zone
5. Leaks from basalt in perched zone to flow through basalt in regional aquifer
6. Flows through Puye Formation in regional aquifer
7. Flows through Totavi Lentil in regional aquifer and emerges at Spring 3 on the Rio Grande

The travel times along each segment of this flow path are given in Table 7-4.

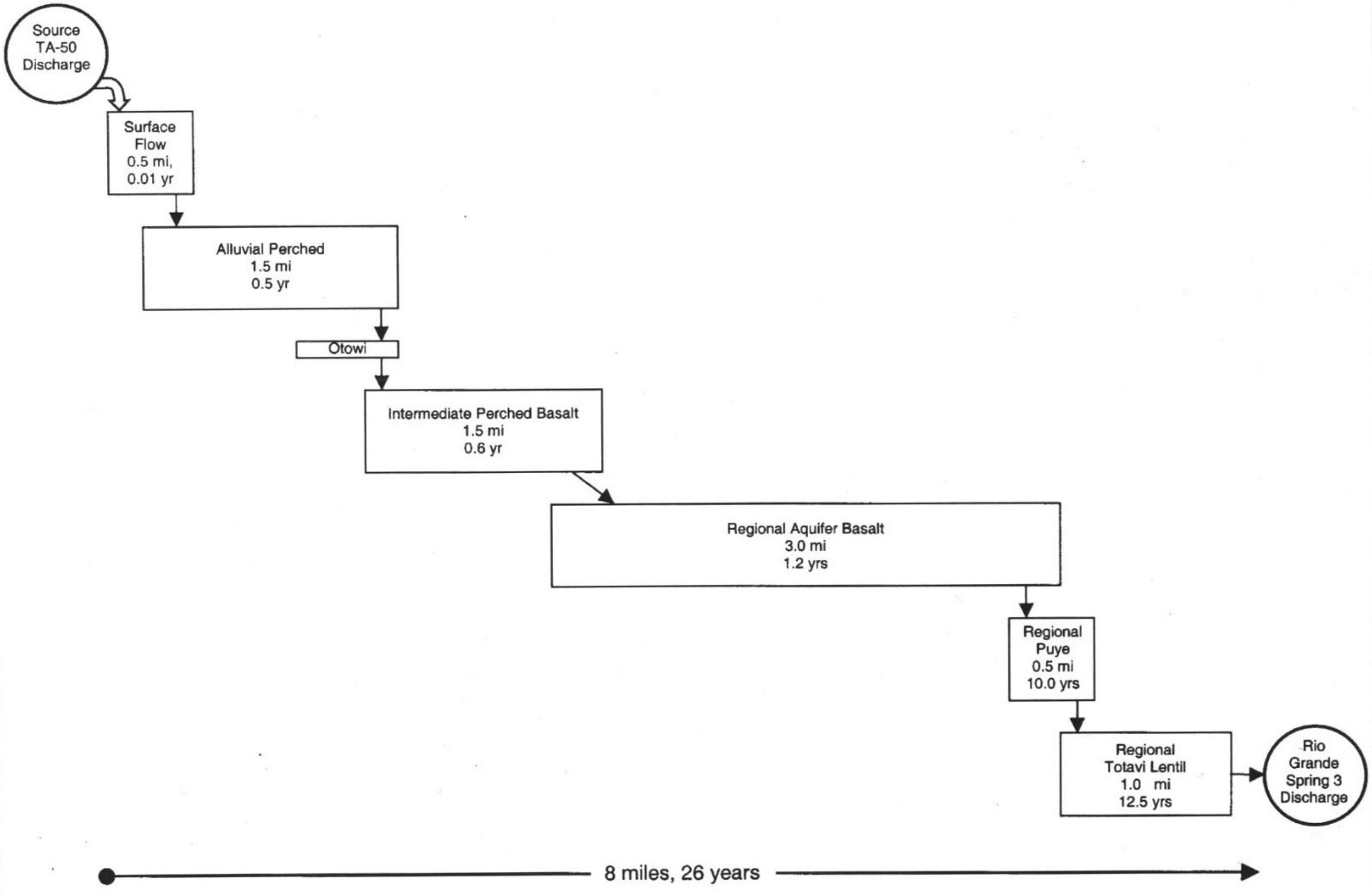

Figure 7-1
Schematic Representation of Hypothetical Fast Flow Path

Table 7-4
Hypothetical Fast Flow Path
TA-50 to Spring 3

Flow path segment	Segment length[227] (mi)	Flow rate (mi/yr)	Time to traverse segment (yr)	Cumulative distance (mi)	Cumulative time (yr)
1: Surface flow from TA-50 discharge	0.5	> 1,000[228]	0.01	0.5	0.01
2: Alluvial perched[229]	1.5	2.8	0.5	2.0	0.5
3: Otowi Member[230]	0.02 (100 ft)	0.2	0.1	2.0	0.6
4: Intermediate perched (basalt)	1.5	2.5	0.6	3.5	1.2
5: Regional aquifer (basalt)[231]	3.0	2.5	1.2	6.5	2.4
6: Regional aquifer (Puye)	0.5	0.05	10.0	7.0	12.4
7: Regional aquifer (Totavi Lentil) to Spring 3	1.0	0.08	12.5	8.0	25.9

Although the flow path illustrated in Figure 7-1 and Table 7-4 is hypothetical, it shows that it is possible for groundwater to travel from contaminated areas at LANL to the Rio Grande during the 61 years LANL has existed.

Therefore, the answer to the first question posed at the beginning of this section is yes. It is possible for groundwater to travel from contaminated areas at LANL to the river during the 61 years LANL has existed. The second question, "Can contaminants being transported by the groundwater reach the river in 61 years?" is addressed below.

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[227] Assumed.

[228] Assumed flow rate of stream is 0.5 ft/s (approximately 3,000 mi/yr).

[229] Infiltration of surface water to perched alluvial aquifer is assumed to occur very rapidly. Thus, no estimate of time to flow between surface and the water table in alluvium is given.

[230] Assumed Otowi properties: vertical hydraulic gradient = 1, hydraulic conductivity = 5 x 10^{-4} cm/s, porosity = 0.5 (Rogers and Gallaher, 1995, pg. 75).

[231] Flow between basalt in intermediate perched zone and basalt in regional aquifer is assumed to occur very rapidly. Thus, no estimate of time to traverse segment is given.

7.2 Contaminant Transport

Most of the contaminants being transported by groundwater are dissolved.[232] However, they do not necessarily travel at the same speed as the groundwater. Some contaminants are "retarded." That is, they travel more slowly than the groundwater because they become attached (sorbed) to the solid materials through which they pass.[233]

A geochemical parameter that controls the degree to which a contaminant will be retarded is the partition coefficient. Contaminants with lower partition coefficients travel faster than those with higher coefficients. Contaminants with a partition coefficient of zero travel at the same speed as the groundwater.

