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*Impact of Tritium Disposal on Surface Water
and Groundwater at Los Alamos National
Laboratory Through 1997*



Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory
for the United States Department of Energy

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*Impact of Tritium Disposal on Surface Water
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Laboratory Through 1997*

David B. Rogers



CONTENTS

ABSTRACT	1
INTRODUCTION	2
ENVIRONMENTAL TRITIUM LEVELS AT LOS ALAMOS	5
TRITIUM IMPACT ON LOS ALAMOS DRINKING WATER	6
ENVIRONMENTAL TRITIUM STANDARDS	7
ENVIRONMENTAL TRITIUM MEASUREMENTS AT LOS ALAMOS	8
GEOLOGIC AND HYDROLOGIC SETTING	9
Geology	9
Climate and Surface Water	9
Groundwater Occurrence	11
ACID AND PUEBLO CANYONS	13
DP AND LOS ALAMOS CANYONS	16
LAMPF Lagoons, TA-53	16
Omega West Reactor, TA-2	17
TA-21 Industrial Liquid Waste Treatment Plant, DP Canyon	18
TA-35 WASTE TREATMENT PLANT	19
MORTANDAD CANYON AND THE TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY	21
SANDIA CANYON	23
TA-33 TRITIUM FACILITY AND MATERIAL DISPOSAL AREA K	23
MATERIAL DISPOSAL AREA G (TA-54)	24
MATERIAL DISPOSAL AREA H (TA-54)	25
MATERIAL DISPOSAL AREAS T (TA-21) AND C (TA-50)	25
TRITIUM LEVELS IN LOS ALAMOS WATER SUPPLY WELLS	25
CONCLUSIONS	27
ACKNOWLEDGMENTS	28
REFERENCES	29

List of Tables

1. Los Alamos National Laboratory Tritium Discharge Summary	2
2. TA-1 Tritium Releases	13
3. TA-45 Tritium Releases	13
4. TA-21 Tritium Releases	19
5. TA-50 Tritium Releases	21
6. MDA G Tritium Disposal (Ci) Based on Hollis (1977)	25

List of Figures

1. Location map showing geologic and topographic features near Los Alamos and the Pajarito Plateau. -----	3
2. Locations of TAs, MDAs, and selected alluvial groundwater observation wells and surface-water-monitoring stations. -----	4
3. Locations of selected wells and springs sampling the main aquifer and intermediate perched groundwater. -----	5
4. Generalized geologic cross section across the Pajarito Plateau. -----	10
5. Illustration of geologic and hydrologic relationships in the Los Alamos area, showing the three modes of groundwater occurrence. -----	11
6. Tritium histories (average annual values) for surface water (Pueblo 2), alluvial groundwater (PO-3B), intermediate groundwater (Test Well 2A), and the regional aquifer (Test Well 2) in Pueblo Canyon. -----	15
7. Tritium histories (average annual values) for alluvial groundwater wells in upper Los Alamos Canyon. -----	18
8. Tritium histories (average annual values) for surface water in DP Canyon and an alluvial groundwater well in upper Los Alamos Canyon at the mouth of DP Canyon. -----	20
9. Tritium histories (average annual values) for TA-50 RLWTF discharge and for alluvial groundwater wells in Mortandad Canyon. -----	22
10. Tritium histories (average annual values) for surface water in Sandia Canyon. -----	23

IMPACT OF TRITIUM DISPOSAL ON SURFACE WATER AND GROUND- WATER AT LOS ALAMOS NATIONAL LABORATORY THROUGH 1997

David B. Rogers

ABSTRACT

Beginning with the Manhattan Project in the 1940s, Los Alamos National Laboratory has utilized tritium in its research programs and has discharged tritium into the environment. This report documents the quantity of tritium that has been disposed—either as liquid effluent or by burial in waste disposal areas—and evaluates the impact on surface water and groundwater of these tritium disposal operations.

Since the early 1980s, the Laboratory has sharply reduced both the number of tritium discharge locations and the total amount of tritium discharged. Because of reduced discharges, dilution by stream flow, high evapotranspiration rates, and a relatively short half-life (12.43 yr), tritium levels in most shallow groundwater and surface water at the Laboratory have decreased significantly since the early 1980s. The Laboratory now discharges tritium as liquid effluent only into Mortandad Canyon, from the TA-50 Radioactive Liquid Waste Treatment Facility. Regarding solid waste disposal sites, available data suggest that tritium migration from these areas has been limited in extent.

Trace levels of tritium have been detected in regional aquifer test wells beneath areas of past and present liquid effluent discharges. Nonetheless, based on 30 yr of environmental monitoring, tritium has not significantly impacted the regional aquifer. The maximum tritium levels found in regional aquifer test wells are only about 2% of the EPA's 20,000-pCi/L maximum contaminant level for tritium in drinking water. Tritium levels found in water supply wells average 1 pCi/L, and a maximum of 3 pCi/L was found in one 1993 sample.

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INTRODUCTION

Beginning with the Manhattan Project in the 1940s, Los Alamos National Laboratory (LANL or the Laboratory) has used tritium in its research programs. The Laboratory has also discharged tritium into the environment since the Manhattan Project days. This report documents the quantity of tritium that has been disposed either as liquid effluent or by burial in waste disposal areas. These disposal locations and the estimated total tritium discharges are summarized in Table 1. This report also evaluates the impact on surface water and groundwater of these tritium disposal operations. The Laboratory has monitored surface and groundwater for possible contamination since 1945. Specific measurements of tritium activity in environmental samples began in the late 1960s.

Since the early 1980s, the Laboratory has greatly reduced the number of locations where tritium is discharged to the environment. In addition, the total tritium activity contained in Laboratory discharges has decreased significantly. Because of lower tritium discharges, dilution by stream flow, high evapotranspiration rates, and the short half-life of tritium (12.43 yr), the tritium activity in most surface water and shallow canyon-bottom groundwater has fallen quickly. The Laboratory now discharges tritium as liquid effluent only into Mortandad Canyon, from the TA-50 Radioactive Liquid Waste Treatment Facility.

Table 1. Los Alamos National Laboratory Tritium Discharge Summary

Location	Period	Estimated Total Disposed (in Ci, decayed to 1997*)
Liquid Effluent Discharges:		
TA-1	1943-1951	1.1-23.1
TA-45 Waste Treatment Plant	1951-1964	4.3
TA-53 LAMPF Ponds	1978-1989	90.7
Omega West Reactor leak	1956-1993	23.1
TA-21 Waste Treatment Plant	1952-1985	14.5
TA-35 Waste Treatment Plant	1953-1974	Unknown
TA-50 Waste Treatment Plant	1963-1996	287.1-288.4
TA-33 Tritium Facility	1955-1990	Unknown
Material Disposal Areas		
TA-33 MDA K	1955-1990	Unknown
TA-54, MDA G	1957-1995	880,279
TA-21, MDA T	1945-1951	1.2
TA-54, MDA H	1960-1986	Unknown
TA-50, MDA C	1960-1969	12,835

*Decay corrections after either 1977 or 1981 use a tritium half-life of 12.43 yr, or decay constant of 0.05576/yr.

The following sections of this report provide background information on tritium and the setting of Los Alamos National Laboratory. Later sections describe areas at the Laboratory where tritium has been released and provide a perspective on the extent to which tritium has entered surface water and groundwater. The lack of impact of tritium on Los Alamos drinking water is introduced below and discussed in more detail in a later section. Locations referred to in the text, including observation and water supply wells, canyons, technical areas, and material disposal areas are shown in Figures 1, 2, and 3.

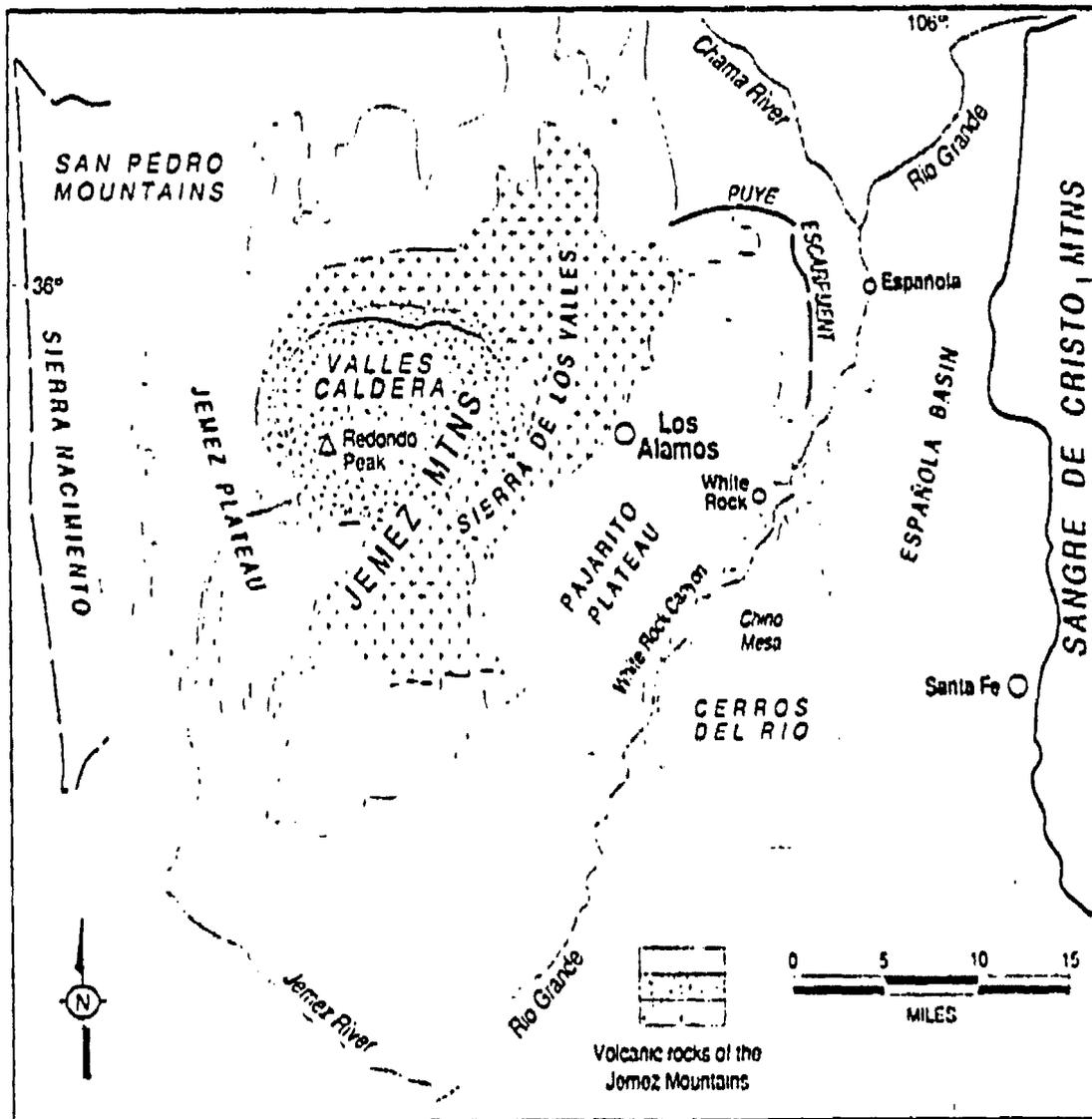


Figure 1. Location map showing geologic and topographic features near Los Alamos and the Pajarito Plateau.

