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Impact of Strontium-90 on Surface Water and Groundwater at Los Alamos National Laboratory Through 2000

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Impact of Strontium-90 on Surface Water and Groundwater at Los Alamos National Laboratory Through 2000

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IMPACT OF STRONTIUM-90 DISPOSAL ON SURFACE WATER AND GROUNDWATER AT LOS ALAMOS NATIONAL LABORATORY THROUGH 2000

by

David B. Rogers

ABSTRACT

Beginning with the Manhattan Project in the 1940s, Los Alamos National Laboratory has produced waste streams containing strontium-90 through its research programs and has disposed of strontium-90 in the environment. This report documents the quantity of strontium-90 that has been disposed—either as liquid effluent or by burial in waste disposal areas—and evaluates the impact of these disposal operations on surface water and groundwater.

Strontium-90 moves slowly through groundwater because it becomes adsorbed onto rock and sediment particles: a large portion of strontium-90 will adhere to the surface of soil or sediment particles while a smaller portion will be dissolved in the water. Much of the strontium-90 released by the Laboratory is still present in surface sediments near the discharge locations in Acid Canyon, Los Alamos Canyon, and Mortandad Canyon, so strontium-90 levels in adjacent shallow groundwater and surface water at the Laboratory have remained relatively high. The Laboratory now discharges strontium-90 as liquid effluent only into Mortandad Canyon, from the TA-50 Radioactive Liquid Waste Treatment Facility.

While strontium-90 contamination is present at Los Alamos in the shallow alluvial groundwater and surface water of Acid Canyon, Los Alamos Canyon, and Mortandad Canyon, there is no reliable and consistent evidence that this contamination has affected the underlying regional aquifer, which provides drinking water. Strontium-90 appears to have been detected occasionally in regional aquifer water supply wells or test wells beneath areas of past and present liquid effluent discharges Because transport of strontium-90 in groundwater is controlled mainly by adsorption (cation exchange), a steady supply is maintained in the adjacent water as strontium-90 desorbs from soils. Therefore, if strontium-90 were present in groundwater, it should be regularly—rather than sporadically—detected in test wells within the regional aquifer. These apparent detections in the regional aquifer are more likely due to analytical outliers than to the presence of strontium-90 in groundwater, as the measurements are not repeatable. Twenty-five years of environmental monitoring have shown that strontium-90 has not appeared in the regional aquifer beneath Los Alamos.

INTRODUCTION

Strontium-90 is a fission product, produced during the detonation of nuclear weapons or the operation of nuclear reactors. Strontium-90 also occurs as an impurity in the production of plutonium and other nuclear materials used for nuclear weapons construction. Beginning with the Manhattan Project in the 1940s, activities at Los Alamos National Laboratory (LANL, or the Laboratory)—including nuclear weapons component fabrication, metallurgical research, and plutonium recovery operations—have produced waste streams containing strontium-90. The Laboratory has discharged portions of these waste streams as liquid effluents into the environment since the Manhattan Project days, particularly in Acid Canyon, Los Alamos Canyon, and Mortandad Canyon (Figure 1). Other mainly solid waste has been stored or buried at material disposal areas (MDAs) around the Laboratory. Treatment to minimize the radioactivity of liquid effluent waste streams began in 1951, and the Laboratory continues to reduce its impact on the environment through waste reduction and effluent treatment.

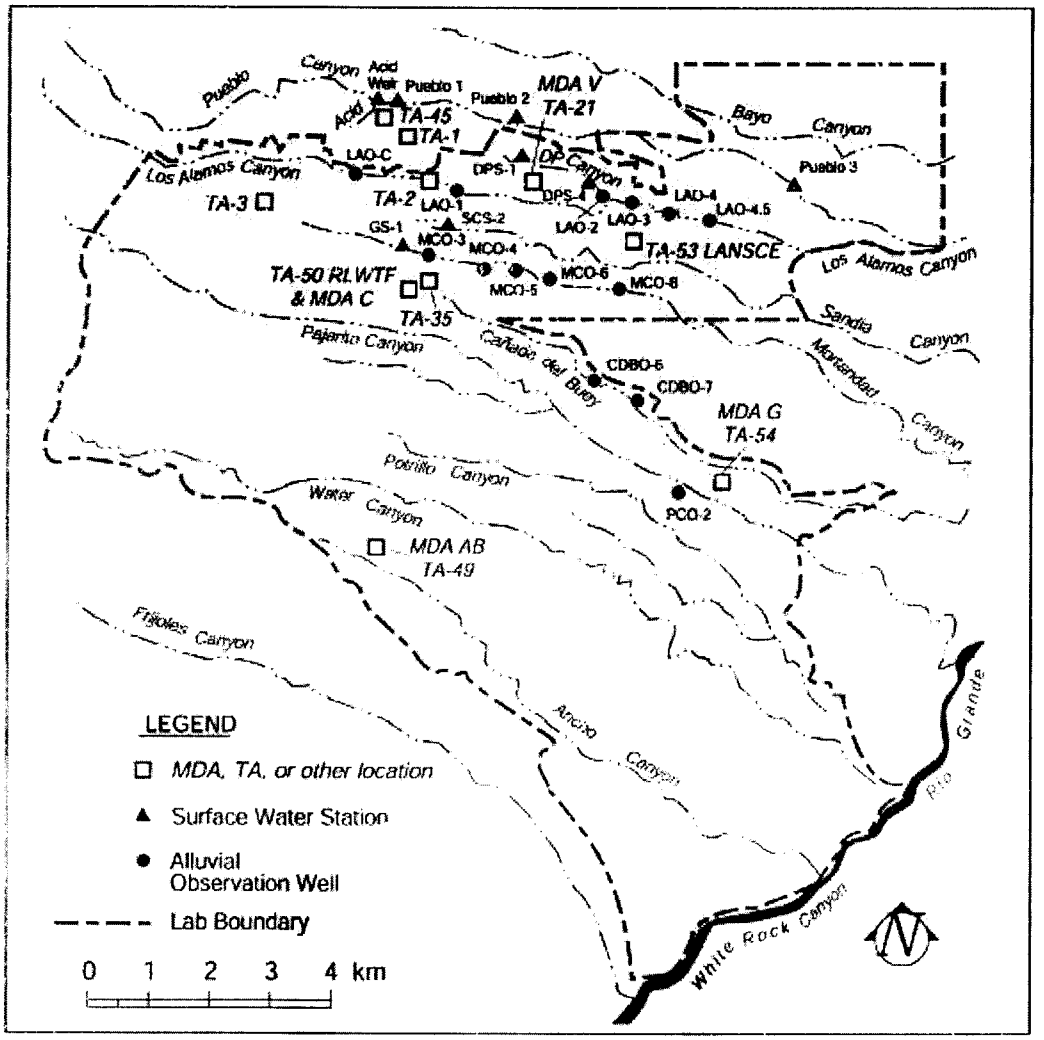


Figure 1. Locations of TAs, MDAs, selected alluvial groundwater observation wells, and surface-water-monitoring stations.

This report documents the quantity of strontium-90 that has been disposed at the Laboratory either as liquid effluent or by burial in MDAs. This documentation is limited by a lack of complete records from the earlier history of the Laboratory. The disposal locations and the estimated total strontium-90 disposed are summarized in Table 1. This report also describes the impact of these strontium-90 disposal operations on surface water and groundwater. The Laboratory has monitored surface and groundwater for possible contamination since 1945. Specific measurements of strontium-90 activity in environmental samples began in the early 1960s.

Table 1. Los Alamos National Laboratory Strontium-90 Discharge Summary

Location	Period	Estimated total disposed (in mCi, decayed to 2000[1])
Liquid effluent discharges		
TA-1	1943-1951	25.9 - 27.6
TA-45 Waste Treatment Plant	1951-1964	0 - <5.7
TA-21 Waste Treatment Plant	1952-1985	4.5 – 28.6[2]
TA-35 Waste Treatment Plant	1956-1963	77.8
TA-50 Waste Treatment Plant	1963-1999	232.3 – 233.2
Material Disposal Areas		
TA-54, MDA G	1957-1995	1,342,500
TA-21, MDA V	1945-1961	<57.5
TA-50, MDA C	1960-1969	15,516

[1]Decay corrections after either 1977 or 1981 use a Sr-90 half-life of 28.78 yr, or decay constant of 0.024084/yr. Decay corrections in original data sources may have used other half-life values.

[2]Strontium isotope values in literature sources combine strontium-89 and strontium-90 for some years and are a large overestimate of the strontium-90 releases.

Since the early 1980s, the Laboratory has decreased the number of locations where radioactive effluents are discharged to the environment. In addition, the total strontium-90 activity contained in Laboratory discharges has decreased significantly. Mortandad Canyon is now the only location receiving Laboratory discharges of strontium-90 in liquid effluent. The discharges come from the Technical Area 50 (TA-50) Radioactive Liquid Waste Treatment Facility (RLWTF).

The following sections of this report provide background information on the setting of Los Alamos National Laboratory. Later sections describe areas at the Laboratory where strontium-90 has been released or disposed and provide a perspective on the extent to which strontium-90 has entered surface water and groundwater. The lack of strontium-90 in Los Alamos drinking water is discussed in detail later in this report. Locations referred to in the text, including monitoring wells and water supply wells, canyons, technical areas, and MDAs are shown in Figures 1, 2, and 3.