Partition coefficients depend on the chemical composition of the groundwater as well as the properties of the solid material through which the water flows. The partition coefficients presented in Table 7-5 were derived from experiments conducted on tuffs from LANL and Yucca Mountain, Nevada.[234] Partition coefficients do not appear to have been measured for the other geologic units at LANL. It should be noted that the partition coefficients in Table 7-5 are for porous media.[235] Partition coefficients for fractured media may be significantly smaller.[236]

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[232] Contaminants may also be attached to colloidal particles that are suspended in the groundwater (DOE, 2000a, pg. 30). Some contaminants, such as plutonium, may travel significantly faster when transported by colloids than they otherwise would (Kersting, et al., 1999). The importance of contaminant transport via colloids at LANL is not known.

[233] Sorption is a reversible process. As some contaminant molecules leave the groundwater solution and become attached to the solids, others detach from the solids and reenter solution.

[234] LANL, 2003a, pp. J-4 and J-5; and Krier, et al., 1997, table 7. Except for perchlorate. The perchlorate partition coefficient is assumed to be zero. This value is based on information in LANL, 2003c, pg. 6; RAC, 2003, pg. 5; and Urbansky, 2002, pg. 2.

[235] Flow occurs through the intergranular pores in a rock rather than through fractures.

[236] Krier, et al., 1997, tables 10 and 11.

Table 7-5
Partition Coefficients for Selected LANL Groundwater Contaminants

Contaminant	Partition coefficient (mL/g)
Perchlorate	0
RDX	0
Tritium	0
Americium	141
Cesium	428
Plutonium	4 - 711
Strontium	116

The relative speed of a contaminant with respect to the groundwater is calculated as follows:[237]

$$\mathbf{v_c/v_w = 1/[1 + (\rho_B\ K_d)/n]}$$

Where:

v_c = contaminant speed
v_w = groundwater speed
ρ_B = bulk density of aquifer (1.2 g/cm^3)[238]
K_d = partition coefficient
n = porosity of aquifer (0.5)[239]

Example calculations:

Perchlorate ($K_d = 0$)

$$v_c/v_w = 1/[1 + (1.2[0])/0.5] = 1$$

Plutonium ($K_d = 5$)

$$v_c/v_w = 1/[1 + (1.2[5])/0.5] = 0.08$$

In the examples above, perchlorate is not retarded ($v_c/v_w = 1$) and will travel at the speed of the groundwater. Plutonium is retarded ($v_c/v_w = 0.08$) and will travel at about 8% of the groundwater speed. It should be noted that this result is for dissolved plutonium migrating

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[237] Freeze and Cherry, 1979, pg. 404.
[238] Mean density of Otowi Member (Rogers and Gallaher, 1995, pg. 75).
[239] Approximate porosity of Otowi Member (Rogers and Gallaher, 1995, pg. 75).

through a porous medium. Plutonium sorbed to colloidal particles or migrating through fractures may travel significantly faster.

The answer to the second question posed at the beginning of this section depends on the contaminant. It is possible for some contaminants (e.g., perchlorate, RDX and tritium) to travel from contaminated areas at LANL to the river during the 61 years LANL has existed. Other contaminants may be too retarded to reach the Rio Grande in the time available.

7.3 Conclusion

The third condition listed in Section 1.0 is satisfied. It is possible for groundwater and some of the contaminants it transports to reach the Rio Grande in 61 years or less.

8.0 Indications of LANL-Derived Contamination in Springs Along the Rio Grande

This section examines cases where contaminants associated with LANL have been reported in springs along the Rio Grande. The object is to determine whether any of these cases support the conclusion that LANL-derived contaminants are being discharged at the springs.

8.1 Tritium in Springs

Tritium has been detected in most of the springs discharging along the Rio Grande (Table 8-1).

As shown in Appendix A, tritium data at LANL fall into three categories.

- Tritium activities less than 1.5 pCi/L indicate that the groundwater was recharged before LANL was established in 1943.
- Tritium activities greater than 1,500 pCi/L indicate that the groundwater is contaminated with LANL-derived wastes.
- Tritium activities between 1.5 pCi/L and 1,500 pCi/L indicate that the groundwater is a mixture derived from at least two of the following sources: pre-LANL recharge, post-bomb recharge or LANL wastes. At least a portion of the groundwater was recharged after LANL was established.

Many of the tritium activities reported in Table 8-1 are greater than 1.5 pCi/L, but none are greater than 1,500 pCi/L. Therefore, the groundwater discharging at many of the springs was recharged after LANL was established and may contain LANL-derived contaminants.

However, the tritium data do not necessarily support the conclusion that the groundwater contains LANL-derived wastes.

Table 8-1[240]
Tritium in Springs Discharging to the Rio Grande

Spring	Date	Tritium (pCi/L)
Sacred	5/24/95 5/24/95	3.42/3,800[241]
Indian	5/12/93 5/25/95	4.19 4.06
La Mesita	5/24/95 7/19/99	ND ND
1	9/94 9/20/99 9/25/00	0.87 ND ND
2	11/91 9/94 9/25/00	4.21 3.82 ND
Sandia	9/94 8/6/99 9/20/99 9/25/00	ND ND 1.77 2.00
CCNS	11/15/02 1/14/03	10.8 12.6
3	9/24/90 11/91 9/94 9/25/00	3.40 1.65 2.20 2.51
3A	9/94 4/9/99 9/25/00	2.75 1.22 ND
3AA	9/94	ND
3B	9/24/90 11/91 9/27/94	0.91 ND ND

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[240] Data from: Blake, et al., 1995, pg. 28; CCNS, 2003; LANL, 1994a, pg. VII-25; LANL, 1996a, pg. 259; LANL, 1996b, pg. 274; NMED, 2004a; and M. Dale, NMED, personal communication, 2004.

[241] The tritium value of 3,800 pCi/L was obtained using the liquid scintillation analytical method (LANL, 1996b, pp. 176 and 274). However, the duplicate sample (3.42 pCi/L) was analyzed by the University of Miami Tritium Laboratory using the electrolytic enrichment method (LANL, 1996b, pg. 274; and Rogers, 1998, pg. 9). The method used by the University of Miami is believed to be more accurate (LANL, 1996b, pg. 176). See Appendix A for a discussion of tritium analyses.