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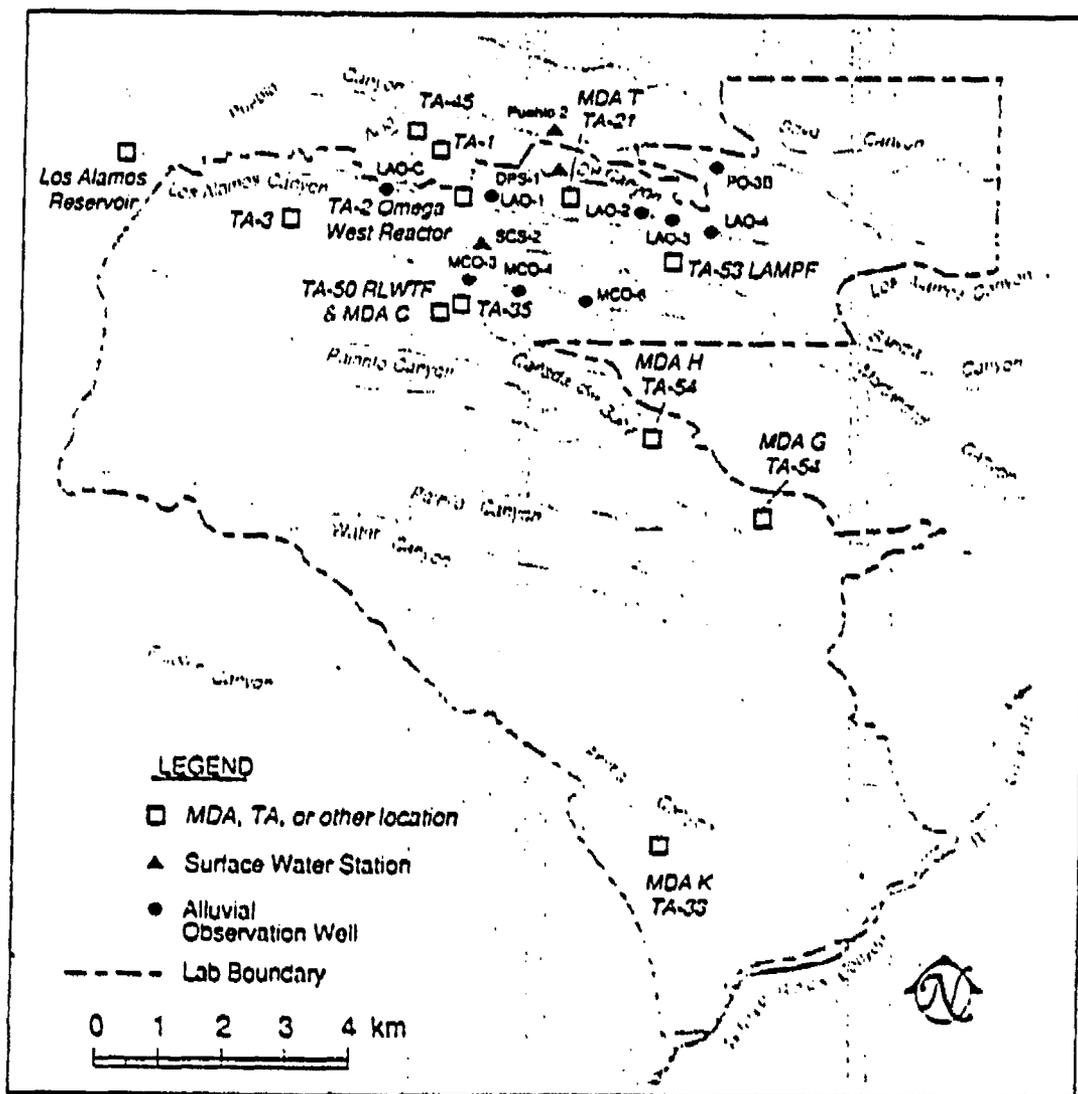


Figure 2. Locations of TAs, MDAs, and selected alluvial groundwater observation wells and surface-water-monitoring stations.

The quantity of a radionuclide is expressed in terms of the number of atoms that decay in a given time, known as the activity of the sample. The basic unit of activity is the curie (Ci), defined as 3.7×10^{10} disintegrations per second. This is the approximate specific activity of one gram of radium. This unit is quite large for expressing activities of most radionuclides found in water, so small fractions of a curie are often used as the basic unit. Metric prefixes are used to indicate fractions of a curie, for example, the picocurie (pCi or 10^{-12} Ci) or the nanocurie (nCi or 10^{-9} Ci). The quantity of a radionuclide in water is expressed in curies per liter of water, for example as pCi/L. In some cases, values are stated in a form such as $6,600 \pm 800$ pCi/L, where the first number is the analytical result,

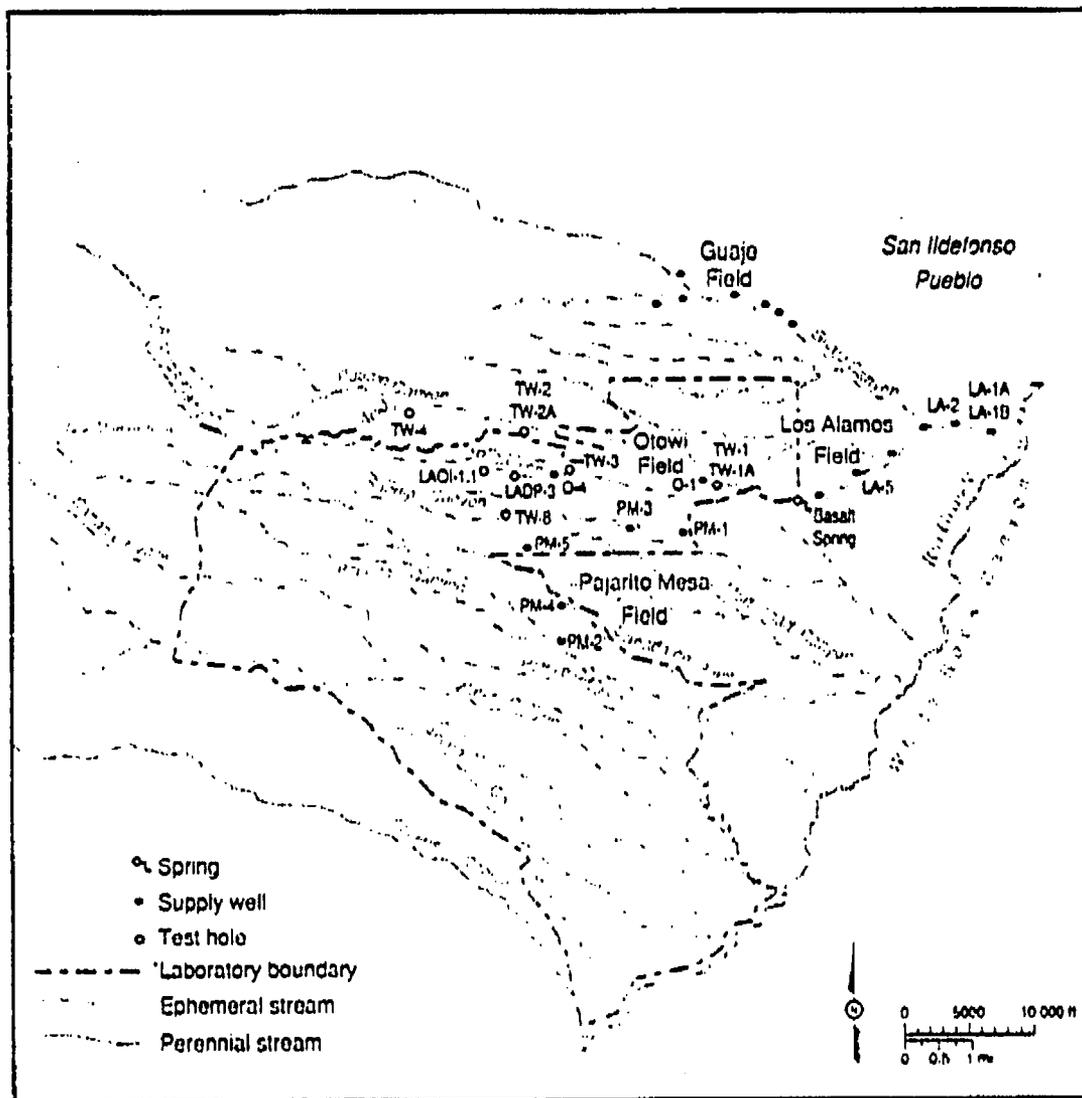


Figure 3. Locations of selected wells and springs sampling the main aquifer and intermediate perched groundwater.

and the second number is one standard deviation of the analytical uncertainty of measurement.

ENVIRONMENTAL TRITIUM LEVELS AT LOS ALAMOS

Tritium is a naturally occurring isotope of hydrogen. Tritium is produced in the atmosphere by cosmic rays and in rocks by decay of naturally occurring radioactive elements. Tritium is also produced by nuclear reactors and as part of the development and testing of nuclear weapons. Because tritium is an isotope of hydrogen, tritium

commonly occurs in nature as part of a water molecule. Before atmospheric testing of nuclear weapons began, tritium levels in northern New Mexico precipitation were about 20 pCi/L (Adams 1995). This is 5 to 10 times higher than the tritium level detected in the Los Alamos public water supply wells. By the mid-1960s, tritium in atmospheric water in northern New Mexico reached a peak level of about 6,500 pCi/L. At present, atmospheric levels in northern New Mexico are about 30 pCi/L, and those in the Los Alamos vicinity range from 20 to 450 pCi/L (Adams 1995).