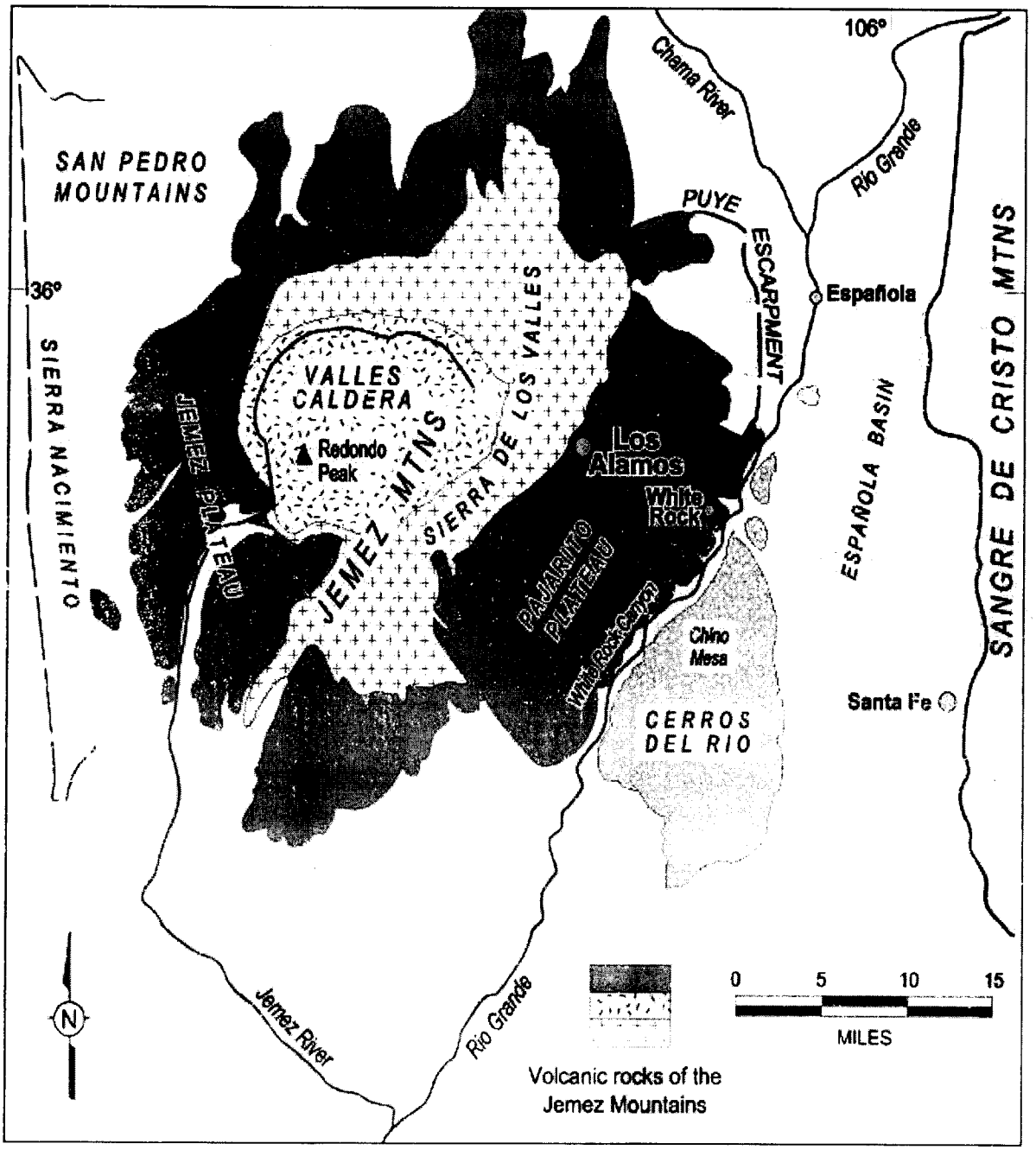


Figure 2. Map showing location of geologic and topographic features near Los Alamos and the Pajarito Plateau.

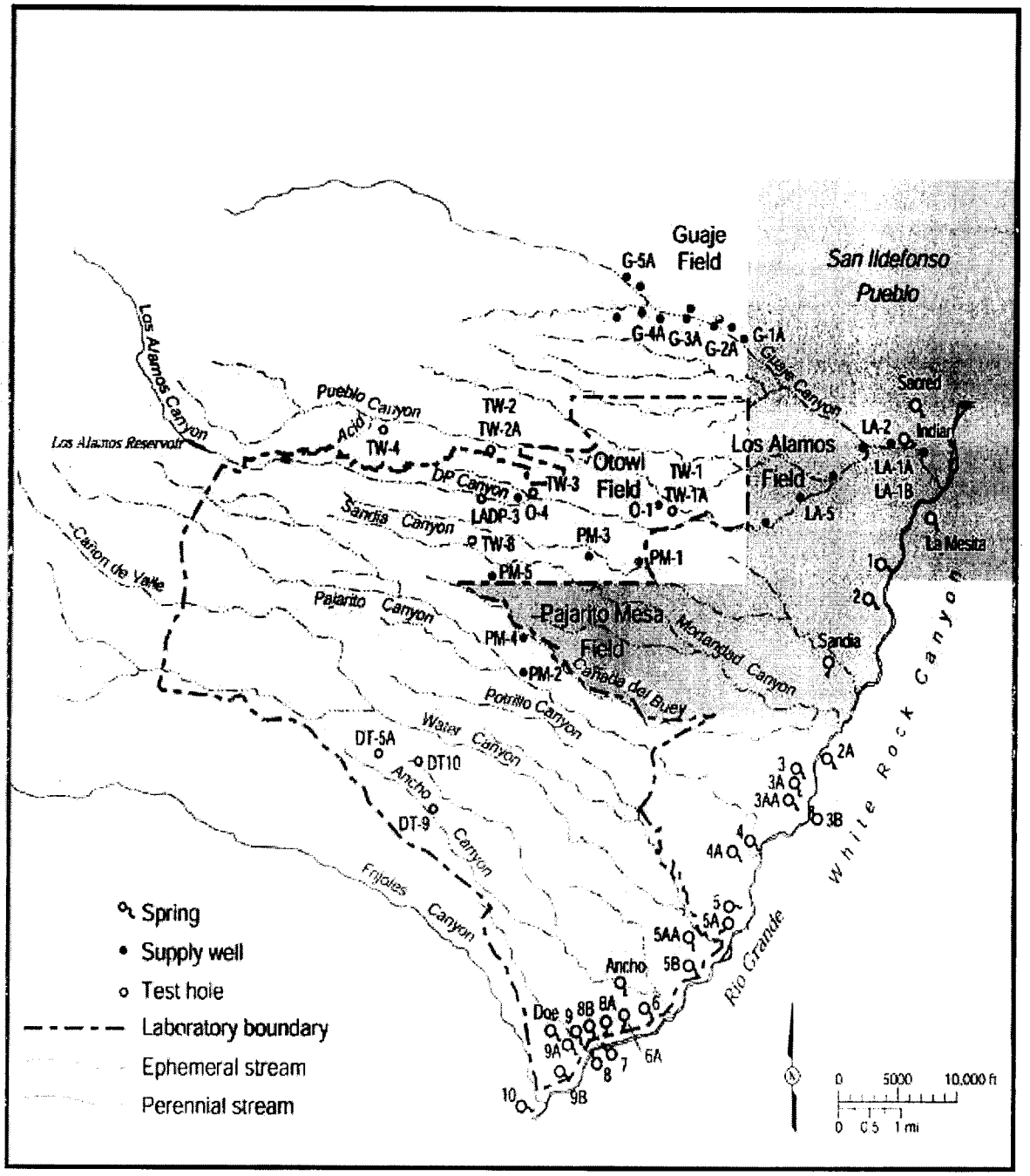


Figure 3. Locations of selected wells and springs where the regional aquifer and intermediate perched groundwater are sampled.

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 for reporting analyses of water samples. Metric prefixes are used to indicate fractions of a curie, for example, the picocurie (pCi or 10^{-12} 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 7.3 ± 3.5 pCi/L, where the first number is the analytical result, and the second number is one standard deviation of the analytical uncertainty of measurement.

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 2). The Rio Grande, within the Rio Grande Rift, borders the Laboratory on the east. Rocks of the Bandelier Tuff, formed from volcanic ashfall deposits and pyroclastic flows erupted from the Jemez Mountains volcanic center approximately 1.2 to 1.6 million years ago, cap the Pajarito Plateau (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.

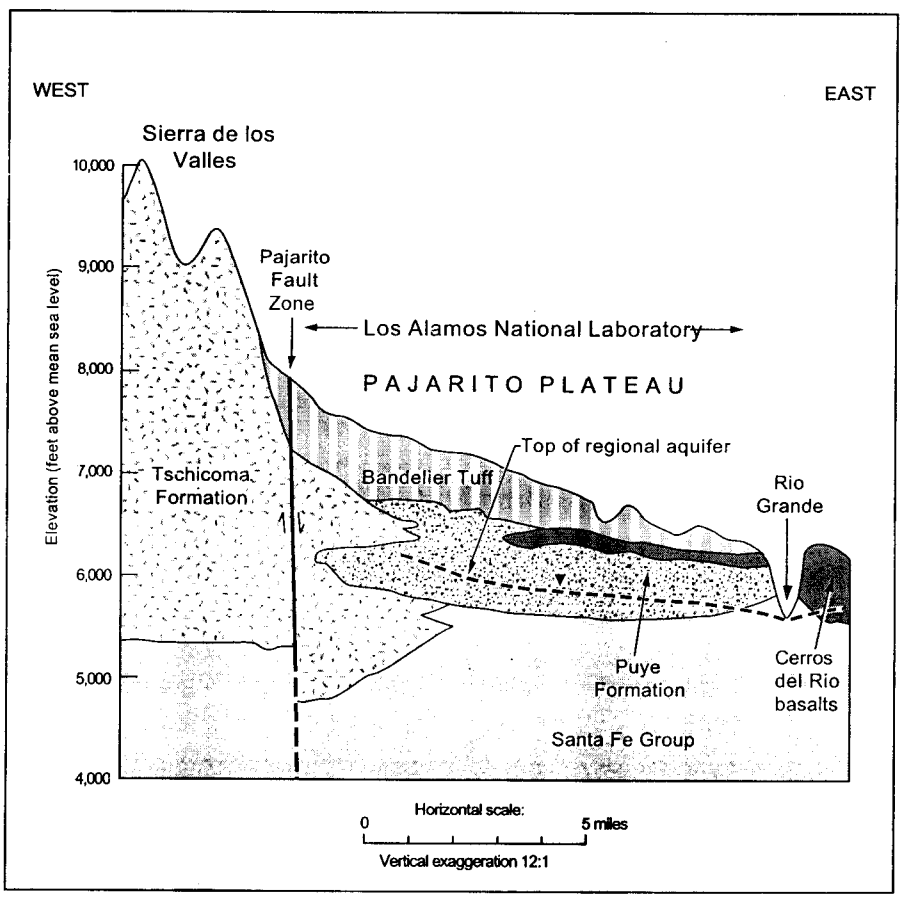


Figure 4. Generalized geologic cross section of the Pajarito Plateau.

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 Puye Formation conglomerate underlies the tuff beneath the central and eastern portion of the plateau. The Cerros del Rio basalt flows interfinger with the Puye Formation conglomerate beneath the Laboratory. These formations overlie the sediments of the Santa Fe Group, which extend across the Rio Grande Valley and are more than 3,300 ft thick.

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 east-west oriented canyons. These contain riparian vegetation and small streams that for the most part have short-lived or intermittent flow.

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 evaporation, transpiration, and infiltration deplete streams. 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. The Cerro Grande fire of May 2000 removed much of the vegetation from the headwaters of several canyons and may result in greatly increased runoff for a few years.

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) 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 in this section.

Streams have filled some parts of canyon bottoms with alluvium up to 100 ft thick. 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, evapotranspiration and infiltration into underlying rocks deplete it. The chemical quality of some of the alluvial groundwater shows the effects of discharges from the Laboratory.

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 aquifer is the only aquifer in the area capable of serving as a municipal water supply. Water in the aquifer flows generally east or southeast towards the Rio Grande, and an underflow of groundwater from the Sierra de los Valles (the eastern range of the Jemez Mountains) appears to be the main source of recharge for the regional aquifer.

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 Cerros del Rio basalts and the lower part of the Puye Formation beneath the central and western part of the plateau (Figures 4 and 5). 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, basalt, and sediments with low (<10%) moisture content.