Table 8-1 (continued)
Tritium in Springs Discharging to the Rio Grande

Spring	Date	Tritium (pCi/L)
4	9/94	15.4
	9/25/00	12.1
	1/28/02	11.3
4A	11/91	2.40
	9/94	1.39
	4/9/99	0.90
	1/28/02	0.93
4B	1/28/02	48.9
4C	1/28/02	11.6/11.3[242]
5	9/94	ND
	5/11/99	ND
5A	9/94	4.05
	9/26/00	1.97
5B	9/94	4.67
Ancho	9/25/90	3.4
	11/91	4.21
	9/94	1.78
	5/13/99	ND
	9/21/99	4.03
	9/26/00	1.51
6	11/91	1.78
	9/94	6.80
	5/13/99	1.19
	9/26/00	1.22
6A	9/25/90	ND
	11/91	ND
	9/94	ND
	9/21/99	2.80
	9/26/00	1.42
7	9/25/90	1.46
	11/91	2.10
	9/94	1.30
	9/21/99	0.90
	9/26/00	1.39
8	9/25/90	5.83
	11/91	7.09
	9/94	4.54

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[242] Field duplicate samples.

8A	9/26/00	2.93

Table 8-1 (continued)
Tritium in Springs Discharging to the Rio Grande

Spring	Date	Tritium (pCi/L)
8B	9/26/90	4.66
	9/94	2.04
9	9/94	1.04
	9/22/99	ND
9A	11/91	1.78
	9/94	2.69
	5/18/99	ND
	9/27/00	ND
9C	9/27/00	ND
DOE	9/25/90	17.71
	9/92	3.47
	9/94	2.24
	9/27/00	4.77
10	9/94	3.76

8.2 Perchlorate in Springs

Perchlorate has been reported in samples from springs along the Rio Grande (Table 8-2). Potential sources of perchlorate for CCNS Spring, the Spring 3 series, the Spring 4 series and Spring 5 series are Mortandad and Pajarito Canyons.[243] Potential sources for the other springs have not been identified.

All of the analyses in Table 8-2 were performed with the liquid chromatography/mass spectrometry/mass spectrometry (LC/MS/MS) method. Other analyses of spring discharge are available, but their reliability is questionable. See Appendix B for a discussion of perchlorate analyses.

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[243] Perchlorate concentrations in effluent discharged to Mortandad Canyon averaged 254 µg/L and 169 µg/L in 2000 and 2001, respectively (LANL, 2002b, pg. 301). Perchlorate concentrations in effluent discharged to Pajarito Canyon have exceeded 500 µg/L (LANL, 2003c, pg. 2).

Table 8-2
Perchlorate Concentrations Reported in Springs Along the Rio Grande[244]

Spring	Sample Date	Perchlorate (μg/L)
Sacred	6/25/02	0.40
La Mesita	6/24/02	1.11
CCNS (2B)	1/14/03	0.12
3	3/8/04	0.42
3A	3/28/02	0.50
	3/8/04	0.40
3AA	3/28/02	ND (< 0.25)[245]
	3/8/04	0.43
3C	3/8/04	0.40
4	1/28/02	0.30
	3/26/02	0.32
	3/5/04	0.61/0.66[246]
4A	1/28/02	0.50
	3/5/04	0.46
	4/15/04	0.50
4AA	1/28/02	0.4
	3/28/02	0.46
	11/23/02	0.41
	3/5/04	0.50
4B	1/28/02	ND (< 0.25)
	3/26/02	0.31
	3/5/04	0.44
4C	1/28/02	0.30/0.40[249]
	5/12/03[247]	0.56
	5/12/03[248]	0.60/0.65
	3/5/04	0.65
5	3/26/02	ND (< 0.25)
	10/7/03	0.29
	3/11/04	0.40
5A	3/26/02	ND (< 0.25)
6	3/12/04	0.35
6A	3/12/04	0.29
7	10/7/03	0.21

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[244] Data sources: NMED, 2003c, NMED, 2003b, and NMED, 2004e.
[245] Method detection limit (MDL).
[246] Duplicate analyses.
[247] Analysis by NMED.
[248] Analysis by LANL.
[249] Duplicate sample.

8A	3/18/04	0.26
9	3/18/04	0.28
9A	3/18/04	0.29
DOE	3/18/04	0.23

The perchlorate found in the springs is not necessarily derived from LANL. Low concentrations of perchlorate have been found in groundwater samples from Taos, Española and Albuquerque (0.22 µg/L, 0.17 µg/L and 0.24 µg/L, respectively).[250] The source of this perchlorate is not known. The highest background concentration is 0.5 µg/L (see Section 4.0 on background concentrations above). Thus, the only detections of perchlorate that can confidently be associated with LANL are those greater than 0.50 µg/L. This leads to the conclusion that LANL-derived perchlorate has discharged from Spring 4C.[251]

The detection of 1.11 µg/L perchlorate in La Mesita Spring is interesting. This spring discharges from the Tesuque Formation.[252] The water may originate from the west, in which case the perchlorate may represent LANL-derived contamination.[253] Or it may originate from the east, in which case it represents a non-LANL source of perchlorate. The origin of the water is not known.

8.3 Radionuclides in Springs

Radionuclides have been reported in samples from springs along the Rio Grande (Table 8-3). Potential sources of radionuclides include contaminated groundwater along Pueblo, Los Alamos and Mortandad Canyons (see Section 5.0 on groundwater contamination above).

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[250] NMED, 2003b.

[251] The tritium activities in Springs 4 and 4C are greater than 1.5 pCi/L (see Table 8-1 above). This indicates that a portion of the water discharged by these springs was recharged after LANL was established.

[252] Purtymun, 1995, pg. 285.

[253] This is unlikely because the tritium activity of water from La Mesita Spring is less than 1.5 pCi/L (see above). This indicates that most, if not all, of the water from this spring was recharged after LANL was established.

Table 8-3
Radionuclide Detections Reported in Springs Discharging to the Rio Grande[254]

Spring	Sample Date	Radionuclide (pCi/L)
Sacred	10/19/00	strontium-90 (1.99, ND)[255]
Sandia	9/25/00 /01	plutonium-238 (0.081) americium-241 (0.035, ND)
2	9/25/00	plutonium-238 (0.042)
4A	9/25/00 9/25/00 /01	americium-241 (0.051, ND) cesium-137 (9.09) plutonium-238 (0.074)
5A	/96	plutonium-238 (0.145, ND)
Ancho	10/24/01	strontium-90 (0.3, ND)
6A	/99	americium-241 (0.033)
9	/01	americium-241 (0.032)

Although the radionuclides listed in Table 8-3 are usually thought of as being relatively immobile (see Section 7.2 on contaminant transport above), they may be transported rapidly if they are sorbed to colloidal particles.[256] Thus, radionuclides may have traveled from LANL to the Rio Grande since LANL was established.