Because tritium often occurs as part of a water molecule, the rate of infiltration of tritium into the earth is the same as the infiltration rate of water. Other radionuclides such as plutonium-238 or strontium-90 infiltrate at a much slower rate, if at all. The progress of these latter radionuclides is either halted or significantly slowed by the chemical processes of adsorption (adherence to the surfaces of soil particles, for example) or precipitation (the formation of solid chemical phases).

Tritium has a half-life of 12.43 yr. This relatively short half-life combined with low naturally occurring levels of tritium means that groundwater isolated from the surface should have a very low tritium activity. Groundwater that contains between 16 and 65 pCi/L of tritium most likely shows the effects of recent recharge, that is, recharge within the last four decades (Blake 1995). Groundwater with a tritium activity below about 1.6 pCi/L is probably old and isolated from surface recharge. The age of such groundwater is more than 3,000 yr, but there may be large dating uncertainties associated with small tritium activities. Groundwater with a tritium activity greater than 1,000 pCi/L and collected after 1990 can only be the result of contamination (Blake 1995).

TRITIUM IMPACT ON LOS ALAMOS DRINKING WATER

The regional aquifer underlying the Pajarito Plateau is the primary source of water supply for the Laboratory and for Los Alamos County. The regional aquifer is monitored annually by sampling test wells, water supply wells, and springs that discharge along the Rio Grande. The test wells are for monitoring purposes only and are not part of the water supply system. Trace levels of tritium have been detected in test wells sampling the regional aquifer beneath areas of past and present liquid effluent discharges. Tritium levels found in water supply wells are much lower. Despite these trace levels of tritium, there has been no significant tritium impact on the regional aquifer. This conclusion is based on 30 yr of environmental monitoring data. The maximum tritium levels found in regional aquifer test wells are only about 2% of the Environmental Protection Agency's (EPA's) 20,000-pCi/L maximum contaminant level for tritium in drinking water.

The highest test well tritium level found was 361 pCi/L, in Pueblo Canyon Test Well 1 during 1993. The average tritium activity in supply wells is 1 pCi/L, with a maximum of 3.0 pCi/L found in Otowi-4 in 1993.

Although only small tritium levels have been found in existing monitoring wells, concern over possible impact on the regional aquifer has prompted the Department of Energy (DOE) and the Laboratory to embark on an expanded groundwater characterization program at Los Alamos.

ENVIRONMENTAL TRITIUM STANDARDS

The DOE Environmental Protection, Safety, and Health Protection Program establishes concentration guides for radionuclide activities permissible for waters in controlled (closed to public access) and uncontrolled (open to public access) areas near DOE facilities. The concentration guides for water are based on DOE's radiation protection standard (or public dose limit) of 4 mrem/yr for water. The concentration guides represent the smallest estimated concentrations for a radionuclide that taken in continuously for 50 years will result in an annual dose equal to the public dose limit in the 50th year of exposure. These concentration guides are based on recommendations of the International Commission on Radiological Protection, on the EPA's regulations in 40 CFR 61, and on recommendations of the National Commission on Radiation Protection and Measurements. The concentration guides are determined assuming a water ingestion rate of 2 L/day. The concentration guides for water are applicable to effluent discharges and impacted surface and groundwater but not to soil moisture.

Up until 1985, the DOE set an upper limit of 3,000,000 pCi/L for tritium activities in uncontrolled areas and a limit of 100,000,000 pCi/L in controlled areas. The DOE reduced the concentration guide for tritium in uncontrolled areas to 2,000,000 pCi/L in 1985. These radiation protection standards were finalized in 1990 by DOE Order 5400.5. For comparison, the Nuclear Regulatory Commission (NRC) regulations contained in 40 CFR 106 also limit radioactivity in effluent discharges to unrestricted areas. The NRC regulations, applicable since 1992, restrict tritium activity to 1,000,000 pCi/L. This value is half the current DOE concentration guide for uncontrolled areas and applies only to NRC-licensed facilities.

The DOE standard for tritium in a DOE-administered drinking water system is 80,000 pCi/L. Otherwise, radioactivity in the public water supply is governed by EPA regulations contained in 40 CFR 141 (EPA 1991). For manmade beta- and photon-emitting radionuclides, the drinking water regulations specify concentrations limited to a

level that would result in a 4-mrem/yr dose calculated according to a specified procedure. The present EPA-calculated value for tritium is 20,000 pCi/L. The EPA (1991) proposed a revised value of 60,000 pCi/L for the tritium activity that would result in a 4-mrem/yr dose. This higher tritium activity resulted from additional data on the health effects of radiation and a better understanding of the risks posed to human health by radionuclides.

According to environmental monitoring data for the Laboratory, the tritium activities in surface water and shallow canyon-bottom groundwater within the Laboratory boundary have never exceeded the DOE's controlled area tritium concentration guide of 100,000,000 pCi/L. Tritium activities in surface and shallow canyon-bottom groundwater have been below the applicable DOE uncontrolled area concentration guides of 3,000,000 pCi/L (before 1985) or 2,000,000 pCi/L, with two exceptions. These locations are discussed below and are shown in Figures 2 and 3. The first exception occurred during the late 1960s, when the activity of tritium in DP Canyon surface water exceeded the DOE uncontrolled area limit of 3,000,000 pCi/L. A second exception involved discharges from the TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF). Tritium activities in effluent discharges, surface water, and groundwater in Mortandad Canyon have exceeded the DOE concentration guide for tritium in uncontrolled areas during two periods in 1976-77 and 1986-88. Tritium levels in DP Canyon and Mortandad Canyon have been much lower in recent years. The treatment plant at TA-21 ceased operation in 1986. Discharges that have occurred since 1988 in Mortandad Canyon have had much lower tritium activities.

ENVIRONMENTAL TRITIUM MEASUREMENTS AT LOS ALAMOS

Before about 1970, few specific tritium measurements were made on environmental samples at Los Alamos. Instead, gross alpha and beta measurements were performed. An exception was a survey made between 1966 and 1969 (Purtymun 1973a). The detection limit for these measurements was 50,000 pCi/L. This survey detected tritium in surface water and alluvial groundwater in DP, Los Alamos, and Mortandad canyons. At the time of this survey, the US Atomic Energy Commission concentration guide for tritium in uncontrolled areas was 3,000,000 pCi/L.

After 1970, tritium measurements used the liquid scintillation technique, which has a detection limit of about 1,000 pCi/L. Although smaller detection limits are sometimes cited, the detection limit for some samples may be even higher. During the early and mid-1980s, unreliable tritium measurements were made on numerous environmental samples at Los Alamos. Significant airborne cross contamination of environmental samples evidently occurred while they were being processed within the analytical

laboratory. The sources of tritium contamination included emissions from the Van de Graaf generator operating near the environmental chemistry laboratories, and contamination of samples caused by storage of other highly tritium-contaminated soil and water samples in the chemistry laboratories. Both of these problems affected sample analysis, and, for example, led to apparent tritium values in 1981 and 1982 of 4,000 to 25,000 pCi/L in several regional aquifer wells which have not indicated such tritium levels before or since.

Beginning in about 1991, samples from springs and wells expected to have very low tritium activities were sent to the University of Miami Tritium Laboratory for a special analysis that uses *electrolytic enrichment*. The detection limit for this analytical laboratory is about 1 pCi/L. The purpose of these measurements is to detect very small amounts of tritium in waters isolated from the land surface or in areas expected to have little tritium contamination.

GEOLOGIC AND HYDROLOGIC SETTING

Geology

Los Alamos National Laboratory is located in Northern New Mexico on the Pajarito Plateau, which extends eastward from the Jemez Mountains (Figure 1). The Laboratory is bordered on the east by the Rio Grande, within the Rio Grande Rift. The Pajarito Plateau is capped by rocks of the Bandelier Tuff, consisting of volcanic ashfall deposits and pyroclastic flows erupted from the Jemez Mountains volcanic center about 1.2 to 1.6 million years ago (Figure 4). The tuff is over 1,000 ft thick in the western part of the plateau and thins eastward to about 260 ft above 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 4). The tuff is underlain by the Puye Formation conglomerate beneath the central and eastern portion of the plateau. The Cerros del Rio basalt flows interfinger with the 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.

Climate and Surface Water

Rainfall in the Los Alamos area totals about 18.7 in./yr, and varies greatly with elevation. The plateau is semiarid, with ponderosa forest at higher elevations giving way to piñon-juniper woodlands as elevation decreases. The plateau is separated into finger mesas by canyons, which contain riparian vegetation and small streams that for the most part have short-lived or intermittent flow.