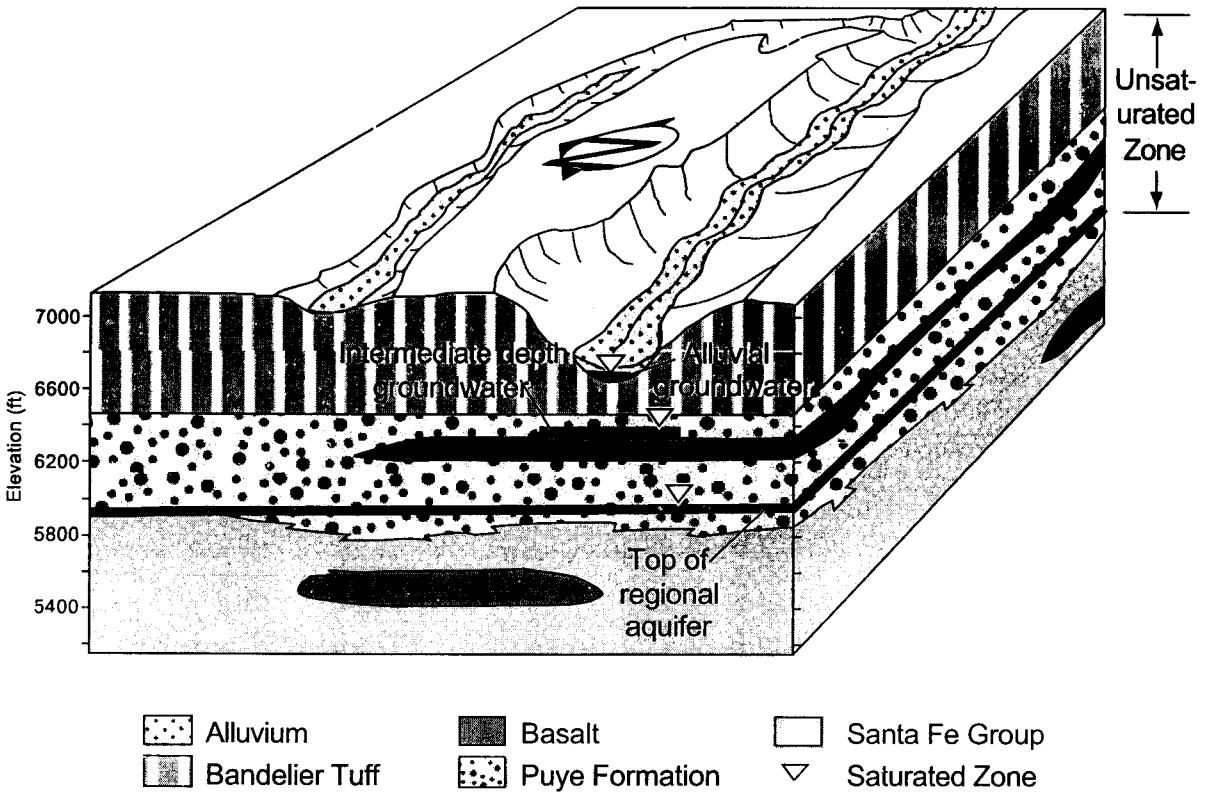


Figure 5. Illustration of geologic and hydrologic relationships in the Los Alamos area, showing the three modes of groundwater occurrence.

Beneath portions of Pueblo, Los Alamos, Mortandad, and Sandia Canyons (canyon locations shown in Figures 1 and 3), perched groundwater occurs at intermediate depths within the thick zone of unsaturated rock (that is, the 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 (tritium), organic (the high explosives RDX and TNT and degradation products), and inorganic (perchlorate and nitrate) contamination from Laboratory operations.

Perched water also occurs about 700 feet deep 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 Sierra de los Valles.

Recharge reaching the regional aquifer from the intermediate perched groundwater is likely to vary in quantity and generally have a minor chemical impact. The limited extent and volume of the intermediate groundwater bodies and the dry rock that underlies them limit their contribution to groundwater recharge reaching the regional aquifer.

BACKGROUND INFORMATION ON STRONTIUM-90

Strontium-90 has a half-life of 28.78 yr (Horiguichi 1996). Other references cite strontium-90 half-life values between 27 and 29 years. About 17 MCi (17 million Ci) of strontium-90 entered the atmosphere because of aboveground nuclear weapons testing (Eisenbud 1997). Most of the radioactive fallout from atmospheric nuclear weapons testing has been deposited in the Northern Hemisphere, where activities of strontium-90 range from 60 to 80 mCi/km^2 (Eisenbud 1997). Purtymun (1987) found that in Northern New Mexico, the strontium-90 activity in soils and river sediments caused by fallout is typically lower than 0.87 pCi/g.

Production of plutonium and other nuclear materials for nuclear weapons begins by irradiating nuclear fuel rods or other targets in nuclear reactors. Chemical separation is used to collect plutonium from the fuel rods, and strontium-90 is present with the plutonium as an impurity (DOE, 1997).

Fate of Strontium-90 in the Environment

Radionuclides have varying chemical behavior, so they move through the environment at different rates. For example, tritium (an isotope of hydrogen) often occurs as part of a water molecule, so its rate of infiltration through rock or soil is the same as that of water. Other radionuclides, such as plutonium-238 or strontium-90, move at a much slower rate. The mobility of these latter radionuclides is significantly decreased mainly by adsorption (adherence to the surfaces of soil particles, for example) and possibly by precipitation (the formation of solid chemical phases). Precipitation of solid phases from solution requires higher concentrations than have been found in groundwater or surface water at the Laboratory.

Because of adsorption, strontium-90 that is discharged moves slowly through the environment. A large portion of the strontium-90 adsorbs to sediments and soils, and continual desorption in small amounts results in the persistent presence of strontium-90 in surrounding surface and groundwater. Much of the strontium-90 released by the Laboratory is still present in surface sediments of Acid Canyon, Los Alamos Canyon, and Mortandad Canyon near the discharge locations, so strontium-90 levels in adjacent shallow groundwater and surface water at the Laboratory have remained relatively high. The extent to which strontium adsorbs onto sediments is controlled by the concentration of solid organic matter and clay minerals (Longmire 1996).

Strontium-90 moves slowly through groundwater and soil profiles. Field studies have found that strontium-90 from fallout remains in the upper 10 cm of the soil profile for years, and that movement of strontium-90 in groundwater occurs at rates less than 5 m/yr (Eisenbud 1997). These conclusions vary with the particular local qualities of rock or soil type, infiltration rates, and water chemistry. Despite adsorption, strontium-90 is more mobile than other fallout-deposited and reactor-produced radionuclides, such as cesium-137, americium-241, and plutonium isotopes; thus, strontium-90 is the most likely of these radionuclides to be transported some distance through the subsurface. If adsorbed to colloids, small quantities of a radionuclide may move more rapidly through aquifer pores.

Environmental Strontium-90 Standards

The Department of Energy (DOE) establishes derived concentration guides (DCGs) 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 100 mrem/yr and are determined assuming a water ingestion rate of 2 L/day. The concentration guides represent the smallest estimated concentrations for a radionuclide that, taken 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 Environmental Protection Agency (EPA) regulations in 40 CFR 61, and on recommendations of the National Commission on Radiation Protection and Measurements. The concentration guides for water are applicable to effluent discharges and impacted surface and groundwater but not to soil moisture.

Until 1985, the DOE set an upper limit of 300 pCi/L for strontium-90 activities in uncontrolled areas and a limit of 10,000 pCi/L in controlled areas. The DOE increased the concentration guide for strontium-90 in uncontrolled areas to 1,000 pCi/L in 1985. These radiation protection standards were finalized in 1990 by DOE Order 5400.5. In comparison, the Nuclear Regulatory Commission (NRC) regulations contained in 10 CFR 20 also limit radioactivity in effluent discharges to unrestricted areas. The NRC regulations, applicable since 1991, restrict strontium-90 activity to 500 pCi/L. This value is half the current DOE concentration guide for uncontrolled areas and applies only to NRC-licensed facilities. The NRC limits strontium-90 discharges to sewers to a monthly average activity of 5,000 pCi/L.

Radioactivity in the public water supply is governed by EPA regulations contained in 40 CFR 141. 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 strontium-90 is 8 pCi/L. The DOE standard

for strontium-90 in a DOE-administered drinking water system is 40 pCi/L, also based on a 4-mrem/yr dose. This higher strontium-90 activity resulted from dose calculations based on additional data regarding the health effects of radiation and a better understanding of the risks posed to human health by radionuclides. The EPA (1991, 2000a) proposed a revised value of 42 pCi/L for the strontium-90 activity that would result in a 4-mrem/yr dose. In its final rule, the EPA (2000b) maintained the 8 pCi/L maximum contaminant level (MCL), pending further review.

Environmental Strontium-90 Levels above Standards at Los Alamos

Strontium-90 activities in the 1990s continued to exceed the EPA MCL of 8 pCi/L in surface water or shallow groundwater in three canyons where the Laboratory has discharged radioactive liquid effluents. These locations are discussed in detail here and are shown in Figures 1 and 3:

- Acid Canyon surface water (Acid Canyon is a tributary of Pueblo Canyon.)
- Los Alamos Canyon alluvial groundwater and DP Canyon surface water (DP Canyon is a tributary of Los Alamos Canyon.)
- Mortandad Canyon surface water and alluvial groundwater

Strontium-90 activities in surface water and shallow canyon-bottom groundwater have also exceeded the applicable DOE uncontrolled area concentration guides of 300 pCi/L (before 1985) or 1,000 pCi/L (after 1985) in these three canyons. The first instance occurred in the early 1960s when the activity of strontium-90 in surface water in Acid Canyon exceeded the uncontrolled area guide of 300 pCi/L. Discharges into Acid Canyon from the treatment plant at TA-45 ceased in 1964.

The second case occurred during the late 1960s, when the activity of strontium-90 in DP Canyon surface water exceeded the DOE controlled area concentration guide of 10,000 pCi/L. Strontium-90 values in DP Canyon surface water were also near or above the pre-1985 uncontrolled area limit of 300 pCi/L until the early 1980s but have been below the post-1985 limit of 1,000 pCi/L since the 1980s. Discharges into DP Canyon from the treatment plant at TA-21 ceased in 1986.

A third exception occurred in Mortandad Canyon because of discharges from the TA-50 RLWTF. Average annual strontium-90 activities in effluent discharges from the RLWTF into Mortandad Canyon have exceeded the DOE concentration guide for strontium-90 in uncontrolled areas for 11 of 20 years from 1963 to 1982; the levels have been below 300 pCi/L since 1982. The surface water strontium-90 activity at station Mortandad at GS-1 in Mortandad Canyon exceeded the uncontrolled area concentration guide in five samples during 1970 and one sample in 1971. Strontium-90 activity in shallow groundwater exceeded the uncontrolled area concentration guide in 1971 at MCO-3.