However, the radionuclide data in Table 8-3 are suspect. In every case where a detection was accompanied by a duplicate analysis, the radionuclide was not detected by the duplicate analysis.

In addition, strontium-90 was detected in the Westside Artesian well.[257] This detection is almost certainly invalid because this well is almost four miles north of the Otowi Bridge, which is not down gradient of LANL.[258] The water also appears to be quite old. Samples from the Westside Artesian well contained no measurable tritium or carbon-14.[259]

In view of the above, the radionuclide data do not appear to be useful indicators of LANL-derived contaminants in the springs.

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[254] Table lists only springs with at least one detection of americium-241, cesium-137, plutonium-238, plutonium-239/240 or strontium-90. All of the samples were filtered. Data Sources: LANL Environmental Surveillance Reports: 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2000, 2001 (LANL, 1994a, LANL, 1995a, LANL, 1996a, LANL, 1996b, LANL, 1997a, LANL, 1999b, LANL, 2000b, LANL, 2001a, LANL, 2002b), Longmire, 2002a and NMED, 2004b.

[255] Not detected in duplicate sample.

[256] Kersting, et al., 1999.

[257] LANL, 1996b, pg. 257.

[258] LANL, 1996b, pg. 293. It is assumed that LANL is the only source of strontium-90 in groundwater.

[259] LANL, 1995a, pg. VII-30.

8.4 Ancho Spring

Ancho Spring emanates from the Totavi Lentil in Ancho Canyon, about 3/4 mile from the Rio Grande (see Figure 3-2).[260] The discharge rate to the Rio Grande is approximately 65 gallons per minute.[261] Ancho Spring is down gradient from TA-16, an area that is known to be contaminated with high explosives (see Section 5.4 on TA-16 above).

In 1995, two of the explosives found at TA-16 (RDX and HMX) were detected in the discharge of Ancho Spring (Table 8-4).

Table 8-4
Explosives Detected in Ancho Spring[262]

Date	Explosive	Concentration (μg/L)
9/12/95	2,4-dinitrotoluene	0.18
9/12/95	HMX	4.9
9/12/95	RDX	23
9/12/95	tetryl	0.61

More than 1.5 pCi/L of tritium has been found in the discharge of Ancho Spring (see Table 8-1 above). This indicates that at least a portion of the water emanating from the spring was recharged since LANL began operating.[263] Thus, LANL-derived contaminants may be discharged from the spring.

However, LANL has analyzed Ancho Spring water for high explosives at least six times since 1995 and none have been found.[264]

If the high explosives detected in 1995 were coming from TA-16 or some similar source, why haven't they been found since then? There are several possible explanations. Perhaps the explosives entered the groundwater as a discrete 'slug' that has since been flushed from the aquifer. Perhaps the 1995 samples were contaminated with sediments.[265] Perhaps the reported results are laboratory errors. The answer is not known. However, there is no evidence that shows that the results are invalid. Therefore, they cannot be dismissed. These

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[260] Purtymun, 1995, pp. 283 and 284.

[261] Purtymun, 1995, pg. 284.

[262] LANL, 1996b, pg. 216.

[263] See Appendix A for a discussion of tritium at LANL.

[264] LANL, 1997a, pg. 208; LANL, 1999b, pg. 151; LANL, 2000b, pp. 178 and 283; LANL, 2001b, pp. 358 - 360; and LANL, 2002b, pp. 377 and 380.

[265] At the time the results were reported, LANL stated that the samples may have been contaminated by soils that contained high explosives (LANL, 1996b, pg. 162). There is no indication that any of the samples collected from Ancho Spring were filtered to remove soil or sediment (LANL, 1996b, pp. 199, 203, 208, 212 and 216). Explosive contaminated sediments may have been transported to the spring via surface water or through the air. However, LANL does not appear to have analyzed any soils or sediments at Ancho Spring for explosives.

results lead to the conclusion that LANL-derived contaminants were discharged from Ancho Spring.

Although no explosives have been detected in Ancho Spring since 1995, the explosive tetryl was detected in Spring 6 in 2002.[266] Spring 6 emanates from fractures in basalt on the bank of the Rio Grande, just downstream of the mouth of Ancho Canyon (Figure 3-2).[267] Tritium analyses indicate that a portion of the water discharged by this spring was recharged before LANL began operating.

8.5 CCNS Spring

CCNS Spring discharges along the bank of the Rio Grande, about 1/2 mile downstream from the mouth of Mortandad Canyon (Figure 3-2).[268] Concerned Citizens for Nuclear Safety (CCNS) discovered the spring in October 2002 while the river was at a low stage.

The chemical character of the water discharging from CCNS Spring is distinct from that of other springs in the area. CCNS Spring contains significantly higher concentrations of chloride and nitrate. It also contains relatively high concentrations of sulfate and total dissolved solids (TDS). The concentrations of these constituents in CCNS Spring versus their considerations in other springs are illustrated in Figures 8-1 and 8-2.

Given the location of CCNS Spring, these relatively high concentrations may indicate that it has been affected by LANL wastes discharged to Mortandad Canyon. Contaminated alluvial groundwater in Mortandad Canyon also contains high concentrations of these solutes.

In addition, the discharge from CCNS Spring contained more than 10 pCi/L of tritium.[269] This indicates that at least a portion of the water discharging from the spring was recharged after LANL began operating.

Figure 8-1 is a bivariate plot of chloride and nitrate concentrations in springs along the Rio Grande,[270] Mortandad alluvial groundwater[271] and effluent from the White Rock Sewage Treatment Plant.[272] Figure 8-2[273] is a similar plot for sulfate and TDS.

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[266] 9/24/02, tetryl = 0.055 µg/L (JP) (LANL, 2004b, Table S5-12). The qualifier "JP" means the reported value is estimated and there was more than 25% difference in detected concentrations between two columns (LANL, 2004a).

[267] Purtymun, 1995, pg. 285.

[268] Also known as Spring 2B (M. Dale, NMED, personal communication, 2004).

[269] CCNS, 2003, see table above.

[270] Data for 2001 and 2003. Data for Springs 1, 2, 3, 3AA, 4, 4A, 5, 6, 6A, 9 and 9A, and La Mesita, Sandia, CCNS and Ancho Springs. All data from LANL, 2002b, pp. 354 and 355, except for CCNS Spring and Springs 3AA, 6 and 9A. Data for these springs are from samples collected by NMED on April 30, 2003.

[271] Data from LANL, 1995b, pg. VII-14; and LANL, 2002b, pg. 356.

[272] Data from NMED, 2003c.