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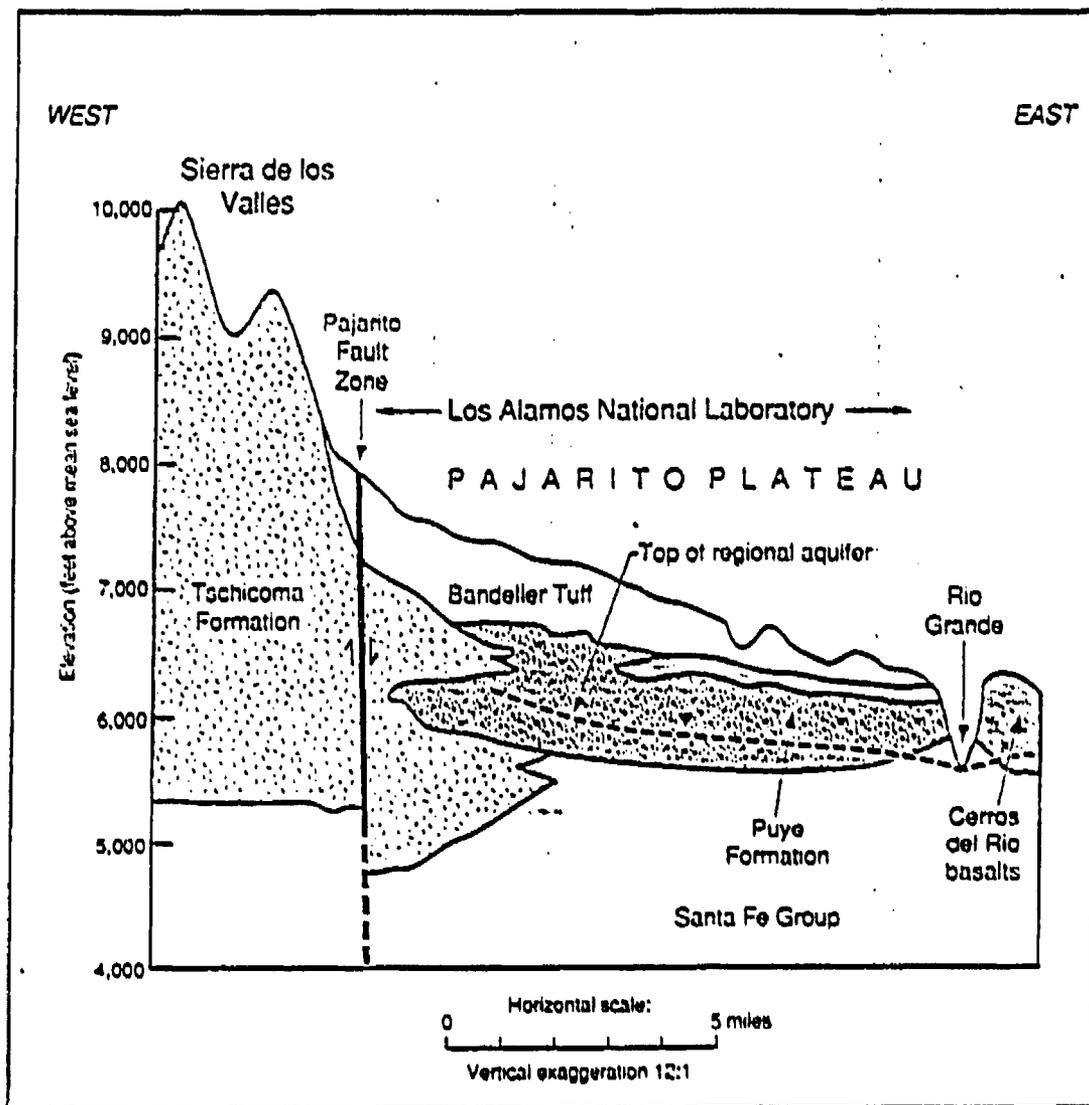


Figure 4. Generalized geologic cross section across the Pajarito Plateau.

Perennial springs on the flanks of the Jemez Mountains supply base flow into the upper reaches of some canyons, but the volume is insufficient to maintain surface flows across the Laboratory site before streams are depleted by evaporation, transpiration, and infiltration. Runoff in some canyons, resulting from large thunderstorms or heavy snowmelt, reaches the Rio Grande several times a year. Effluents from sanitary sewage, industrial waste treatment plants, and cooling-tower blowdown enter some canyons at rates sufficient to maintain surface flows for varying distances.

Groundwater Occurrence

Groundwater beneath the Pajarito Plateau occurs in three modes, two of which are perched (Figure 5). Perched groundwater is a body of groundwater above a less permeable layer that is separated from an underlying main body of groundwater by an unsaturated zone. The three modes of groundwater occurrence are (1) perched alluvial groundwater in canyon bottoms, (2) limited-extent zones of intermediate-depth perched groundwater whose location is controlled by subsurface changes in rock type and permeability, and (3) the regional aquifer beneath the Pajarito Plateau. These types of groundwater are described in more detail below.

Streams have filled some parts of canyon bottoms with alluvium ranging up to as much as 100 ft in thickness. Stream runoff percolates through the alluvium until downward flow is impeded by less permeable layers of tuff. This creates shallow bodies of perched groundwater within the alluvium. As water in the alluvium moves down the canyon, it is depleted by evapotranspiration and infiltration into underlying rocks. The chemical quality of some of the alluvial groundwater shows the effects of discharges from the Laboratory.

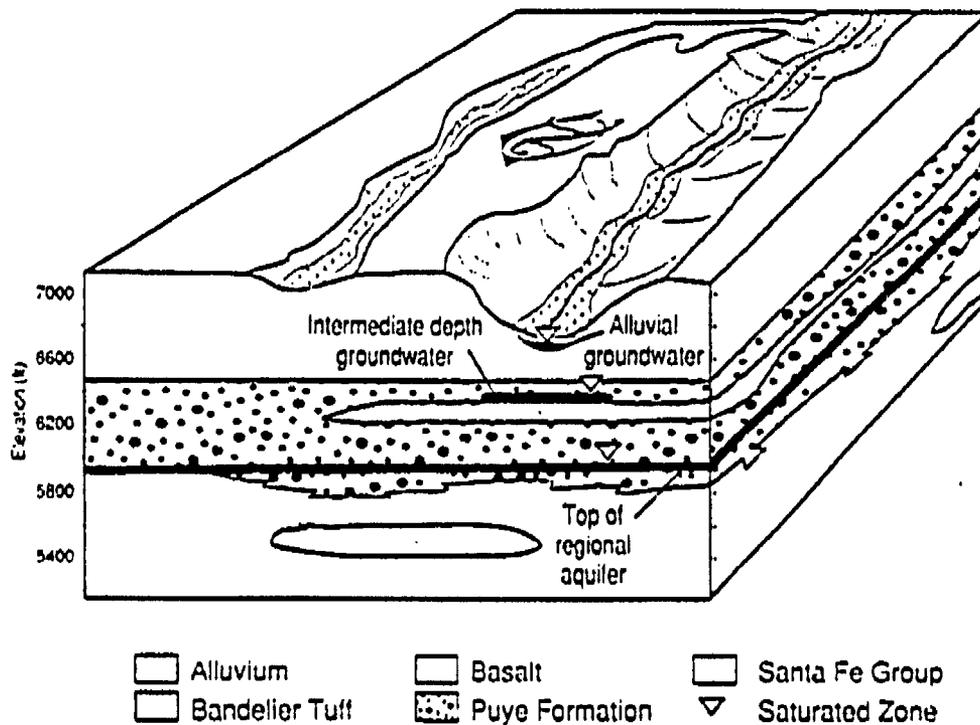


Figure 5. Illustration of geologic and hydrologic relationships in the Los Alamos area, showing the three modes of groundwater occurrence.

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 (Figure 4). This is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Tesuque Formation (part of the Santa Fe Group). The aquifer rises farther into the lower part of the Puye Formation beneath the central and western part of the plateau (Figures 4 and 5). Depth to the regional aquifer is about 1,000 ft beneath the mesa tops in the central part of the plateau. The regional aquifer is separated from alluvial and intermediate perched waters by about 350 to 620 ft of unsaturated tuff and sediments with low (<10%) moisture content.

Beneath portions of Pueblo, Los Alamos, and Sandia canyons (canyon locations shown in Figures 2 and 3), perched groundwater occurs at intermediate depths within the thick zone of unsaturated rock (Bandelier Tuff, basalts, and Puye Formation) underlying the alluvium. The intermediate perched groundwater occurs within the lower part of the Bandelier Tuff and within the underlying conglomerates and basalt (Figure 5). The perched groundwater has been found at depths ranging from about 120 ft in Pueblo Canyon to about 450 ft in Sandia Canyon. Its location is controlled by variations in the permeability of the rocks underlying the plateau. These intermediate-depth groundwater bodies are formed in part by recharge from the overlying perched alluvial groundwater. The intermediate groundwater shows radioactive and inorganic contamination from Laboratory operations.

Recharge reaching the regional aquifer from the intermediate perched groundwater is likely to be small in quantity and small in its tritium impact. This is because of the limited extent and small volume of the intermediate groundwater bodies and because the dry rock separating these two zones permits only small rates of groundwater flow. Tritium levels in the intermediate groundwater will be detailed below. The highest tritium levels found in the intermediate perched groundwater beneath Pueblo Canyon in the late 1970s were near the EPA drinking water limit of 20,000 pCi/L. The highest levels below Los Alamos Canyon were about 25% of the EPA limit in the mid-1990s. Tritium levels in each of these areas have subsequently dropped off rapidly. The addition of a small amount of this shallow groundwater (infiltrating from the alluvium or the intermediate perched zones) to a much larger amount of regional aquifer water would probably not result in a large tritium impact.

Perched water also occurs within the Bandelier Tuff at the western Laboratory border near the Jemez Mountains. The source of this perched water may be infiltration from streams discharging from the mouths of canyons along the mountain front and underflow of recharge from the Jemez Mountains.

ACID AND PUEBLO CANYONS

Acid Canyon, a small tributary of Pueblo Canyon, was the original disposal site for liquid wastes generated by research on nuclear materials for the World War II Manhattan Engineer District atomic bomb project. From 1943 to 1951, Acid Canyon received untreated radioactive industrial effluent from the TA-1 research activities. The TA-45 treatment plant was completed in 1951 and discharged treated effluents that contained residual radionuclides into Acid Canyon from 1951 to 1964.

Tritium discharge estimates for TA-1 and TA-45 are shown in Tables 2 and 3. A study of TA-1 and TA-45 for the Formerly Utilized Sites Remedial Action Program (FUSRAP, ESG 1981) estimated total tritium discharges from TA-1 into Acid Canyon between 1943 and April 1951 to be 18.25 Ci. The activity of this tritium would have decayed to 3.4 Ci in 1977 (and to 1.1 Ci in 1997). Discharge estimates for TA-1 compiled under the Comprehensive Environment Assessment and Response Program (CEARP, DOE 1987) are about twenty times larger than FUSRAP values for TA-1 (Table 2). These CEARP estimates are attributed to the DOE Onsite Discharge Information System database. During operation of the TA-45 treatment plant from 1951 through 1964, an additional 40.2 Ci of tritium was released (ESG 1981), as shown in Table 3.

FUSRAP		CEARP	
Period (decay to yr)*	Tritium (Ci)	Period (decay to yr)	Tritium (Ci)
1943-1951	18.3	1943-1951	--
1943-1951 (1977)	3.4	1943-1951 (1981)	56.3
1943-1951 (1997)	1.1	1943-1951 (1997)	23.1

*Decay corrections after either 1977 or 1981 use a tritium half-life of 12.43 yr. or decay constant of 0.05576/yr.