Effluent discharges from a radioactive liquid waste treatment plant predating the current RLWTF were discharged into Ten Site Canyon, a tributary of Mortandad Canyon, from about 1956 through 1963. While volumes of effluents did not cause surface water to flow into Mortandad Canyon, the effluent strontium-90 levels did exceed DOE concentration guides. The activity of strontium-90 in effluent exceeded the DOE controlled area concentration guide of 10,000 pCi/L in 1956 and 1957. Strontium-90 values in effluent remained above the pre-1985 uncontrolled area limit of 300 pCi/L from 1958 through 1962.

Environmental Strontium-90 Measurements at Los Alamos

Before about 1967, few specific strontium-90 measurements were made on environmental samples at Los Alamos. For actinides, gross alpha and beta measurements were performed. Some strontium-90 analyses with an analytical detection limit of 0.3 pCi/L were made in the early 1960s by the US Geological Survey (USGS) for a few stations, including some water supply wells and Acid Weir, a surface water monitoring station at the mouth of Acid Canyon (Figure 1). These early surveys detected strontium-90 in surface water and alluvial groundwater in DP Canyon, Los Alamos Canyon, and Mortandad Canyon.

Strontium-90 Analytical History

Beginning in 1970, strontium-90 has been monitored as part of the Laboratory's Environmental Surveillance Program. From 1970 until 1999, nearly all radionuclide analyses for the water and sediments portion of the Environmental Surveillance Program were performed by the Laboratory's internal analytical chemistry provider, a division that has had many titles over the years. The division is now called C or Chemistry Division. Before becoming C-Division, it was called the Chemical Sciences and Technology Division (CST).

CST provided detection limits for strontium-90 analysis of water samples from 1991 through 1999. The detection limit was 3 pCi/L, except in 1994 when it was given as 1 pCi/L. CST was unable to document a decrease in the detection limit for 1994, so we presume that the detection limit for that year was also 3 pCi/L. USGS samples analyzed before 1970 appear to have had a detection limit of 0.3 pCi/L, based on USCS archival data reports. In 2000, LANL began sending strontium-90 samples to outside laboratories for analysis and received detection limits between 0.2 and 0.5 pCi/L.

The strontium-90 analytical procedure followed before 1997 included four steps: digestion, separation, yttrium-90 ingrowth, and beta counting. A hot nitric acid digestion was used for waters, and hot nitric acid and hydrofluoric acids were used to digest sediments and soils before the strontium-90 was isolated.

Strontium-90 was isolated from other potentially interfering radionuclides by extraction with bis (2-ethylhexyl) hydrogen phosphate, oxalate precipitation, and filtration. Yttrium-90 was allowed to ingrow, and then beta emission was counted by gas proportional counting. In the mid-1990s the method was modified to use a smaller sample to reduce the waste generated by the method, which raised the detection limit. Because the EPA drinking water standard for strontium-90 is 8 pCi/L, this detection limit was not low enough to provide adequate warning of potential problems to the water supply. An alternate analytical technique that offered lower detection limits was needed.

CST started evaluating and testing a new strontium-90 method in 1995 in an attempt to lower analytical detection limits, improve cost-effectiveness, and minimize solvent use. The new method used a chelating filter (disk). CST ran National Institute of Standards and Technology, Environmental Measurements Laboratory, and open quality control samples during its data development and validation. The division presented the procedure and data for peer review at the Bioassay, Environmental, and Analytical Radiochemistry conference in October 1996. This method was used for most strontium-90 analysis from 1997 to 1999.

Criteria for Determining Detections

CST determined detection limits for each analytical method. Radiological detection limits are based on Currie's formula (Currie 1968). In deriving the detection limits, CST included the average uncertainties associated with the entire analytical method. Sources of error considered included average counting uncertainties, sample preparation effects, digestion, dilutions, gravimetric and pipetting uncertainties, and spike recoveries.

While these method detection limits determined by CST or other analytical laboratories give an idea of the average limit of detection for a particular measurement technique, the detection limits for CST data before 1999 did not apply specifically to an individual sample measurement. Therefore, the question of whether or not an individual measurement resulted in detection must be evaluated in light of its individual measurement uncertainty as well as the average method detection limit.

For radiochemical analytical results, the analytical uncertainties are reported in the tables of the annual report "Environmental Surveillance at Los Alamos." These uncertainties represent a one standard deviation (one sigma) propagated uncertainty. "It is virtually unanimously accepted that an analyte should be reported as present when it is measured at a concentration three-sigma or more above the corresponding method blank" (Keith 1991). Therefore, we report radiochemical detections as values greater than three times the reported uncertainty and greater than the method detection limit or minimum detectable activity (MDA).

The decision of whether or not an analytical detection has occurred is a choice that includes the statistical confidence level that one is willing to accept in evaluating samples. The question of detection is not absolute but is an application of a statistical model to a set of samples. For example, the choice of a three sigma criterion, above which an analytical result is called a detection, carries with it the risk of a certain number of false positives (cases in which the result for a sample containing no analyte will be called a detection) and false negatives (cases in which the presence of an analyte will be overlooked). The choice of a detection criterion is also the choice of how many false positive and negative results will be tolerated.

The limit of quantification or LOQ is the analytical result level above which the concentration of an analyte can be quantified with confidence. "When the analyte signal is 10 or more times larger than the standard deviation of the measurements, there is a 99% probability that the true concentration of the analyte is ±30% of the calculated concentration" (Keith 1991). Thus, measured values near the detection limit or less than 10 times the analytical uncertainty do not provide a reliable indication of the amount present. The importance of this number is demonstrated when analytical results are compared against standards; the analytical result should be greater than 10 times the analytical uncertainty for the comparison to be meaningful.

1999 Environmental Surveillance Strontium-90 Measurements at Los Alamos

Because of concern about the possible presence of strontium-90 in water samples from the regional aquifer, Environment, Safety, and Health (ESH) Division's Water Quality and Hydrology group requested in 1999 that CST's (now C-Division's) Analytical Chemistry Sciences group establish lower detection limits for the analytical method. This was accomplished by increasing the sample size and the count time.

Once 1999 analytical results became available, the Water Quality and Hydrology Group determined that numerous analytical results for strontium-90 were questionable. The Water Quality and Hydrology Group submitted a Corrective Action Request to the Analytical Chemistry Sciences Group. The request included an initial list of seven samples suspected of being in error. After several iterations, this list was expanded to 28 samples. The Water Quality and Hydrology Group's concerns regarding possible analytical problems were based on

- comparison of analytical results to previous sample values,
- comparison of analytical results to split sample results from the New Mexico Environment Department's DOE Oversight Bureau,
- gross beta measurements too small to support strontium-90 values for these samples and lack of strontium-90 in reanalysis of the samples,
- knowledge that strontium-90 was detected in our quality control blanks (which could have been contaminated during preparation or analysis), and
- unfavorable analytical results for our quality control spiked samples.

The Analytical Chemistry Sciences Group responded with a draft Corrective Action Report dated August 10, 2000. The Corrective Action Report noted that the analytical method employs selective extraction resins. Possibly, a change in the formulation of the resin used in the filter disks may have resulted in strontium-90 false positives, because radon was present in samples. This change in the resin occurred after the initial method validation for the strontium-90 separation procedure.

By the time the Water Quality and Hydrology Group submitted its portions of the annual report "Environmental Surveillance at Los Alamos during 1999" in August 2000 (Environmental Surveillance Program, 2000), we did not have sufficient confidence in the strontium-90 results for 1999 runoff, surface water, groundwater, and sediments samples. For this reason, the Laboratory and DOE concluded that the entire strontium-90 data set for 1999 would not be used.

Summary of Strontium-90 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 LANL Environmental Surveillance Program monitors the regional aquifer 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.

Transport of strontium-90 in groundwater is controlled by adsorption: a large portion of strontium-90 will be attached to soil or sediment particles while a smaller portion will remain dissolved in the water. Were strontium-90 present in groundwater, it would be regularly detected because a steady supply is maintained in the adjacent water as strontium-90 desorbs from soils. This is the case for alluvial groundwater in Mortandad Canyon, DP Canyon, Los Alamos Canyon, and Pueblo Canyon, but not for the regional aquifer.

The strontium-90 data for regional aquifer wells and springs are addressed in more detail later in this report. Strontium-90 appears to have been occasionally detected in regional aquifer water supply wells or test wells, in some cases beneath areas of past and present liquid effluent discharges. As the

measurements are not repeatable, these apparent detections are more likely caused by analytical outliers than by the presence of strontium-90 in groundwater. Twenty-five years of environmental monitoring data do not make a case that strontium-90 is present in the regional aquifer.

At values near the detection limit, it is difficult to determine whether or not an analyte has been detected in an individual sample. Therefore, it is important to base a conclusion about the presence or absence of strontium-90 on a large number of samples and to establish an analytical detection limit at a value substantially below any regulatory or health-related limits. Beginning in 2000, for water supply and regional aquifer well samples, Los Alamos has obtained detection limits for strontium-90 analysis of 0.2 to 0.5 pCi/L, or 2.5% to 6.25% of the 8 pCi/L EPA drinking water MCL. Although no strontium-90 has been found in existing regional aquifer monitoring wells or water supply wells, concern about the possible impact on the regional aquifer has prompted DOE and the Laboratory to embark on an expanded groundwater characterization program at Los Alamos, a program known as the Hydrogeologic Work Plan (LANL 1998).

LIQUID EFFLUENT DISCHARGES CONTAINING STRONTIUM-90

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 containing residual radionuclides into Acid Canyon from 1951 to 1964 (Environmental Surveillance Group (ESG) 1981).

Strontium-90 discharge estimates for TA-1 and TA-45 are shown in Tables 2 and 3. A study of TA-1 and TA-45 for DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) (ESG 1981) estimated total strontium-90 discharges to be 94 mCi in untreated effluents from TA-1 into Acid Canyon between 1943 and April 1951. The activity of this strontium-90 would have decayed to 46 mCi in 1977 (and to 26.4 mCi in 2000). Discharge estimates for TA-1 compiled under the Comprehensive Environment Assessment and Response Program (CEARP, DOE 1987) and for the 1979 LANL Final Environmental Impact Statement (DOE 1979) are similar to the FUSRAP (ESG 1981) values for TA-1 (Table 2). During operation of the TA-45 treatment plant from 1951 through 1964, less than 10 mCi of additional strontium-90 was released in treated effluent (DOE 1979), as shown in Table 3.

Table 2. TA-1 Strontium-90 Releases

DOE (1979)		FUSRAP		CEARP	
Period (decay to yr)[1]	Sr-90 (mCi)	Period (decay to yr)	Sr-90 (mCi)	Period (decay to yr)	Sr-90 (mCi)
1943-1951	--	1943-1951	94	1943-1951	--
1943-1951 (1977)	48	1943-1951 (1977)	46	1943-1951 (1981)	41
1943-1951 (2000)	27.6	1943-1951 (2000)	26.4	1943-1951 (2000)	25.9

[1]Decay corrections after either 1977 or 1981 use a Sr-90 half-life of 28.78 yr, or decay constant of 0.024084/yr. Decay corrections in original data sources may have used other half-life values.