[273] Data sources the same as Figure 8-1. TDS of White Rock Sewage Treatment Plant calculated as sum of anions and cations.

These figures show that the chemical character of CCNS Spring water is similar to that of the alluvial groundwater in Mortandad Canyon. However, it is also similar to the effluent from the sewage treatment plant. Thus, CCNS Spring may be affected by 1) contaminants originating in Mortandad Canyon, 2) sewage effluent or 3) both. The available data do not support an unambiguous conclusion.

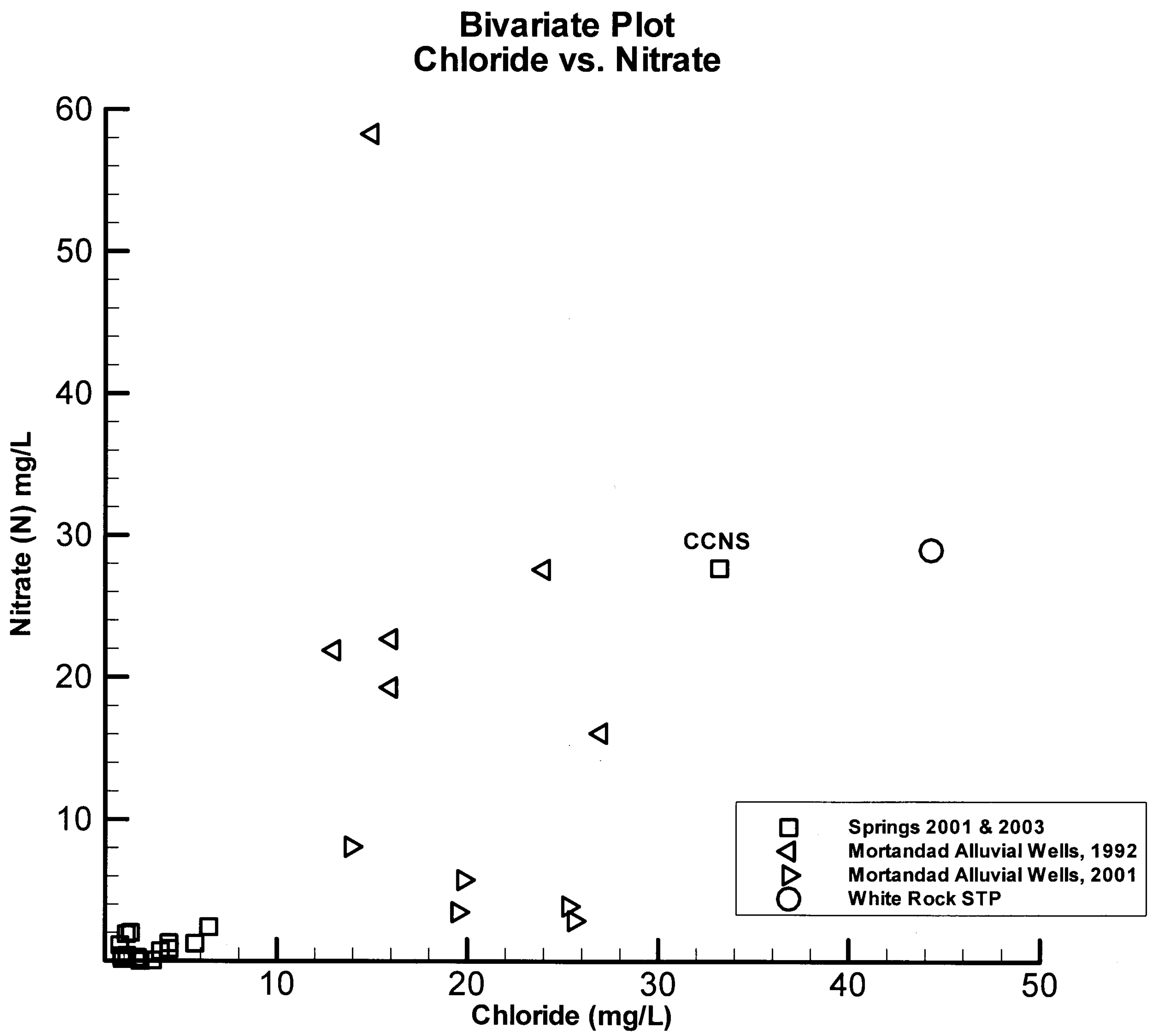
Bivariate Plot
Chloride vs. Nitrate
Nitrate (N) mg/L
60
50
40
30
20
10
CCNS
□ Springs 2001 & 2003
◁ Mortandad Alluvial Wells, 1992
▷ Mortandad Alluvial Wells, 2001
○ White Rock STP
10
20
30
40
50
Chloride (mg/L)