FUSRAP		CEARP	
Period (decay to yr)	Tritium (Ci)	Period (decay to yr)	Tritium (Ci)
1951-1964	40.2	1951-1964	--
1951-1964 (1977)	13.1	1951-1964 (1981)	10.5
1951-1964 (1997)	4.3	1951-1964 (1997)	4.3

Tritium histories for several monitoring stations in Pueblo Canyon are shown in Figure 6. During the 1970s tritium activities in alluvial groundwater and surface water in Pueblo Canyon ranged from less than 1,000 pCi/L up to 19,000 pCi/L (DOE 1979). Activities up to 3,600 pCi/L (at surface water station Pueblo 2 in 1992) have been observed in the 1990s. Test Well 2A (sampling intermediate perched groundwater beneath Pueblo Canyon at a depth of 120 ft) had tritium activities of 18,000 to 24,000 pCi/L in the late 1970s, with values during the 1990s of 200 to 3,100 pCi/L. Test Well 1A (also sampling perched groundwater at a depth of 188 ft) has had electrolytic enrichment tritium measurements of 79 to 132 pCi/L from 1992 through 1995. Higher values in Test Well 1A that reflect analytical laboratory contamination were measured by the liquid scintillation method in the 1980s, up to $6,600 \pm 800$ pCi/L in 1982. Most measurements for Test Well 1A during the 1980s were nondetections.

Basalt Spring lies in Lower Los Alamos Canyon on San Ildefonso Pueblo land (Figure 3). This spring discharges from intermediate perched groundwater and is below the confluence of both Pueblo and Los Alamos canyons. Tritium values for Basalt Spring are similar to tritium levels in Test Well 1A in Pueblo Canyon. A hydrologic connection between Test Well 1A and Basalt Spring was determined to exist through early studies by the US Geological Survey at Los Alamos (Weir et al. 1963, Purtymun 1995). Electrolytic enrichment analyses for Basalt Spring during the period from 1991 to 1995 have yielded tritium values ranging from 88 to 160 pCi/L. Five tritium detections using the liquid scintillation technique occurred during the 1970s and 1980s. The highest was 51,000 pCi/L in 1982 and is probably the result of sample contamination in the analytical laboratory. Four other values ranging from 1,600 to 5,300 pCi/L occurred between 1975 and 1986.

Most of the measurements for the Pueblo Canyon regional aquifer wells during the 1980s were nondetections. A 1986 liquid scintillation measurement in Test Well 1 gave a value of $10,600 \pm 400$ pCi/L, but this measurement occurred during the time of likely analytical laboratory contamination of samples. Similarly, Test Well 2 had a value of $25,000 \pm 1,000$ pCi/L in 1982. In samples collected in the 1990s, regional aquifer test wells beneath Pueblo Canyon have shown tritium detectable only by electrolytic enrichment. The exception is a 1991 liquid scintillation value in Test Well 2 of $1,800 \pm 300$ pCi/L. Later electrolytic enrichment values show a maximum of 16 pCi/L in Test Well 2 and 360 pCi/L in Test Well 1. One measurement in Test Well 4 showed 10 pCi/L, but this may have been related to water added to the well during reconditioning. In summary, the highest reliable and repeatable tritium measurements from the regional aquifer beneath Pueblo Canyon are from Test Well 1 and are in the range of 360 pCi/L.

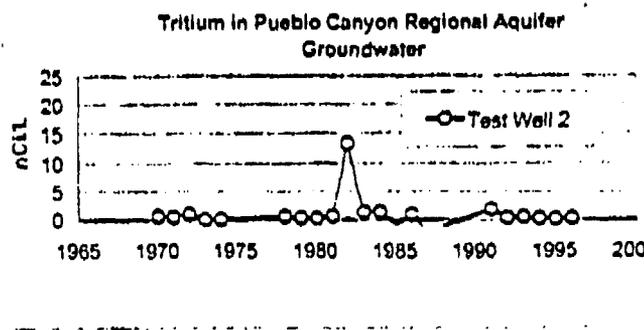
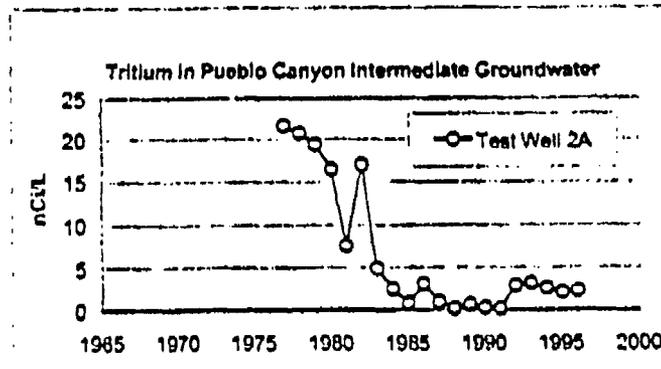
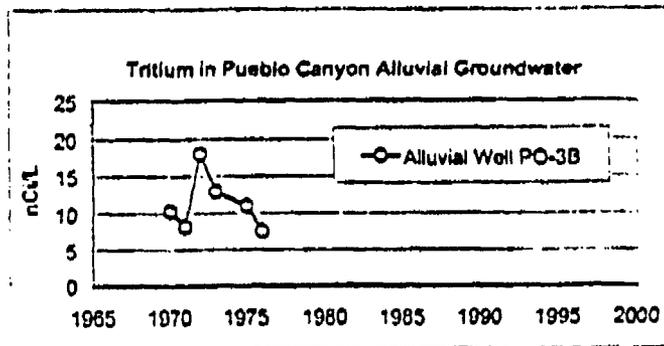
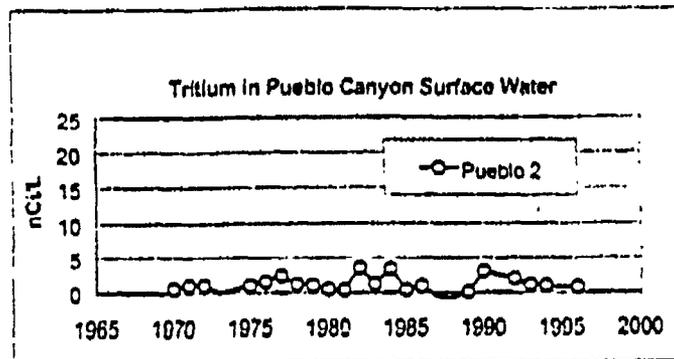


Figure 6. Tritium histories (average annual values) for surface water (Pueblo 2), alluvial groundwater (PO-3B), intermediate groundwater (Test Well 2A), and the regional aquifer (Test Well 2) in Pueblo Canyon (nCi/L or 1,000 pCi/L).

DP AND LOS ALAMOS CANYONS

In the past, Los Alamos Canyon received treated and untreated industrial effluents containing radionuclides. In the upper reach of Los Alamos Canyon there were releases of treated and untreated radioactive effluents beginning with the Laboratory's earliest Manhattan Project operations at TA-1 (mid to late 1940s). Some release of water and radionuclides from the research reactors at TA-2 occurred, including the Omega West Reactor. Los Alamos Canyon also received discharges containing radionuclides from the Los Alamos Neutron Science Center at TA-53. Radioactive effluent from an industrial liquid waste treatment plant at TA-21 entered Los Alamos Canyon via DP Canyon, a tributary.

LAMPF Lagoons, TA-53

Los Alamos Canyon received discharges containing radionuclides from the sanitary sewage lagoon system at the Los Alamos Meson Physics Facility (LAMPF, now the Los Alamos Neutron Science Center) at TA-53. The northern two of the three ponds received radioactive waste from their construction in 1969 (LANL 1994). The largest source of radioactive liquid waste is cooling water from the accelerator beam stops and experimental areas. The first beam was produced in 1970 (LANL 1994), so tritium was probably present in the ponds from that date. The low-level radioactive waste stream was separated from the sanitary system at TA-53 in 1989 and directed into a total retention evaporation lagoon. Total discharge of tritium from the ponds to Los Alamos Canyon from 1978 to 1989 was approximately 187.4 Ci. The 1997 decayed activity of this tritium would be 90.7 Ci. This estimate is based on tritium discharges reported in annual environmental surveillance reports for this period; records for earlier years are not available.

Studies discussed in environmental surveillance reports up through 1984 indicate that in most years the effluent draining from the lagoons completely infiltrated within the first 1,000 m of the 3,000-m drainage distance to Los Alamos Canyon. Surface water and sediment samples collected from the drainage between 1979 and 1982 showed tritium activities as high as 680,000 pCi/L (ESG 1983). Tritium activities decreased to a maximum of 15,000 pCi/L in surface water and 20,000 pCi/L in sediments at the junction of the drainage with Los Alamos Canyon.

Omega West Reactor, TA-2

In January 1993 operators at the Omega West Reactor realized during a test that the reactor cooling system was leaking. The reactor basement flooded on an annual basis because of high water levels in the Los Alamos Canyon stream. This flooding began after surface water diversion from the Los Alamos Canyon Reservoir for irrigation was reduced and flow in the canyon increased. At the time the leak was discovered, tritium activities in water in the reactor basement ranged from 100,000 to 120,000 pCi/L (EPG 1995). The reactor and the leak were shut down in subsequent months.

It became evident that the reactor leak may have been a significant tritium source in Los Alamos Canyon for several years following the installation of the cooling system in 1956. If the leak occurred for 36 years, the total tritium discharge through 1992 would have been a maximum of about 70 Ci, with a decayed activity to 1997 of 23.1 Ci. This estimate assumes that the leak began on installation of the cooling system in 1956 and occurred at an average rate of 70 gal./day, with a cooling water tritium activity of 20,000,000 pCi/L.

Since the 1970s, shallow alluvial groundwater wells upstream of the reactor had shown tritium levels ranging from 100 to 3,700 pCi/L (Figure 7). At a well immediately downstream from the reactor (LAO-1), tritium levels were variable with a mean value of 15,000 pCi/L (maximum of 85,000 pCi/L). After cessation of the leak, tritium levels in downstream surface water and alluvial groundwater rapidly fell to near the detection limit of the liquid scintillation method for tritium analysis, roughly 1,000 pCi/L (ESP 1996).