Table 3. TA-45 Strontium-90 Releases

DOE (1979) Period (decay to yr)	Sr-90 (mCi)	CEARP Period (decay to yr)	Sr-90 (mCi)
1951-1964	--	1951-1964	--
1951-1964 (1977)	<10	1951-1964 (1981)	0
1951-1964 (2000)	<5.7	1951-1964 (2000)	0

Strontium-90 histories for several monitoring stations in Pueblo Canyon are shown in Figure 6. In the early 1960s strontium-90 activities in surface water at Acid Weir ranged from 100 pCi/L to over 500 pCi/L. The subsequent decline in strontium-90 activity probably reflects treatment of effluent beginning in 1951, the cessation of discharges in 1964, and movement of the strontium-90 along the drainage. The three surface water stations in Pueblo Canyon show a few detections of strontium-90, but activities are much lower than at Acid Weir.

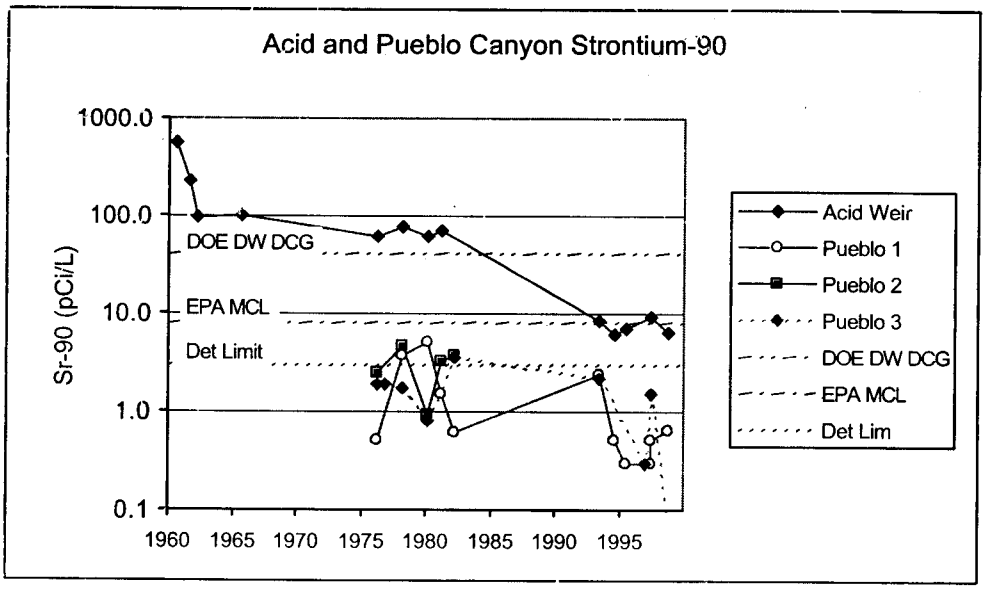


Figure 6. Strontium-90 history for surface water at Acid Weir in lower Acid Canyon near the junction with Pueblo Canyon and surface water stations in Pueblo Canyon. The values for the DOE drinking water derived concentration guide, the EPA primary drinking water MCL, and the detection limit after 1980 are shown. For stations other than Acid Weir, most samples are nondetections.

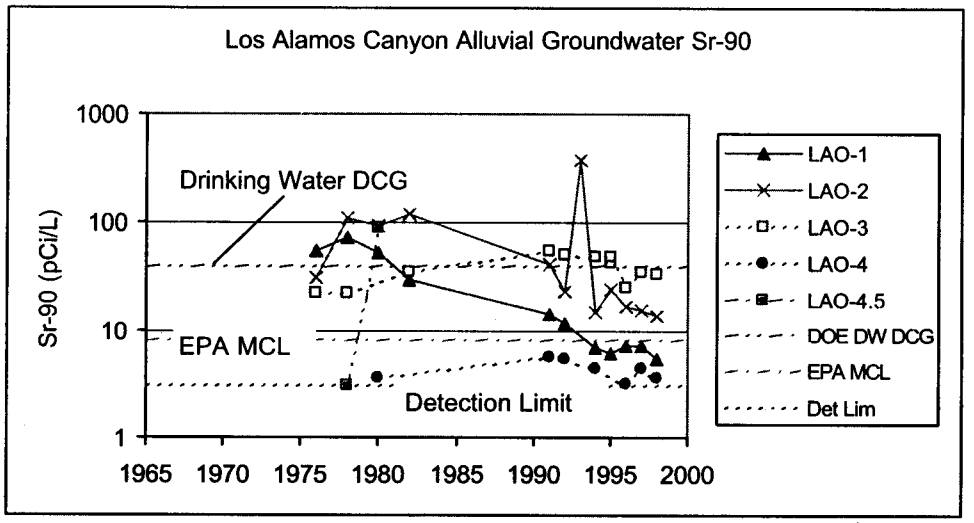
In 1994, an apparent strontium-90 detection occurred in Test Well 4, located on the mesa top near the junction of Acid and Pueblo Canyons. This well samples the regional aquifer at a depth of 1170 ft. The detection came from a New Mexico Environment Department (NMED) sample; a LANL sample with a similar analytical result but a large uncertainty resulted in a nondetection. The NMED sample is the only one of 29 samples from Test Well 4 in which strontium-90 has been detected, so the 1994 result is an analytical outlier, and strontium-90 is probably not present in the aquifer near the well.

No detections of strontium-90 have occurred in Test Wells 2 or 2A, which sample the regional aquifer at 760 ft and intermediate groundwater at 120 ft in Pueblo Canyon, about 1.5 miles downstream from the mouth of Acid Canyon. Test Wells 1 and 1A provide samples of the regional aquifer at 585 ft and intermediate groundwater at 190 ft in Pueblo Canyon near its junction with Los Alamos Canyon. One detection of strontium-90 occurred in Test Well 1A in 1981, at 3.3 ± 0.8 pCi/L (± one standard deviation). This result is an analytical outlier. The groundwater at Test Well 1A probably does not contain strontium-90 because this was the only detection out of 12 samples between 1976 and 1998; the result has not been repeated over time.

DP and Los Alamos Canyons

In the past, Los Alamos Canyon received treated and untreated industrial effluents containing radionuclides. Some release of water and radionuclides from the Manhattan Project operations and from the research reactors at TA-2 occurred. Los Alamos Canyon also received discharges containing radionuclides from the Los Alamos Neutron Science Center at TA-53. These TA-53 radionuclides were mainly short-lived activation products, including tritium from operation of the accelerator, rather than fission products such as strontium-90. Radioactive effluent from a treatment plant for industrial liquid waste at TA-21 entered Los Alamos Canyon via DP Canyon, a tributary.

Figure 7 shows strontium-90 histories for surface water and alluvial groundwater stations in DP and Los Alamos Canyons; only strontium-90 detections are plotted in the figure. If more than one sample was collected in a year, the average value for the year is plotted. No other regularly monitored surveillance surface water or alluvial groundwater stations in DP or Los Alamos Canyons had strontium-90 detections during this period.



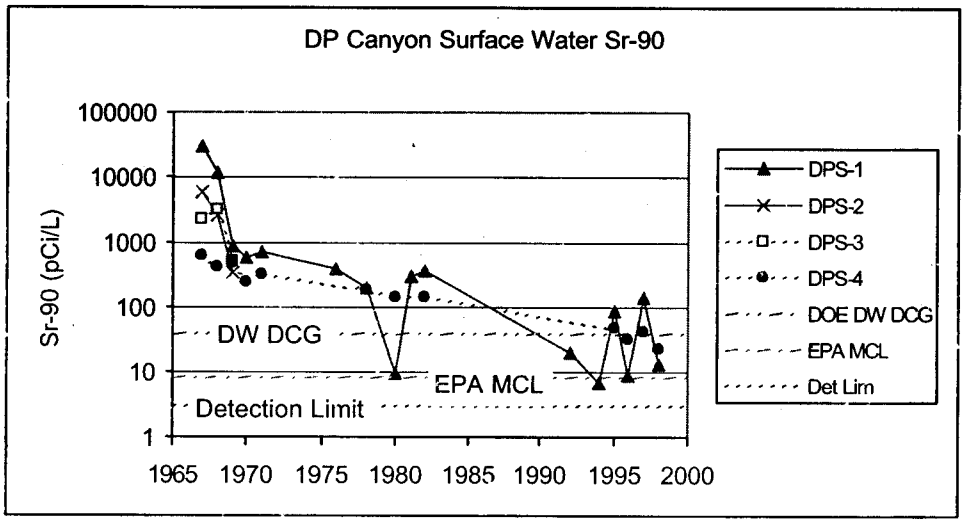


Figure 7. Strontium-90 histories (average annual values) for alluvial groundwater wells in upper Los Alamos Canyon (top) and surface water in DP Canyon (bottom). Only samples with strontium-90 detections are shown.

TA-1 Effluents and TA-2 Reactors

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, during the mid-to-late 1940s (LANL 1995). These releases apparently occurred in the reach of Los Alamos Canyon upstream from TA-2 and below observation well LAO-C. TA-41, just upstream from TA-2, was used for testing weapons components and may have been the source of some fission products entering the canyon (LANL 1995).

Since the 1970s, a shallow alluvial groundwater well (LAO-C) upstream from the reactor sites at TA-2 has had no detections of strontium-90. At a well immediately downstream from the reactor sites and the TA-1 discharge sites (LAO-1), strontium-90 levels decreased from 50 to 70 pCi/L in the late 1970s to 5 to 7 pCi/L in the late 1990s.

Within the intermediate perched groundwater at a depth of 325 ft beneath Los Alamos Canyon, Environmental Restoration Project well LADP-3 did not detect strontium-90 in 1993 (Broxton 1995). LADP-3 is located about two miles downstream of the Omega West Reactor but upstream of DP Canyon. The Omega West was the last reactor to operate at TA-2 and was shut down in 1993.

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 of Los Alamos Canyon, from 1952 to 1986. After 1986, the effluent was diverted to the TA-50 RLWTF. Between 3.5 and 27.2 mCi of strontium-90 (decay corrected to 2000) were released from this plant between 1952 and 1977 (Table 4). The range of released quantities of strontium-90 is given because the strontium isotope values in DOE (1979) and CEARP (DOE 1987) for some years combine strontium-89 and strontium-90. Strontium-89 has a 52-day half-life compared with the 29.1-year half-life of strontium-90. The combined isotope releases in Table 4 thus represent a large overestimate of the strontium-90 releases. The FUSRAP (ESG 1981) values are presented in the report as strontium-90 only but clearly include strontium-89. Figures for strontium-90 discharges from 1978 through 1985 were compiled from annual environmental surveillance reports.