Figure 8-1

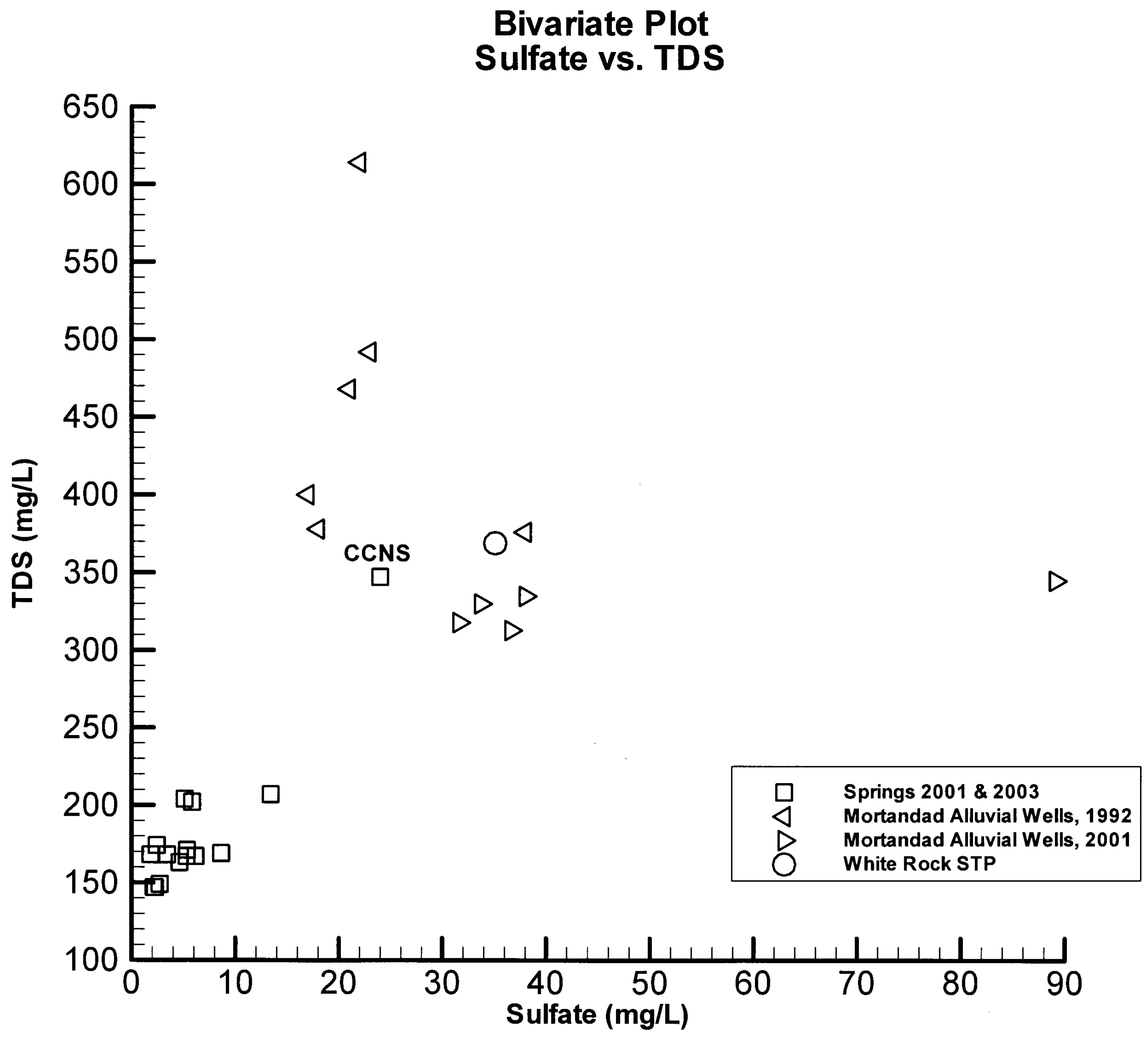
Bivariate Plot
Sulfate vs. TDS
TDS (mg/L)
650
600
550
500
450
400
350
300
250
200
150
100
0
10
20
30
40
50
60
70
80
90
Sulfate (mg/L)
CCNS
Springs 2001 & 2003
Mortandad Alluvial Wells, 1992
Mortandad Alluvial Wells, 2001
White Rock STP

Figure 8-2

8.6 Conclusion

There are a number of cases where contaminants associated with LANL may have been detected in springs along the Rio Grande. However, one case, CCNS Spring, is ambiguous. Some of the data, e.g., perchlorate and radionuclides, are questionable. There are only two cases where a clear relationship to LANL activities can be established and the data appear to be reliable. They are the explosives at Ancho Spring and Spring 6 and the perchlorate in Springs 4 and 4C. In both cases, the contaminants were detected in springs that are down gradient of contaminant sources. In addition, tritium analyses indicate that at least a portion of the water emanating from these springs was recharged after LANL began operating. Therefore, it is concluded that LANL-derived contaminants have emerged at springs along the Rio Grande.

9.0 Summary

The conditions stated in Section 1 are satisfied.

1. Contaminants from LANL have entered the groundwater.

2. Groundwater from LANL flows toward the Rio Grande.

3. It is possible for groundwater, and at least some of the contaminants it transports, to travel from contaminated areas at LANL to the Rio Grande during the 61 years LANL has existed.

4. Contaminants from LANL have reached springs discharging to the Rio Grande. Explosives have reached Ancho Spring and Spring 6 and perchlorate has reached Springs 4 and 4C.

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Appendix A
Tritium at LANL

Tritium is a radioactive form of hydrogen. The name refers to the fact that this form of hydrogen contains three particles in the nucleus: two neutrons and one proton (^3H). Normal hydrogen contains only a proton (^1H).

Tritium has a half-life of 12.3 years.[274] That is, after 12.3 years half the tritium present in a sample will be gone. It decays to helium.

Chemically, tritium acts like normal hydrogen. It forms water just as hydrogen does.

Tritium is produced naturally in the upper atmosphere by cosmic radiation. It is also produced artificially by nuclear explosions, in nuclear reactors and high-energy accelerators.

At LANL, tritium in groundwater originates from three sources:

- Pre-bomb precipitation. Before the atmospheric testing of nuclear weapons, natural precipitation contained approximately 20 pCi/L of tritium.[275] Thus, the tritium concentration at the time LANL was established (1943) was approximately 20 pCi/L.
- Post-bomb precipitation. Beginning in 1952 atmospheric testing of nuclear weapons produced large amounts of tritium.[276] In the mid-1960s, tritium concentrations in precipitation over northern New Mexico reached a peak of approximately 6,500 pCi/L.[277]
- Discharges of LANL wastes to Pueblo, Los Alamos and Mortandad Canyons. Since 1943, tritium concentrations in LANL effluents have commonly exceeded 50,000 pCi/L.[278, 279]

Figure A-1 depicts the decay of tritium in groundwater derived from precipitation that fell at the time LANL was established (pre-bomb). Figure A-2 depicts the decay of tritium in groundwater derived from precipitation that fell at the post-bomb peak (1965).

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[274] Freeze and Cherry, 1979, pg. 136.
[275] LANL, 1997a, pg. 126.
[276] Freeze and Cherry, 1979, pg. 136.
[277] LANL, 1997a, pg. 126.
[278] LANL, 1997a, pg. 219.
[279] LANL also discharges tritium to the atmosphere. Airborne tritium concentrations at LANL are significantly higher than concentrations in surrounding communities (LANL, 2002b, pp. 114 – 115).