Within the intermediate perched groundwater at a depth of 325 ft beneath Los Alamos Canyon, Environmental Restoration Project Well LADP-3 showed a tritium level of 5,500 pCi/L in 1993 (Broxton 1995). LADP-3 is located about two miles downstream of the Omega West Reactor but upstream of DP Canyon. The tritium level in LADP-3 had declined to 1,470 pCi/L by early 1995 (LANL 1995) and fell further to 890 pCi/L by late 1996 (P. Longmire, personal communication, 1998). A second intermediate-depth well, LAOI-1.1 found a maximum of 2.3 pCi/L of tritium at a depth of 295 ft in 1995 (LANL 1995). This well is located about 2,000 ft downstream from the Omega West Reactor. The rapid decline of tritium activities in Well LADP-3 is attributed to cessation of the reactor leak.

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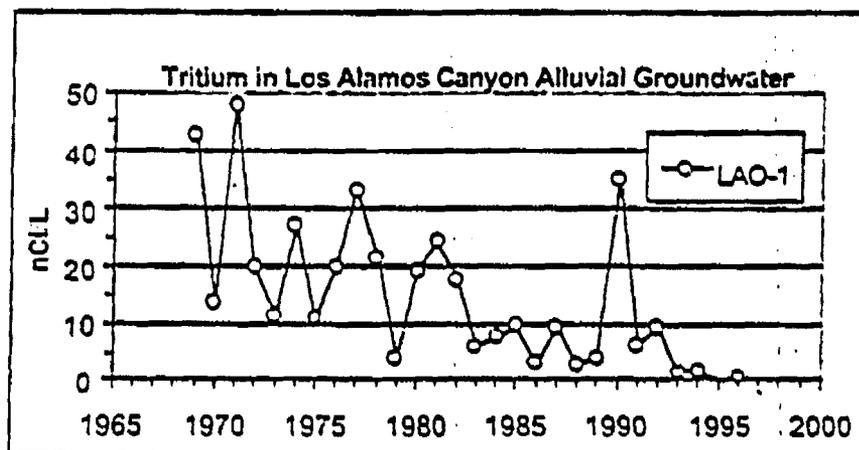
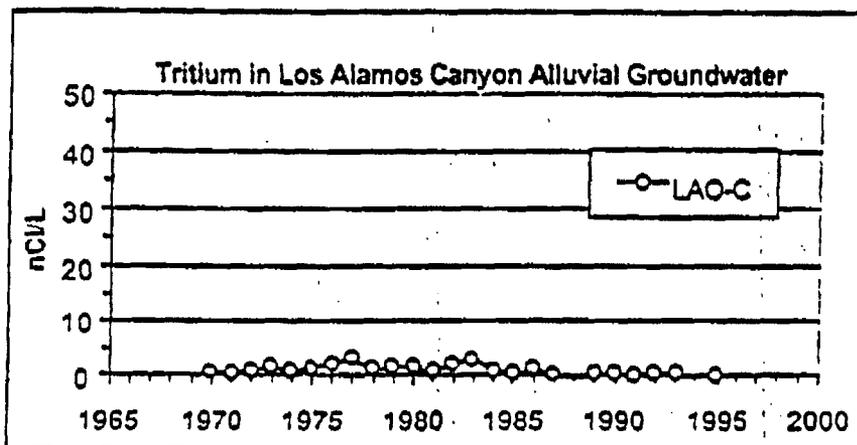


Figure 7. Tritium histories (average annual values) for alluvial groundwater wells in upper Los Alamos Canyon (nCi/L or 1,000 pCi/L). LAO-C is upstream of the Omega West Reactor, and LAO-1 is downstream of the reactor.

TA-21 Industrial Liquid Waste Treatment Plant, DP Canyon

An industrial liquid waste treatment plant that served the former plutonium-processing facility at TA-21 discharged effluent containing radionuclides into DP Canyon, a tributary to Los Alamos Canyon, from 1952 to 1986. After 1986, the treated effluent was diverted to the RLWTF. About 36 Ci of tritium (decay corrected to 1977) were released from this plant between 1952 and 1977 (Table 4). Figures for tritium discharges from 1978 through 1985 were compiled from annual environmental surveillance reports.

In the late 1960s, tritium activities in DP Canyon surface water (Figure 8) ranged from 170,000 to 4,860,000 pCi/L (Purtymun 1973a). During the same period, alluvial groundwater tritium activities in Los Alamos Canyon alluvial groundwater wells LAO-2,

Period (decay to yr)	Tritium (Ci)	Period (decay to yr)	Tritium (Ci)
Original Study	FUSRAP	CEARP	
1952-1977 (1977)	36.0	1952-1981 (1981)	30.7
1952-1977 (1997)	11.8	1952-1981 (1997)	12.6
This Study			
1978-1985	6.5	1982-1985	4.1
1978-1985 (1997)	2.9	1982-1985 (1997)	1.9
Total			
1952-1985 (1997)	14.7	1952-1985 (1997)	14.5

LAO-3, and LAO-4, located below the confluence with DP Canyon, ranged from below the detection limit (50,000 pCi/L) to 860,000 pCi/L. The tritium levels in DP Canyon surface water and Wells LAO-2, LAO-3, and LAO-4 have decreased dramatically since discharge from the TA-21 treatment facility halted in 1986 to less than 2,000 pCi/L.

Test Well 3 is a regional-aquifer-monitoring well located in Los Alamos Canyon just below the intersection with DP Canyon. Between 1993 and 1996, tritium measurements using electrolytic enrichment have shown a maximum value of 53 pCi/L. This indicates that some recent recharge has reached the regional aquifer at this location. Other regional aquifer wells are located in lower Los Alamos Canyon on Pueblo of San Ildefonso land. Tritium results for these wells are discussed in a later section.

TA-35 WASTE TREATMENT PLANT

Tritium operations were carried out at TA-35 from 1953 to 1974. A wastewater treatment plant operated there from 1951 until 1963 when the TA-50 RLWTF became operational. The effluent from the TA-35 plant was discharged to a branch of Mortandad Canyon, but only limited records are available regarding the amount of discharges that may have occurred. Numerous spills and accidental discharges were associated with the waste treatment plant and reactors at the site. Radioactive contamination resulting from TA-35 discharges has been reported in Mortandad and tributary canyons (DOE 1987). Because tritium measurements did not become routine until about 1970, any impact of TA-35 discharges would have been obscured by subsequent TA-50 discharges into Mortandad Canyon. Tritium released in liquid effluents may have been substantial, considering the nature of operations at TA-35. Surveillance reports indicate, for example, that 3,130 Ci of tritium were released to the atmosphere from TA-35 during 1971.

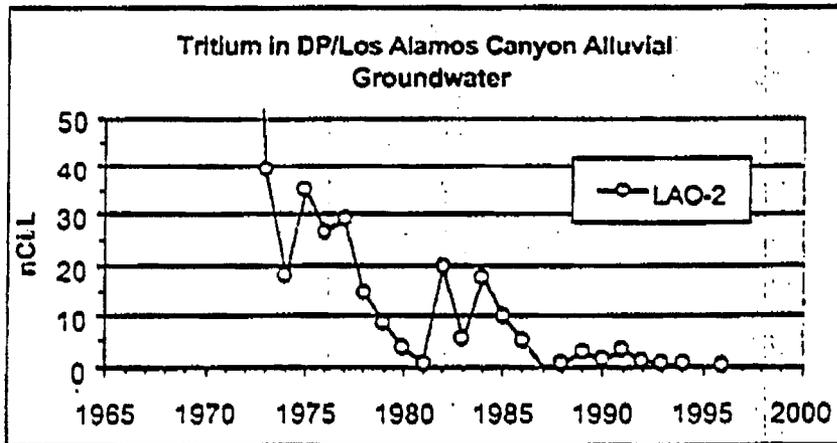
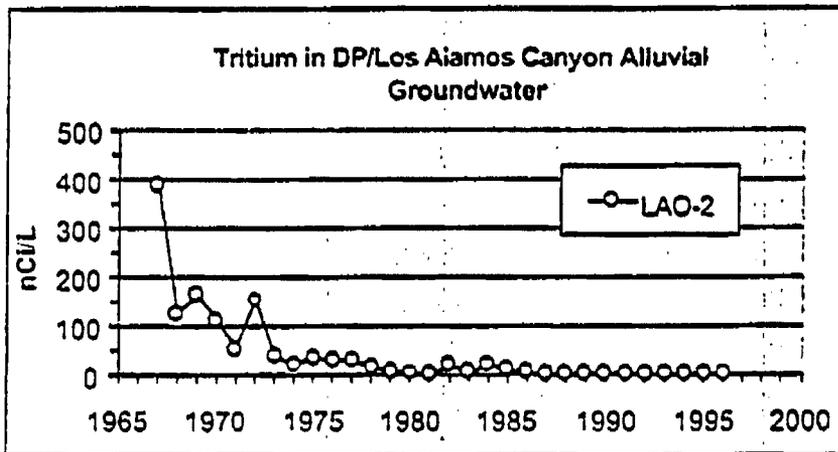
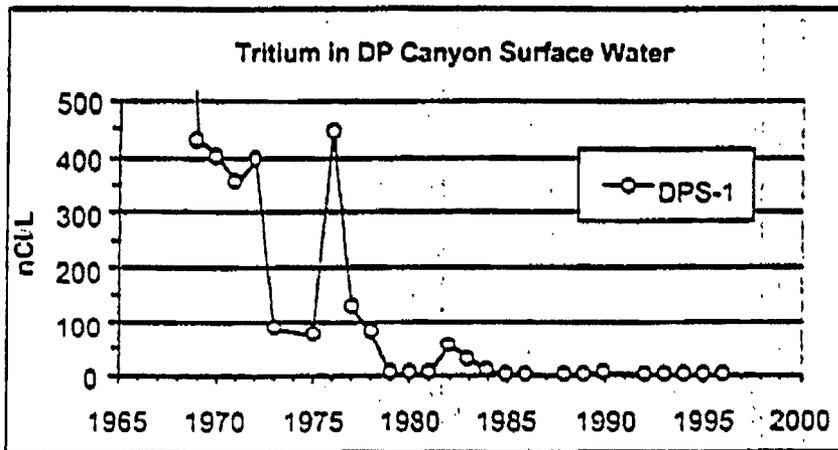


Figure 8. Tritium histories (average annual values) for surface water in DP Canyon and an alluvial groundwater well in upper Los Alamos Canyon at the mouth of DP Canyon (nCi/L or 1,000 pCi/L). The bottom two plots are duplicates at different scales and the scale on the first two plots is ten times that of the previous figure.