Table 4. TA-21 Strontium-90 and Strontium-89/90 Releases[1]

Period (decay to yr)	Sr-90 (mCi)	Sr-89/90 (mCi)	Sr-89/90 (mCi)	Period (decay to yr)	Sr-90 (mCi)	Sr-89/90 (mCi)
Data Source	DOE (1979)		FUSRAP		CEARP	
1952-1977 (1977)	6	41	47	1952-1981 (1981)	6	37
1952-1977 (2000)	3.4	23.6	27.0	1952-1981 (2000)	3.8	23.4
This study						
1978-1985	2.3		2.3	1982-1985	1.1	
1978-1985 (2000)	1.5		1.5	1982-1985 (2000)	0.7	
Total						
1952-1985 (2000)	5.0	28.6	28.6	1952-1985 (2000)	4.5	27.9

[1] Strontium isotope values in DOE (1979) and CEARP (DOE 1987) are presented as combined strontium-89 and strontium-90 for some years. Strontium-89 has a 52-day halflife compared to the 28.78 year half-life of strontium-90. The combined isotope releases thus represent a large overestimate of the strontium-90 releases. The FUSRAP (ESG 1981) values are presented in the report as strontium-90 only, but clearly include strontium-89.

In the late 1960s, strontium-90 activities in DP Canyon surface water ranged from 400 pCi/L at DPS-4 up to 28,600 pCi/L at DPS-1 near the outfall. By the mid 1970s, values at these stations were 200 to 400 pCi/L. Strontium-90 activities in the late 1960s exceeded both the DOE uncontrolled-area DCG (300 pCi/L prior to 1985, 1000 pCi/L after that year) and the 10,000 pCi/L controlled-area DCG as a result of discharges from the TA-21 plant. By 1970, strontium-90 levels had fallen to values below the post-1985 DCG of 1000 pCi/L, even before discharges ceased in 1986.

The impact of strontium-90 from DP Canyon is seen in alluvial groundwater in downstream wells LAO-2 and LAO-3 (LAO-3 is combined with LAO-3A). The activity of strontium-90 decreases substantially downstream from the TA-21 discharge point. During the mid 1970s, strontium-90 activities in well LAO-2 in lower DP Canyon and in Los Alamos Canyon well LAO-3, located below the confluence with DP Canyon, ranged from 21 pCi/L to 111 pCi/L. The activities in these wells are higher than in LAO-1, which is farther upstream in Los Alamos Canyon. The strontium-90 history in wells LAO-3 and LAO-4 suggests that the crest of a slowly moving front of the radionuclide passed these locations during the early 1990s.

Test Well 3 is a regional-aquifer-monitoring well located in Los Alamos Canyon just below the confluence with DP Canyon. Between 1976 and 1998, 19 LANL and 7 NMED strontium-90 measurements show only one detection, in 1994, at 35.1 ± 2.2 pCi/L. LANL and NMED analyzed 17 samples for strontium-90 from Test Well 3 over the next two years with no detections, indicating that the 1994 detection was probably a result of analytical or sampling error. Water supply well Otowi 4 is located near Test Well 3. None of four samples collected from Otowi 4 by NMED or LANL between 1994 and 1998 detected strontium-90. Other water supply wells are located in lower Los Alamos Canyon, on Pueblo of San Ildefonso land. Strontium-90 results for these wells are discussed in a later section.

TA-35 Waste Treatment Plant

Starting in the late 1940s, TA-35 was used for manufacturing radioactive sources and for radiochemistry (DOE 1987). Strontium-90 was one impurity in materials such as radioactive lanthanum used to manufacture radioactive sources. A wastewater treatment plant operated at TA-35 from 1951 until 1963, when the TA-50 RLWTF became operational. The effluent from the TA-35 plant discharged to Ten Site Canyon, a branch of Mortandad Canyon, but only limited records are available regarding the amount of discharges that may have occurred. The DOE Onsite Discharge Information System (DOE 1987) gives a figure of 123 mCi of strontium-90 discharged from 1956 through 1963 (this figure reflects decay to 1981 and would have decayed to 77.8 mCi in 2000). Purtymun (1975) gives a listing of annual strontium-90 discharges from the plant from 1956 through 1963. The total strontium-90 discharge was 223.4 mCi (decayed to 78.3 mCi in 2000), similar to the previously cited value. The greatest discharge was 164 mCi of strontium-90 in 1956, with 36.8 and 10.7 mCi in the next two years and less than 6 mCi each year from 1959 through 1963. The largest annual average effluent concentration was 241,000 pCi/L in 1956, dropping to 22,600 pCi/L in 1957 and below 10,000 pCi/L in subsequent years. Purtymun (1975) notes that effluent volume was not sufficient to reach Mortandad Canyon as surface flow.

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 strontium-90 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. Strontium-90 released in liquid effluents may have been substantial, considering the nature of operations at TA-35.

Mortandad Canyon and the TA-50 Radioactive Liquid Waste Treatment Facility

The Laboratory now discharges strontium-90 as liquid effluent only from the RLWTF into Mortandad Canyon. The RLWTF began operations in 1963. Over the period of operation, americium-241, plutonium-238, and plutonium-239, -240 in the RLWTF effluent have often exceeded the DOE DCGs for public dose. In 1999, the new reverse osmosis and ultrafiltration system at the RLWTF began operation. This system removes additional radionuclides and nitrate from the effluent, and discharges from the plant now meet the DOE public dose DCGs.

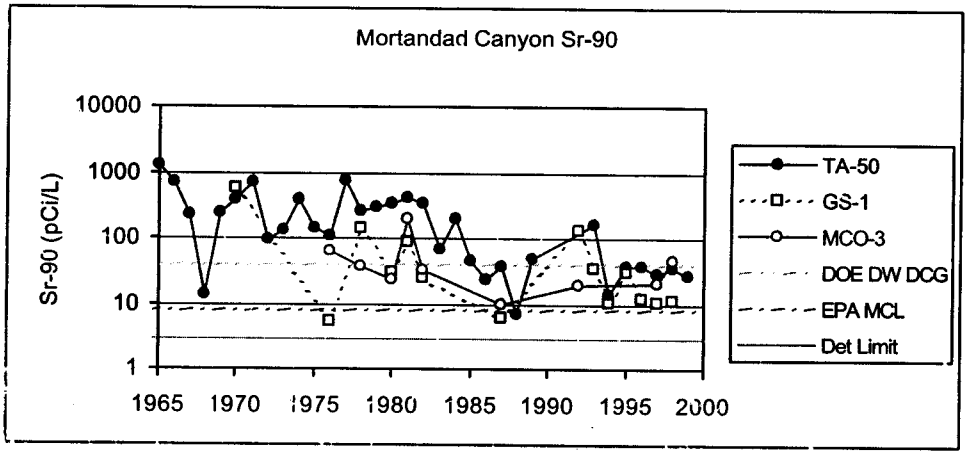
Mortandad Canyon has a small drainage area that heads at TA-3. The TA-50 effluents infiltrate beneath the stream channel and maintain a saturated zone in the alluvium, extending about 2.2 mi downstream from the outfall. The easternmost extent of saturation is on-site, about 1 mi west of the boundary between the Laboratory and San Ildefonso Pueblo. The depth of this saturation ranges from a few feet near the TA-50 outfall to about 60 ft at alluvial observation well MCO-8 near the eastern limit of saturation. Continuous flow of surface water along the drainage has not been observed to reach the San Ildefonso Pueblo boundary since studies began in the early 1960s (Stoker 1991). Table 5 lists the total strontium-90 discharges from the TA-50 plant. Figures for strontium-90 discharges from 1978 through 1999 were compiled from annual environmental surveillance reports and the work plan for Mortandad Canyon (LANL 1997).

Table 5. TA-50 Strontium-90 Releases

Period (decay to yr)	Sr-90 (mCi)	Period (decay to yr)	Sr-90 (mCi)
Data Source	DOE 1979		CEARP
1963-1977 (1977)	295	1963-1981 (1981)	330
1963-1977 (2000)	169.5	1963-1981 (2000)	208.8
This study			
1978-1999	98.2	1982-1999	32.9
1978-1999 (2000)	63.7	1982-1999 (2000)	23.5
Total			
1963-1999 (2000)	233.2	1963-1999 (2000)	232.3

Figure 8 shows long-term trends of strontium-90 activity in surface water and shallow alluvial groundwater in Mortandad Canyon downstream from the outfall for the RLWTF at TA-50. Only radionuclide detections are shown in the figure. If more than one sample was collected in a year, the average value for the year is plotted. The surface water samples are from the station Mortandad at GS-1, a short distance downstream (east) from the TA 50 effluent discharge.

The average annual strontium-90 activity in the TA-50 effluent between 1963 and 1999 ranged from a maximum of 1725 pCi/L in 1964 to a minimum of 6.8 pCi/L in 1988 (Figure 8). Strontium-90 activities in Mortandad Canyon surface water at station GS-1 below the outfall between 1969 and 1996 ranged from a maximum of 1260 pCi/L in December 1970 to a minimum of 5.2 pCi/L in 1976. Average annual alluvial groundwater activities between 1972 and 1995 have ranged from one value of 412 pCi/L at MCO-3 in September 1971 to many nondetections.



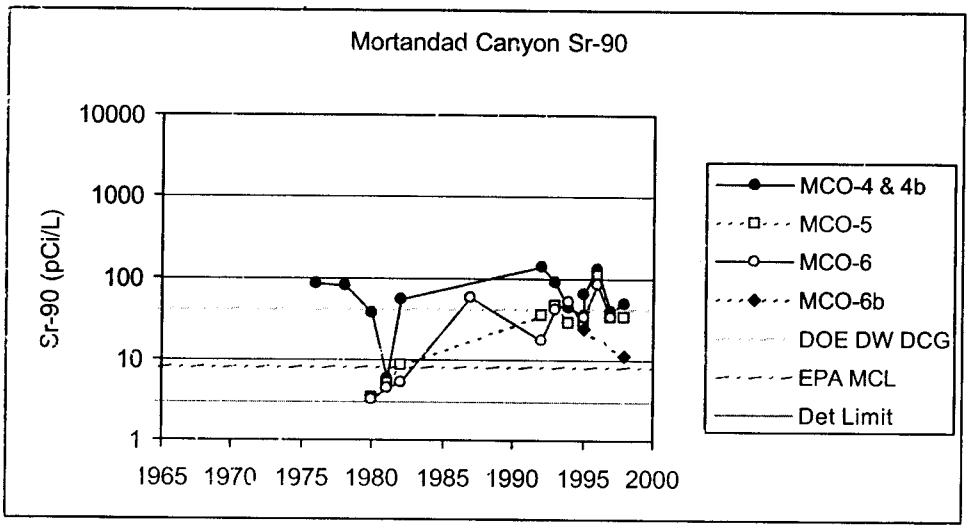


Figure 8. Strontium-90 histories (average annual values) for TA-50 RLWTF discharge, surface water station Mortandad at GS-1, and alluvial groundwater wells in Mortandad Canyon. Only samples with strontium-90 detections are shown.