Decay of Tritium in Groundwater Derived from Pre-bomb (1943) Precipitation

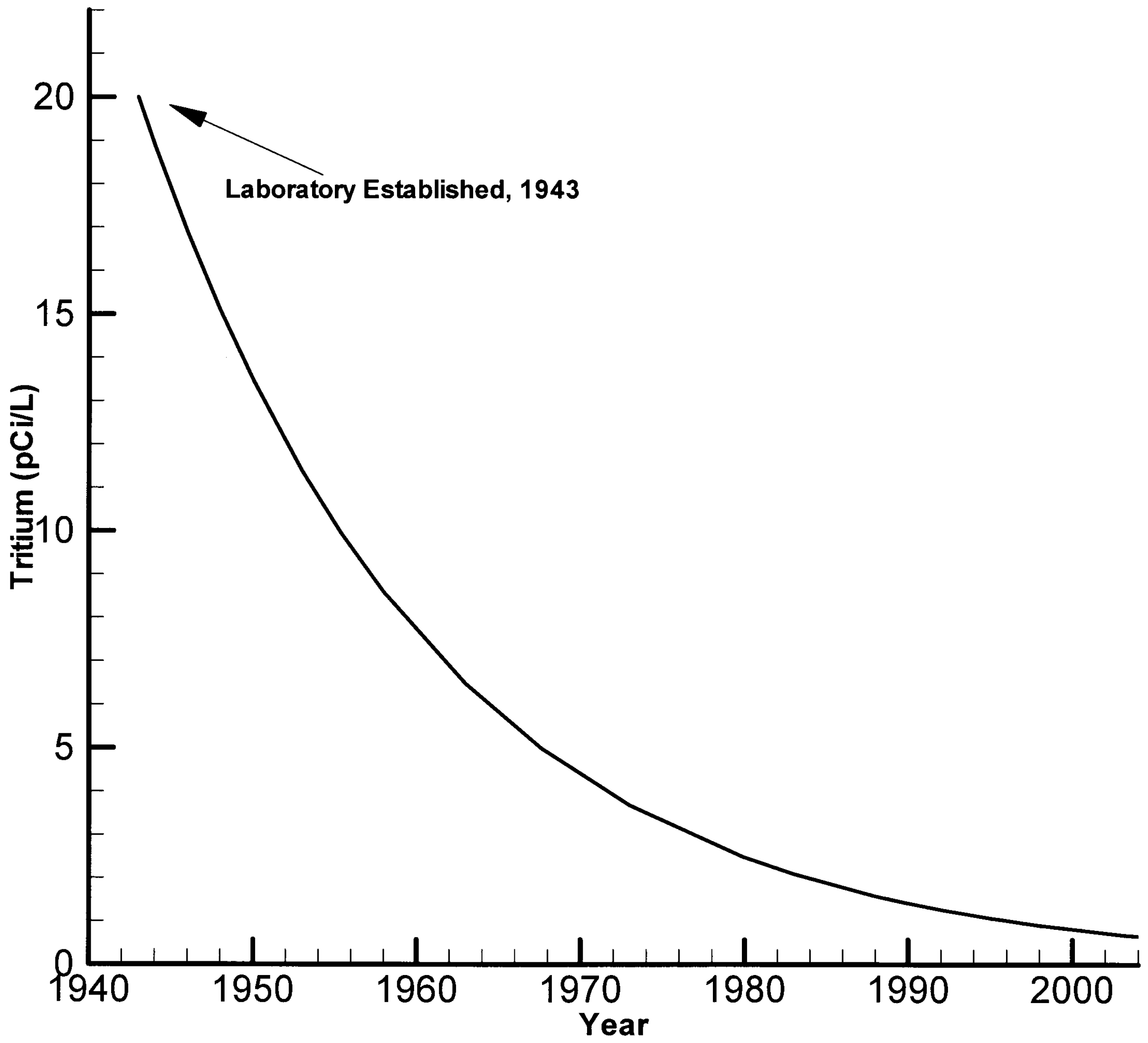

Figure A-1

Decay of Tritium in Groundwater
Derived from Post-bomb (1965) Precipitation

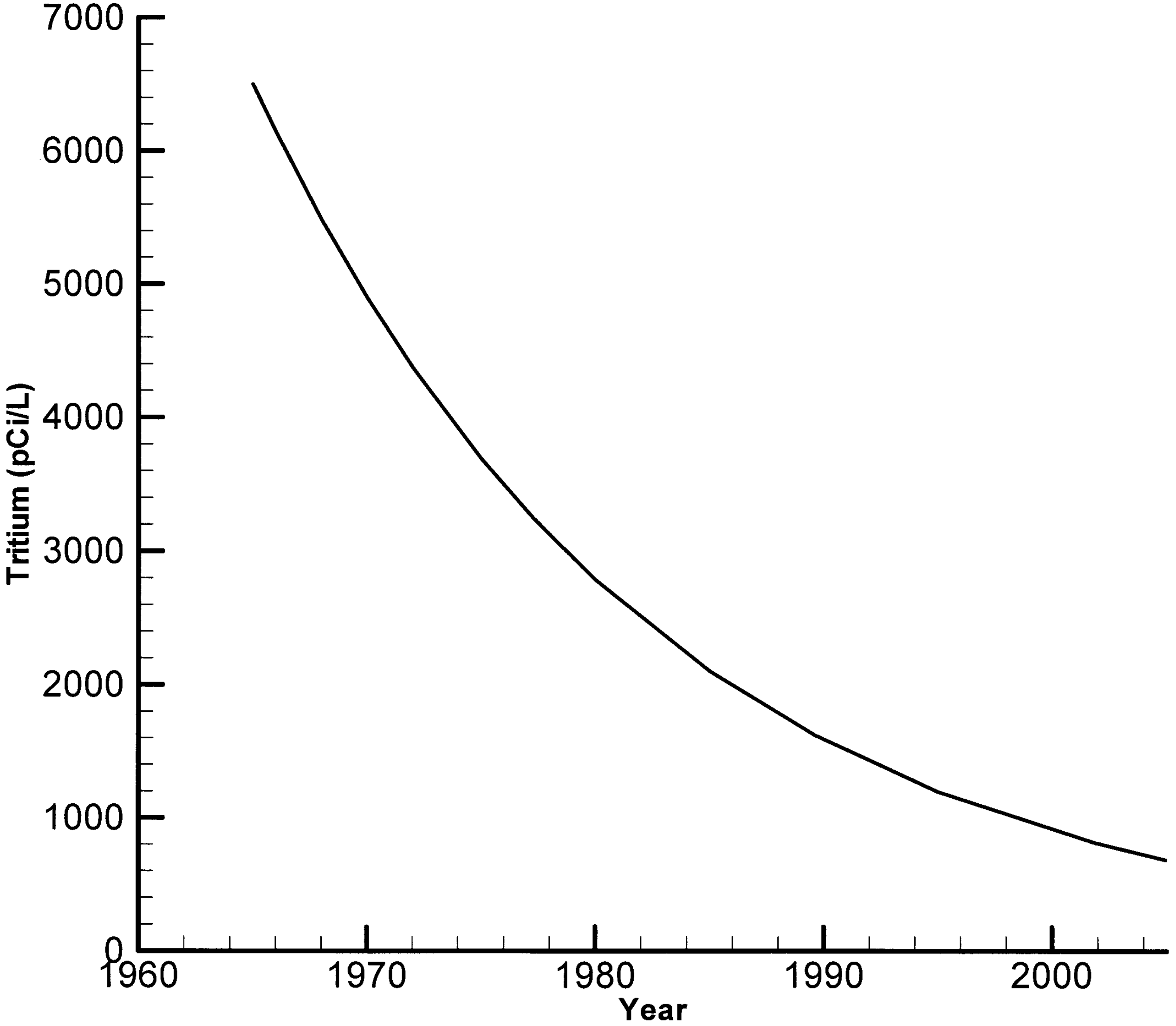

Figure A-2

In view of the above, the following conclusions are drawn regarding the interpretation of tritium values at LANL:

1. By 1995, groundwater derived from rain that fell prior to the establishment of LANL contained less than 1.5 pCi/L of tritium (Figure A-1). Therefore, groundwater that contained more than 1.5 pCi/L after 1995 was probably recharged after LANL was established.