MORTANDAD CANYON AND THE TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

The Laboratory now discharges tritium as liquid effluent from the RLWTF only into Mortandad Canyon. The RLWTF began operations in 1963. Tritium is not removed from the waste stream by the treatment process at the RLWTF. In order to decrease the amount of tritium in the effluent, the Laboratory plans to significantly reduce the quantity of tritium flowing into the RLWTF beginning in the summer of 1998.

Mortandad Canyon has a small drainage area that heads at TA-3. The TA-50 effluents infiltrate the stream channel and maintain a saturated zone in the alluvium extending about 2.2 mi downstream from the outfall. The easternmost extent of saturation is on-site, about 1 mi west of the boundary between the Laboratory and the Pueblo of San Ildefonso. Continuous flow of surface water along the drainage has not been observed to reach the Pueblo of San Ildefonso boundary since studies began in the early 1960s (Stoker 1991). Table 5 lists the total tritium discharges from the TA-50 plant. Figures for tritium discharges from 1978 through 1996 were compiled from annual environmental surveillance reports and the Work Plan for Mortandad Canyon (LANL 1997).

The average annual tritium activity in the TA-50 effluent between 1972 and 1995 was 945,000 pCi/L, with a maximum of 4,688,000 in 1976 and a minimum of 41,400 in 1995 (Figure 9). Tritium activities in Mortandad Canyon surface water below the outfall have averaged at 262,800 pCi/L over the same period, ranging from 4,260,000 pCi/L (one value of 8,400,000 pCi/L) in 1987 to a nondetection in 1988. Average annual alluvial groundwater activities between 1972 and 1995 have ranged from one value of 12,000,000 pCi/L at MCO-3 in 1987 to a nondetection at MCO-3 in 1988, with an average of 224,000 pCi/L. The mean alluvial groundwater tritium activity for all stations from 1990 through 1995 was 52,900 pCi/L.

Table 5. TA-50 Tritium Releases

Period (decay to yr)	Tritium (Ci)	Period (decay to yr)	Tritium (Ci)
Original Study	DOE 1979	CEARP	
1963-1977 (1977)	251.1	1963-1981 (1981)	296.7
1963-1977 (1997)	82.3	1963-1981 (1997)	121.6
This Study			
1978-1996	396.3	1982-1996	285.4
1978-1996 (1997)	206.1	1982-1996 (1997)	165.5
Total			
1963-1996 (1997)	288.4	1963-1996 (1997)	287.1

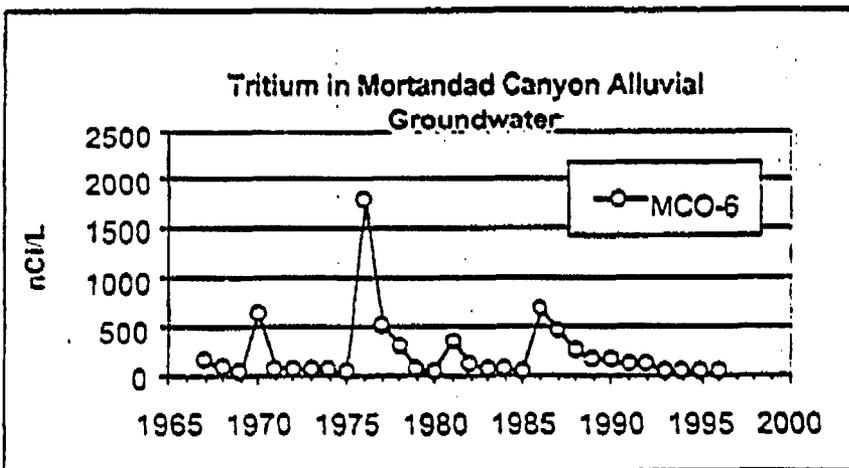
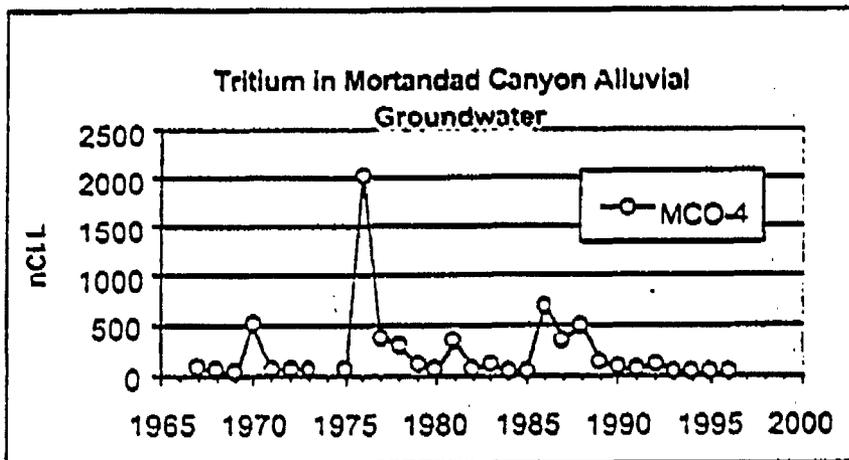
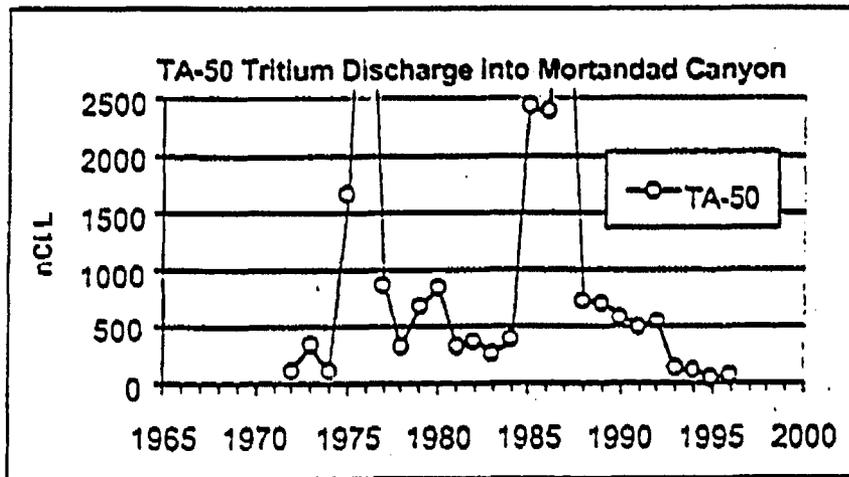


Figure 9. Tritium histories (average annual values) for TA-50 RLWTF discharge and for alluvial groundwater wells in Mortandad Canyon (nCi/L or 1,000 pCi/L).

Test Well 8 is a regional aquifer test well located below the RLWTF outfall in Mortandad Canyon. Possible detections of tritium in Test Well 8 occurred in 1976 ($2,700 \pm 300$ pCi/L) and in 1982 ($9,100 \pm 600$ pCi/L). These measurements were done by the liquid scintillation method, and the second one occurred during a period of likely analytical laboratory contamination. Results of electrolytic enrichment measurements carried out from 1993 through 1996 have ranged from 5 to 88 pCi/L.

SANDIA CANYON

Data from surface water stations in Sandia Canyon suggest that TA-3 sanitary waste water discharge into the canyon may have been a tritium source up until the early 1980s (Figure 10). Surface water flow in Sandia Canyon is dominated by effluent from TA-3. Tritium histories for the three stations are very similar, suggesting that the tritium in surface water had the same source for all stations. The tritium might have entered the TA-3 sanitary system because of inadvertent cross connections between industrial and sanitary sewage lines.

TA-33 TRITIUM FACILITY AND MATERIAL DISPOSAL AREA K

TA-33 was the site of a high-pressure tritium facility from 1955 until late 1990. Accidental tritium releases over the years contaminated the tritium facility septic system, sumps, and cooling water outflow. These waste streams were collected in a shallow pit and septic tanks designated as MDA K (LANL 1992a). No available records document the curie content of these releases (DOE 1979).

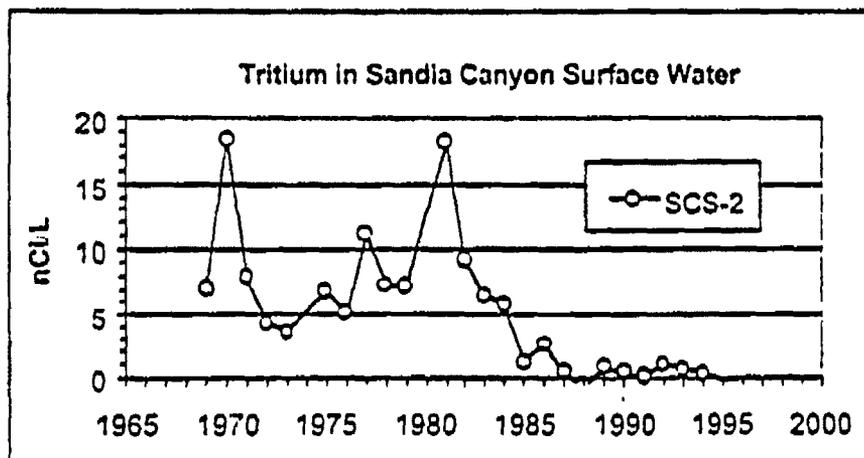


Figure 10. Tritium histories (average annual values) for surface water in Sandia Canyon (nCi/L or 1,000 pCi/L).

Airflow that was passed through the tritium facility to protect personnel was discharged through stacks. For a perspective on the quantity of tritium involved at this facility, the resulting estimated release of tritium to the atmosphere each year was 2,000 to 6,000 Ci. Another estimate suggests that 60,000 Ci of tritium were released to the atmosphere by the facility between 1955 and 1970 (LANL 1992a).

Tritium activities found in soil moisture and vegetation samples at MDA K (ranging from 7,200,000 to 220,000,000 pCi/L) are largely attributed to atmospheric releases. One borehole drilled at MDA K found a tritium activity of 82,000,000 pCi/L in soil water in the unsaturated zone at a depth of 99 ft. At a depth of 175 ft in this borehole, a tritium activity of 9,100,000 pCi/L was found (LANL 1992a).