Radioactivity levels at Mortandad at GS-1 vary daily depending on whether or not individual samples are collected shortly after a release from the RLWTF. These samples also vary in response to changes in amount of runoff from other sources in the drainage. The groundwater samples are from observation wells farther down the canyon. MCO-3 is just downstream from GS-1 and samples groundwater that lies just below the stream bottom. Groundwater radioactivity, except at MCO-3, is more consistent than in surface water at Mortandad at GS-1, as groundwater responds more slowly to variations in runoff water quality.

Strontium-90 has been detected in surface water at Mortandad at GS-1 and in all alluvial observation wells upstream from and including MCO-6B. The activities remain at values in the range of the EPA drinking water standard (8 pCi/L) and the DOE DCG for a DOE-maintained drinking water system (40 pCi/L) and range up to over 100 pCi/L. Strontium-90 has been detected only once downstream from MCO-6B, in MCO-8 in 1976. It appears that strontium-90 has been retained by adsorption within the upstream portion of the alluvium. The level of strontium-90 has risen gradually at downstream wells MCO-5 and MCO-6 over the last 20 years, suggesting that the mass of the radionuclide is moving slowly downstream.

Test Well 8 is a regional aquifer test well located below the RLWTF outfall in Mortandad Canyon. A possible detection of strontium-90 in Test Well 8 occurred in 1976 (9.4 ± 1.6 pCi/L). This is the only detection out of 27 LANL samples and 5 NMED samples taken between 1960 and 1999. Twenty-one samples from this well were analyzed from this well during 1995 and 1996, and no strontium-90 was detected. The 1976 detection is most likely not representative of the water in the regional aquifer at Test Well 8, as strontium-90 present at such a value would be persistent in the aquifer and continue to be detected over the years.

Sandia Canyon

Sandia Canyon has a small drainage area that heads at TA-3. The canyon receives water from the cooling tower at the TA-3 power plant. Treated effluents from the TA-46 Sanitary Wastewater Systems Facility are rerouted to the power plant for reuse as cooling water. These effluents support a continuous flow in a short reach of the upper part of the canyon. Only during summer thundershowers does stream flow approach the Laboratory boundary at State Road 4, and only during periods of heavy thunderstorms or snowmelt does surface flow extend beyond the Laboratory boundary. Data from 33 total analyses from three surface water stations in Sandia Canyon (including SCS-2) from 1976 through 1998 show no detections of strontium-90, indicating that TA-3 sanitary wastewater discharge into the canyon has not been a strontium-90 source.

Pajarito Canyon

In Pajarito Canyon, water in the alluvium is perched on the underlying tuff and is recharged mainly through snowmelt and thunderstorm runoff. Saturated alluvium does not extend beyond the facility boundary. Three shallow observation wells were constructed in 1985 as part of a compliance agreement with the State of New Mexico to determine whether technical areas in the canyon or solid waste disposal activities, including MDA G and MDA L on the adjacent mesa, were affecting the quality of shallow groundwater. No effects were observed; the alluvial groundwater is contained in the canyon bottom and does not extend under the mesa (Devaurs 1985). Between 1992 and 1998,

only one detection of strontium-90 occurred out of 17 samples analyzed from the wells. In 1994, the NMED found 4.5 ± 1.0 pCi/L in a sample from PCO-2; a split sample analyzed by LANL was a nondetection at 1.6 ± 0.7 pCi/L.

Cañada del Buey

Cañada del Buey contains a shallow alluvial groundwater system of limited extent. In 1992, saturation was found within only a 0.8-km-long segment, and only two observation wells have ever contained water (ESP 1994). Treated effluent from the Laboratory's Sanitary Wastewater System Facility may at some time be discharged into the Cañada del Buey drainage system. Therefore, a network of five shallow groundwater monitoring wells and two moisture monitoring holes was installed during the early summer of 1992 within the upper and middle reaches of the drainage (ESP 1994). Of 10 samples collected from CDBO-6 and CDBO-7 between 1994 and 1998, no detections of strontium-90 have been found.

SOLID WASTE DISPOSAL OF STRONTIUM-90

LANL MDAs are identified by letters of the alphabet, such as MDA G. Many MDAs at LANL contain radioactive materials, but before 1959, detailed records of disposed waste were not kept for these areas. No quantitative disposal records exist for MDAs A, B, D, E, F, H, K, W, X, and Y (DOE 1979).

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 2960 Ci of combined strontium-90 and yttrium-90 at MDA G (decayed to 1671 Ci in 2000 using the strontium-90 half-life). Additional estimates of strontium-90 disposed of at MDA G (Hollis 1997) are given in Table 6. The total is 1347 Ci (decay corrected to 2000).

Table 6. MDA G Strontium-90 Disposal (Ci) Based on Hollis (1977)

	Pits		Shafts	
Period	Total disposed	Decayed to 2000[1]	Total disposed	Decayed to 2000[1]
1957-1970	30.3	14.7	48	23.3
1971-9/25/88	1419.6	1063.3	220	164.8
1971-9/25/88 in TRU[2]	17	12.7	76	56.9
9/26/88-1995	0.7	0.6	6.9	6.1
1957-1995 total	1467.6	1091.4	350.9	251.1
total pits and shafts	1818.5	1342.5		

[1]Represents upper limit value, as entire amount disposed is presumed to have decayed from end of disposal period.
[2]Non-retrievably disposed with transuranic waste.

Sediment samples are collected annually at nine stations surrounding MDA G. Strontium-90 has been found at levels above the background of 0.87 pCi/g in only two of 56 samples analyzed between 1991 and 1998. As discussed earlier, no significant strontium-90 has been detected in alluvial groundwater in Pajarito Canyon to the south of MDA G, nor in Cañada del Buey groundwater to the north.

Material Disposal Areas V (TA-21) and C (TA-50)

Adsorption beds at MDA V at TA-21 were used for disposal of liquid laundry waste between 1945 and 1961 (DOE 1979). According to 1979 estimates (DOE 1979), <100 mCi of strontium-90 (decay corrected to 1976 and decayed to <60 Ci in 2000) were placed in MDA V.

MDA C, located at TA-50, opened in 1948 and received waste that was buried in pits and shafts until 1969 (DOE 1979). Between 1960 and 1969, about 27,000 mCi of combined strontium-90 and yttrium-90 (decay corrected to 1976 and decayed to 15,600 mCi in 2000 using the strontium-90 half-life) were buried at MDA C.

STRONTIUM-90 LEVELS IN THE REGIONAL AQUIFER AND LOS ALAMOS WATER SUPPLY WELLS

Los Alamos Water Supply Wells

Sampling locations for the regional aquifer include test wells, supply wells, and springs. Descriptions of the well construction and spring locations can be found in Purtymun (1995). The Los Alamos public water supply wells are located in three fields. The wells are part of the Los Alamos water-supply system and are leased and operated by the County of Los Alamos. 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 now contains five wells, four of which were drilled in 1998. With one exception, wells drilled before 1998 were retired in 1999 because of their age and declining production (G-1A was retained as a back-up production well). The five wells of the Pajarito Mesa Well Field are located in Sandia and Pajarito Canyons and on mesa tops between those canyons. Two wells of the Otowi Well Field, located in Pueblo and Los Alamos Canyons, were drilled in 1990.

The Los Alamos Well Field, located on San Ildefonso Pueblo 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 screened intervals in the water supply wells range in length 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 aquifer. If a contaminant were present in the upper portion of the aquifer, mixing with other water might dilute it to the point at which it is not detected.

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 strontium-90 sources discussed earlier.

- Otowi-1 is in Pueblo Canyon, downgradient from the former TA-1 and TA-45 releases and downgradient from effluent discharges from three Los Alamos County sewage treatment plants, two of which are no longer in use.
- Otowi-4 is in Los Alamos Canyon, below releases from former Manhattan Project activities and from TA-21 and the former Omega West Reactor.
- PM-2 (Pajarito Mesa 2) is upstream from the TA-54 disposal areas (MDAs G, H, and L).
- PM-4 is located on a mesa downstream from 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.

Regional Aquifer Wells and Springs

Eight deep test wells, completed within the regional aquifer, are routinely sampled. The test wells were drilled by the USGS between 1949 and 1960, using the cable tool method. The Laboratory located these test wells where they might detect infiltration of contaminants from areas of effluent disposal operations. These wells penetrate only a few tens or hundreds of feet into the upper part of the regional aquifer. The casings are not cemented, which would seal off surface infiltration along the boreholes.

Numerous springs near the Rio Grande are sampled because they represent natural discharge from the regional aquifer (Purtymun 1980). As such, the springs serve to detect possible discharge of contaminated groundwater from beneath the Laboratory into the Rio Grande. Based on their chemistry, the springs in White Rock Canyon are divided into four groups, three of which have similar, regional aquifer-related chemical quality. The chemical quality of springs in a fourth group reflects local conditions in the aquifer, probably related to discharge through faults or from volcanics. Sacred Spring is west of the river in lower Los Alamos Canyon.

Regional Aquifer Strontium-90 Data to 1998

From 1960 to 1998, USGS, LANL, and NMED analyzed 482 samples for strontium-90 from the regional aquifer and intermediate perched zone in Pueblo Canyon (12 from Test Well 1A and 15 from Test Well 2A). Problems with 1999 strontium-90 data were described in an earlier section. Figure 9 is a histogram showing collection dates for strontium-90 samples from the regional aquifer and intermediate perched zone in Pueblo Canyon up to 1998; most of the samples were collected in 1976, 1980, and during the 1990s. Table 7 lists the total number of samples analyzed for strontium-90 from each regional aquifer water supply well, and Table 8 lists samples for regional aquifer springs and test wells. With a few exceptions, all samples are nondetections for strontium-90. Strontium-90 detections and other samples with the largest analytical results (above the 3-pCi/L analytical detection limit) are shown in Table 9. The samples in Table 9 are sorted by date rather than values, showing the large number that occurred in 1994 and 1995. The coincidence of large analyte values in certain years could indicate systematic errors in sample handling or analysis.

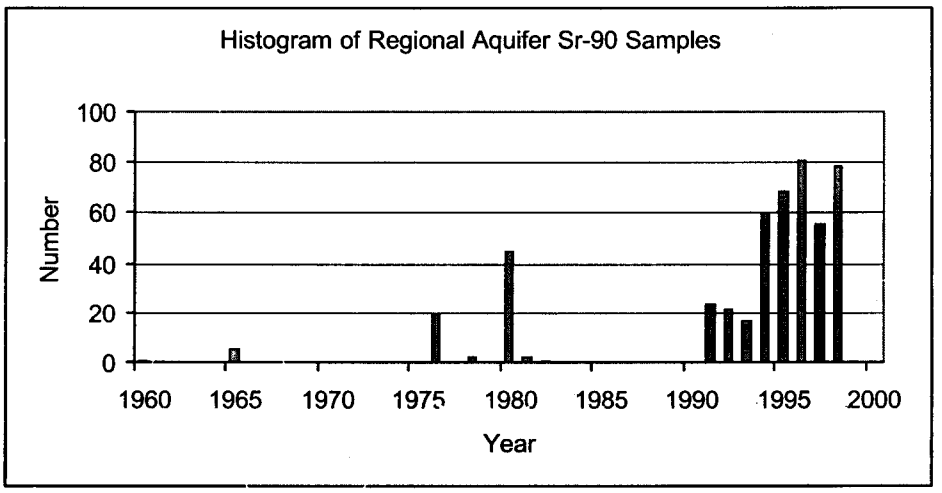


Figure 9. Histogram of 482 strontium-90 samples collected through 1998 by USGS (prior to 1970), LANL, and NMED from regional aquifer wells and springs, and from the intermediate perched zone in Pueblo Canyon.