2. By 1995, groundwater derived from post-bomb precipitation contained less than 1,500 pCi/L of tritium (Figure A-2). Therefore, groundwater that contained more than 1,500 pCi/L of tritium after 1995 was probably contaminated by LANL wastes.

3. After 1995, groundwater that contained more than 1.5 pCi/L but less than 1,500 pCi/L of tritium was either derived entirely from post-bomb precipitation or derived from a mixture of at least two of the following sources: pre-LANL precipitation, post-bomb precipitation or LANL wastes.

Note on validity of tritium analyses:

According to Rogers, many of the tritium samples collected during the early to mid-1980s were contaminated in the analytical laboratory.[280] The contamination occurred because samples were exposed to devices and materials that emitted tritium. This resulted in analytical results that were too high. In view of this, tritium results for samples collected between 1980 and 1990 are not used in this report.

In about 1991, LANL began sending many of its tritium samples to the University of Miami Tritium Laboratory.[281] The analytical method used by the University of Miami (electrolytic enrichment)[282] is considered to be more accurate than the method used by LANL (liquid scintillation).[283]

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[280] Rogers, 1998, pp. 8 and 9.
[281] Rogers, 1998, pg. 9.
[282] Rogers, 1998, pg. 9.
[283] LANL, 1996b, pg. 176.

Appendix B
Perchlorate at LANL

Perchlorate is a toxic ion consisting of one chloride and four oxygen atoms (ClO_4).[284] At LANL it has been used to produce explosives and to process plutonium.[285]

Perchlorate is nonvolatile and stable in groundwater and is not retarded to a significant degree. Therefore, perchlorate can persist in groundwater for many decades and it travels at the same speed as the groundwater that transports it.[286]

LANL has discharged perchlorate-contaminated water to Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon and Cañon de Valle.[287]

Few samples were analyzed for perchlorate until 2000. Regular analyses were initiated after the Environmental Protection Agency (EPA) issued the Unregulated Contaminant Monitoring Rule for perchlorate in 1999.[288]

Perchlorate concentrations in effluent discharged to Pajarito Canyon have exceeded 500 μg/L.[289] Perchlorate concentrations in effluent discharged to Mortandad Canyon averaged 254 μg/L and 169 μg/L in 2000 and 2001, respectively.[290] The effluent discharged to Mortandad Canyon is produced by the Radioactive Liquid Waste Treatment Facility at Technical Area 50 (TA-50).

LANL has taken steps to reduce its discharges of perchlorate. Process modifications at the TA-50 treatment plant have reduced perchlorate concentrations to less than 1 μg/L.[291]

Perchlorate has been reported in a number of wells and springs in the vicinity of LANL. However, many of these reports appear to be unreliable due to problems with the analytical laboratories.

Perchlorate analyses performed by General Engineering Labs (GEL) with the ion chromatography (IC) method are not reliable if the results are less than 4 μg/L.[292] In addition, prior to April 25, 2001, GEL did not perform all the sample preparation steps

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[284] EPA, 2003.
[285] LANL, 2003c, pp. 1 - 2.
[286] RAC, 2003, pg. 5.
[287] LANL, 2003c, pp. 1 - 2.
[288] LANL, 2003c, pg. 1; NMED, 2003a, item 20.
[289] LANL, 2003c, pg. 2.
[290] LANL, 2002b, pg. 301. Perchlorate concentrations in RLWTF effluent were not measured prior to 2000.
[291] LANL, 2003c, pg. 2.
[292] The analyses appear to result in both false negatives and false positives (Minteer, 2001).

required to produce reliable results.[293] Failure to perform the required steps can result in large errors.[294]

LANL and NMED have begun using a new method to analyze perchlorate, liquid chromatography/mass spectrometry/mass spectrometry (LC/MS/MS, method SW846 8321A). The LC/MS/MS method may produce reliable results at concentrations as low as 0.05 µg/L.[295] However, some problems have been identified with some LC/MS/MS analyses. Analyses performed by Acculabs in 2001 were found to be unreliable.[296] There does not appear to be any reason to doubt the reliability of LC/MS/MS analyses performed after 2001.

There are some natural sources of perchlorate, although none are known to occur in the vicinity of LANL.[297]

Groundwater samples from Taos, Española and Albuquerque were found to contain 0.22 µg/L, 0.17 µg/L and 0.24 µg/L of perchlorate, respectively.[298] It is highly unlikely that these samples were affected by LANL operations. Low concentrations of perchlorate (0.20 µg/L - 0.50 µg/L) were also detected in American Spring.[299] This spring would not be affected by LANL operations because it is more than a mile west of the LANL boundary, hydraulically up gradient from LANL.[300] There appears to be a source of perchlorate in northern New Mexico that is not associated with LANL. The source of this perchlorate is not known.

In view of the above, the following conclusions are drawn regarding the interpretation of perchlorate results at LANL.

1. Perchlorate analyses performed by GEL (IC method) are not reliable unless the concentrations exceed 4 µg/L.[301] Analyses performed by GEL prior to April 25, 2001 are not reliable unless the concentrations exceed 12 µg/L.[302]

2. Perchlorate analyses performed by Acculabs prior to 2002 are not reliable.

3. Perchlorate concentrations less than about 0.5 µg/L may represent perchlorate that originated from sources other than LANL.

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[293] Rogers, 2002.
[294] Longmire reported errors as high as 12 µg/L (Longmire, et al., 2002d).
[295] LANL, 2003c, pg. 21.
[296] Rogers and Beers, 2002.
[297] Natural perchlorate is known to occur in potash-bearing evaporite deposits (USGS, 2003, pg. 4).
[298] NMED, 2003b. Samples collected May 2003, analyzed with LC/MS/MS method.
[299] NMED, 2003c.
[300] Purtymun, 1995, pg. 282.
[301] This applies only to analyses performed with the IC method.
[302] This value is based on data presented by Longmire, et al., 2002d. The errors associated with these analyses may be larger than 12 µg/L.

4. Perchlorate concentrations greater than about 0.5 µg/L probably represent LANL contamination.