MATERIAL DISPOSAL AREA G (TA-54)

Material Disposal Area G is the primary solid radioactive waste disposal and retrievable storage area used at Los Alamos since 1957. MDA G is located on a mesa top, with Pajarito Canyon to the south and Cañada del Buey to the north. Except for retrievable transuranic waste, most waste has been placed in lined and unlined pits and shafts. Variations over time in record keeping regarding disposed waste make accurate determination of disposal quantities difficult. A 1979 estimate (DOE 1979) of total radionuclide content of materials placed in subsurface disposal and storage through December 1976 (decay corrected to 1976) included 123,853 Ci of tritium at Area G (decayed to 40,605 Ci in 1997). Additional estimates of tritium disposed of at MDA G (Hollis 1997) are given in Table 6.

A study of tritium migration from the disposal shafts at MDA G (Purymun 1973b) found that tritium activities within the mesa at distances of 40 ft from the shafts reached 10,000,000 pCi/L, at a depth of about 20 ft. At distances of 100 ft from the shafts, tritium activities of 10,000 pCi/L were found. Tritium activities in surface soil moisture near a shaft ranged from 1,100,000 pCi/L within 5 ft of the shaft to 30,000 pCi/L at a distance of 100 ft. Vegetation samples had tritium activities ranging up to values of 101,000,000 pCi/L and 17,700,000 pCi/L.

Tritium has been found at levels up to 88,000 pCi/L in moisture contained in sediment samples collected at nine stations surrounding MDA G. Tritium activities in at least 25 samples collected between 1982 and 1996 have exceeded 5,000 pCi/L. Between 1985 and 1996 no tritium had been detected in alluvial groundwater in Pajarito Canyon to the south of MDA G, nor between 1992 and 1996 in Cañada del Buey groundwater to the north.

Table 6. MDA G Tritium Disposal (Ci) Based on Hollis (1977)

Period	Pits		Shafts	
	Total disposed	Decayed to 1997*	Total disposed	Decayed to 1997*
1957-1970	2.7	0.6	34,000	7,545
1971-9/25/88	6,211	3,760	800,000	484,332
9/26/88-1995	19.1	17.1	430,000	384,624
1957-1995	6,233	3,778	1,264,000	876,501

*Represents upper limit value, as entire amount disposed is presumed to have decayed from end of disposal period.

MATERIAL DISPOSAL AREA H (TA-54)

Material Disposal Area H was originally intended to receive uncontaminated classified waste, which was placed in nine shafts between 1960 and 1986. Radioactive waste including weapons components was placed in each of the shafts, and tritium apparently migrated from the shafts in the 1960s and early 1970s (LANL 1992b). No records exist regarding the quantities of radioactive materials that were disposed of at MDA H. Tritium data were collected during the drilling of shaft 8 in 1969 (Acby 1969). Tritium activities in soil moisture at 40 ft in Shaft 8 were 2,000,000,000 pCi/L (LANL 1992b). Surface soil moisture tritium activities reached 3,000,000 pCi/L. In 1973 during excavation of Shaft 9, tritium activities up to 1,700,000,000 pCi/L (at a depth of 25 ft) were found. Surface soils had tritium levels up to 78,000 pCi/L, and vegetation contained activities up to 3,400,000 pCi/L (J. W. Acby in Purtymun 1994, LANL 1992b).

MATERIAL DISPOSAL AREAS T (TA-21) AND C (TA-50)

According to 1979 estimates (DOE 1979), 4 Ci of tritium (decay corrected to 1976, and decayed to 1.2 Ci in 1997) were placed in adsorption beds at MDA T (at TA-21) between 1945 and 1951. Between 1960 and 1969, about 39,186 Ci of tritium (decay corrected to 1976, and decayed to 12,835 Ci in 1997) were buried in pits at MDA C, located at TA-50.

TRITIUM LEVELS IN LOS ALAMOS WATER SUPPLY WELLS

The Los Alamos public water supply wells are located in three fields. The well fields include the Guaje Well Field, located off site in Guaje Canyon on US Forest Service lands northeast of the Laboratory, and the on-site Pajarito Mesa and Otowi well fields. The Guaje Well Field contains seven wells, five of which had significant production during 1996. The five wells of the Pajarito Mesa Well Field are located in Sandia and

Pajarito canyons and on mesa tops between those canyons. Two new water supply wells were completed in 1990. These are the first wells in the Otowi Well Field, and the wells were designated Otowi-1 and Otowi-4.

The Los Alamos Well Field, located on Pueblo of San Ildefonso lands east of the Laboratory in Los Alamos Canyon, has not been used for Los Alamos water supply since 1991. Four of the wells were turned over to the Pueblo to be used as water supply or monitoring wells. The remaining four wells in the field were plugged in 1993.

The Guaje Well Field is off site and not located near any potential contaminant sources. Some of the wells of the on-site Pajarito Mesa and Otowi Well Fields and the off-site former Los Alamos Well Field are located near or downgradient from potential contaminant sources, including the tritium sources discussed earlier.

- Otowi-1 is in Pueblo Canyon, downgradient from the former TA-1 and TA-45 releases.
- Otowi-4 is in Los Alamos Canyon, below releases from TA-21 and the Omega West Reactor.
- PM-2 (Pajarito Mesa 2) is upstream of the TA-54 disposal areas (MDAs G, H, and L).
- PM-4 is located on a mesa downstream of releases from the former Rover Project at TA-46.
- PM-5 is located on a mesa downstream from the RLWTF discharge into Mortandad Canyon.
- The wells of the former Los Alamos Well Field are downstream from former effluent discharges at TA-1 and TA-45 in Pueblo Canyon, and from TA-2 and TA-21 in Los Alamos and DP canyons.

The screened intervals in the water supply wells range in height from 400 to 500 ft in the Guaje Well Field and 1,200 to 1,600 ft in the Pajarito Mesa and Otowi well fields. Samples collected from these wells thus represent average compositions for water drawn into the well screens from a large portion of the subsurface. Tritium values for electrolytic enrichment samples collected from the Guaje Well Field in 1991 and 1992 average less than 1 pCi/L. Tritium activities in samples from Otowi-4 in 1993 similarly average to about 1 pCi/L. Finally, samples from the Pajarito Mesa Well Field collected between 1991 and 1994 have tritium activities that average less than 1 pCi/L. This average omits one sample for PM-5, collected on 5/19/93, which was contaminated in the analytical laboratory.

The highest tritium level measured in a water supply well at Los Alamos was an electrolytic enrichment tritium measurement of 20 pCi/L from the PM-3 water supply well in 1993. This measurement was later determined to have resulted from

contamination in the analytical laboratory. The average of six other samples collected from PM-3 in 1993 and 1994 was 0.17 ± 0.29 pCi/L.

Wells in the former Los Alamos Well Field have shown tritium levels up to 63 pCi/L, found in LA-1A in 1993. Other maximum tritium levels were 1.6 pCi/L in LA-1B, 13 pCi/L in LA-2, and 1 pCi/L in LA-5. A shallow household well in Lower Los Alamos Canyon on San Ildefonso Pueblo had tritium levels ranging from 100 to 143 pCi/L during the 1990s. Although downstream of potential Laboratory tritium sources, these regional aquifer tritium levels are within the range of values observed in precipitation over the past few decades in northern New Mexico.

The US Department of Health & Human Services Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the trace levels of tritium that were found in Los Alamos and San Ildefonso Pueblo water supply wells. Regarding that now-discredited measurement in PM-3, the ATSDR said (US Department of Health & Human Services 1995),

"it should be emphasized that 20 pCi/L is only 1/1,000 of the present EPA drinking water limit and 3/10,000 of EPA's proposed limit for drinking water. ATSDR considers water at these drinking water levels to be safe for human consumption. The 20 pCi/L is orders-of-magnitude below a level that would present a health hazard to individuals drinking this water. In addition, this concentration is one to two orders of magnitude less than the minimum detectable limit of the recommended liquid scintillation counting method used by the EPA."

CONCLUSIONS

Beginning with the Manhattan Project in the 1940s, Los Alamos National Laboratory has utilized tritium in its research programs. The Laboratory has also discharged tritium into the environment since the Manhattan Project days. This tritium discharge has occurred as liquid effluent discharges into canyons and by burial in solid waste disposal areas. Since the early 1980s, the Laboratory has sharply reduced both the number of tritium discharge locations and the total amount of tritium discharged. Because of reduced discharges, dilution by stream flow, high evapotranspiration rates, and a relatively short half-life, tritium levels in most shallow groundwater and surface water at the Laboratory have decreased significantly since the early 1980s. The exception to this trend of decreased tritium levels is Mortandad Canyon, which is the site of the only current radioactive effluent discharge at the Laboratory. Nonetheless, tritium levels in Mortandad Canyon have also decreased sharply since the 1980s. The Laboratory intends to significantly

decrease the amount of tritium sent to the RLWTF during 1998, thus reducing the quantity of tritium in effluent entering Mortandad Canyon. Regarding solid waste disposal sites such as MDA G, available surface and subsurface data suggest that tritium migration from these areas has been limited in extent.

Based on nearly three decades of environmental monitoring data, tritium activities in surface and shallow canyon-bottom groundwater within the Laboratory boundary have never exceeded the DOE's controlled area tritium concentration guide of 100,000,000 pCi/L. Tritium activities in surface and shallow canyon-bottom groundwater have been below the applicable DOE uncontrolled area concentration guides of 3,000,000 pCi/L (before 1985) or 2,000,000 pCi/L, with two exceptions. These exceptions occurred as a result of past discharges from radioactive liquid waste treatment facilities at TA-21 (into DP Canyon) and at TA-50 (into Mortandad Canyon). Tritium levels in DP Canyon and Mortandad Canyon have been much lower in recent years. The treatment plant at TA-21 ceased operation in 1986. Discharges that have occurred since 1988 in Mortandad Canyon have had much lower tritium activities.

Trace levels of tritium have been detected in regional aquifer test wells beneath areas of past and present liquid effluent discharges. Nonetheless, based on 30 yr of environmental monitoring, there has been no significant tritium impact on the regional aquifer. The maximum tritium levels found in regional aquifer test wells are only about 2% of the EPA's 20,000 pCi/L maximum contaminant level for tritium in drinking water. The highest test well tritium level found was 361 pCi/L in Pueblo Canyon Test Well 1 during 1993. Tritium levels found in water supply wells average 1 pCi/L, with a maximum of 3.0 pCi/L found in Otowi-4 in one 1993 sample.

ACKNOWLEDGMENTS

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David B. Rogers

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