In 1994, large apparent strontium-90 detections occurred in Test Wells 3 and 4, located in Los Alamos and Pueblo Canyons. The detection in Test Well 4 came from an NMED sample; a LANL sample with a similar analytical result but a large uncertainty was a nondetection. Spring 8 also showed a large strontium-90 value. The strontium-90 values for these samples were suspect because they were not supported by correspondingly large gross beta measurements (ESP 1996a) or by previous sampling results. In addition, an unusually high nitrate value was found in 1994 in Test Well 8, which may have been caused by incorrect sample acidification using nitric acid. Test Well 8 is located in Mortandad Canyon downstream from the RLWTF outfall.

In response to the 1994 findings, the Water Quality and Hydrology Group conducted a time-series sampling study on Test Wells 3, 4, and 8 in July 1995. Samples are usually collected after purging a well for three well-bore volumes to ensure that the sample represents water from the aquifer rather than stagnant water within the well bore. The time-series samples were collected at nearly every well-bore volume for 10 to 15 bore volumes and analyzed for tritium, strontium-90, chloride, and nitrate. Results of this study found no detection of strontium-90 in any of the three wells (ESP 1996b). Eight samples were analyzed from Test Well 3, 14 from Test Well 4, and 13 from Test Well 8. Test Wells 3, 4, and 8 were then sampled four times during 1996, with no strontium-90 detected.

During this period, extra sampling was also carried out for three test wells at TA-49. MDA AB at TA-49 was the site of underground nuclear weapons testing from 1959 to 1961. The tests involved high explosives and fissionable material insufficient to produce a nuclear reaction (Purtymun and Stoker 1987). DT-5A was sampled twice in 1994, three times in 1997; DT-9 was sampled twice in 1996 and twice in 1997; DT-10 was sampled twice in 1995, 1996, and 1997. No strontium-90 was detected in the samples.

Table 7. Total Number of Regional Aquifer Water Supply Well Strontium-90 Analyses by USGS, LANL, and NMED

Station	No. of Samples	Date Range	
Guaje Field, Former Wells			
G-1	6	07/12/76	11/11/98
G-2	6	07/12/76	06/08/98
G-3	2	07/12/76	02/28/80
G-4	3	07/12/76	06/25/97
G-5	5	07/12/76	11/11/98
G-6	7	07/12/76	06/08/98
Total	29		
Guaje Field, Current Wells			
G-1A	9	07/12/76	06/08/98
G-2A (GR-2)	6	03/02/98	03/12/98
G-3A (GR-3)	10	05/06/98	05/07/98
G-4A (GR-4)	6	04/09/98	04/17/98
G-5A (GR-1)	10	07/31/98	08/03/98
Total	41		
Former Los Alamos Field			
LA-1A	3	05/18/93	05/24/95
LA-1B	8	03/18/65	10/06/97
LA-2	3	07/09/76	05/12/93
LA-3	2	07/09/76	02/28/80
LA-4	2	07/09/76	02/28/80
LA-5	9	07/09/76	08/05/98
LA-6	2	09/23/65	02/28/80
Total	29		
Otowi Field			
O-1	10	12/17/96	11/12/98
O-4	4	04/28/94	11/12/98
Total	14		
Pajarito Mesa Field			
PM-1	8	07/12/76	06/08/98
PM-2	10	07/12/76	06/08/98
PM-3	12	07/12/76	06/08/98
PM-4	5	08/18/93	07/27/98
PM-5	6	08/18/93	06/08/98
Total	41		

Table 8. Total Number of Regional Aquifer Spring and Test Well Strontium-90 Analyses by USGS, LANL, and NMED[1]

Station	No. of Samples	Date Range	
Otowi Spring	2	07/08/96	09/08/98
Spring 1	11	10/07/80	09/28/98
Spring 2	9	10/07/80	09/28/98
Spring 3	9	10/07/80	11/18/97
Spring 3A	9	10/07/80	09/28/98
Spring 3AA	6	10/07/80	11/18/97
Spring 3B	5	10/07/80	09/27/94
Spring 4	7	10/07/80	09/28/98
Spring 4A	15	06/07/65	09/29/98
Spring 5	9	10/07/80	09/29/97
Spring 5A	9	10/07/80	09/29/98
Spring 5AA	2	10/08/80	10/08/91
Spring 5B	3	09/09/92	09/12/95
Spring 6	7	10/08/80	09/29/98
Spring 6A	6	10/08/80	09/29/97
Spring 7	7	10/08/80	09/29/97
Spring 8	5	10/08/80	10/08/96
Spring 8A	10	10/08/80	09/29/98
Spring 8B	3	09/30/94	09/30/97
Spring 9	9	10/08/80	09/30/97
Spring 9A	10	10/08/80	09/30/98
Spring 9B	4	10/08/80	09/30/98
Spring 10	5	10/09/80	09/30/98
Total	162		
Test Well 1	10	03/03/80	09/01/98
Test Well 1A[1]	12	04/07/76	05/29/98
Test Well 2	8	02/15/80	12/11/97
Test Well 2A[1]	15	06/08/65	09/01/98
Test Well 3	26	04/07/76	09/01/98
Test Well 4	29	06/09/65	09/01/98
Test Well 8	31	12/16/60	09/02/98
Total	131		
Test Well DT-10	12	03/06/80	11/06/98
Test Well DT-5A	11	04/07/76	11/05/98
Test Well DT-9	12	03/17/80	11/05/98
Total	35		

[1]Two wells sample the intermediate perched zone in Pueblo Canyon.

Table 9. Maximum Regional Aquifer[1] Strontium-90 Sample Values from 1960 to 1998

Station	Date	Value	Uncertainty	Detect?[2]	Data Source
Test Well 8	04/12/76	9.4	1.6	Detect	LANL
Test Well 1A[1]	03/30/81	3.3	0.8	Detect	LANL
Test Well DT-5A	09/23/91	3.0	0.9	Detect	LANL
Test Well 3	06/02/94	35.1	2.2	Detect	LANL
Test Well 4	06/20/94	6.6	1.0	Detect	NMED
Test Well 4	06/20/94	6.2	3.4	ND	LANL
Spring 8	09/30/94	19.7	3.8	Detect	LANL
G-1A	06/12/95	7.4	3.5	ND	LANL
G-1A	06/12/95	3.9	0.7	Detect	LANL
PM-1	06/12/95	4.6	10.8	ND	LANL
PM-2	06/12/95	6.6	18.2	ND	LANL
Spring 9B	09/12/95	5.1	0.7	Detect	LANL
G-1	12/08/97	5.2	1.4	Detect	LANL

[1]One well samples the intermediate perched zone in Pueblo Canyon.

[2]ND- nondetect; Detection defined as value ≥ 3 × one sigma uncertainty and ≥ detection limit of 3 pCi/L.

Water Supply Strontium-90 Sampling during 2000

In 2000, the Laboratory sampled water supply wells for several contaminants of concern, including strontium-90. The frequency of monitoring varied from annually to monthly, depending on the contaminant and sampling location. Beginning in 2000, the Laboratory obtained detection limits of 0.2 to 0.5 pCi/L for strontium-90 analysis of water supply and regional aquifer test well samples. These values range from 2.5% to 6.25% of the 8 pCi/L EPA drinking water MCL.

All Los Alamos water supply wells were sampled at least quarterly for strontium-90 in 2000. Tables 10 through 12 compile the quarterly strontium-90 results by well field. All analyses were nondetections, with two exceptions. Strontium-90 was initially detected in samples from Otowi-1 and G-3A. Reanalysis of the original samples and subsequent sampling at both wells have not confirmed either of the detections of strontium-90. The detection for Otowi-1 occurred in a laboratory duplicate analysis; strontium-90 was not detected in the original analysis.

These apparent detections in water supply wells and other regional aquifer water samples are more likely caused by analytical outliers than the presence of strontium-90 in groundwater, as the measurements are not repeatable. Based on 25 years of environmental monitoring, there is no reliable and consistent evidence that strontium-90 has appeared in the regional aquifer.

Strontium-90 Results from Hydrogeologic Workplan Wells

In March 1998, NMED approved a comprehensive hydrogeologic characterization work plan for the Laboratory. The Hydrogeologic Workplan (LANL 1998) was developed partially in response to NMED's denial of the Laboratory's Resource Conservation and Recovery Act (RCRA) groundwater monitoring waiver demonstrations. The plan proposes a multiyear drilling and hydrogeologic analysis program to characterize the Pajarito Plateau and to assess the potential for groundwater contamination from waste disposal operations.

Table 10. Guaje Well Field CY 2000 Strontium-90 Sampling Results (pCi/L)[1]

Location	Sample Date	Code[2]		Result	1-Sigma Uncertainty	MDA	Detect?[3]
G-1A	03/07	UF	CS	0.02	0.04	0.13	ND
G-1A	08/14	UF	CS	0.02	0.22	0.38	ND
G-1A	08/14	UF	CS	-0.02	0.15	0.26	ND
G-1A	08/14	UF	CS	0.03	0.04		ND
G-1A	11/15	UF	CS	0.14	0.07	0.23	ND
G-1A	11/15	UF	DUP	0.03	0.05	0.16	ND
G-2A	03/07	UF	CS	0.03	0.04	0.13	ND
G-2A	03/07	UF	DUP	0.03	0.04	0.13	ND
G-2A	06/20	UF	CS	0.05	0.04	0.13	ND
G-2A	08/14	UF	CS	-0.07	0.22	0.38	ND
G-2A	08/14	UF	CS	0.05	0.17	0.28	ND
G-2A	08/14	UF	CS	-0.04	0.04		ND
G-2A	11/15	UF	CS	0.00	0.07	0.24	ND
G-3A	03/06	UF	CS	0.01	0.04	0.12	ND
G-3A	06/20	UF	CS	0.17	0.04	0.13	Detect
G-3A	06/20	UF	RE	-0.01	0.03	0.10	ND
G-3A	08/03	UF	CS	0.07	0.33	0.56	ND
G-3A	08/03	UF	DUP	0.04	0.20	0.34	ND
G-3A	08/03	UF	CS	0.01	0.04	0.14	ND
G-3A	08/14	UF	CS	-0.09	0.22	0.39	ND
G-3A	08/14	UF	CS	-0.04	0.15	0.26	ND
G-3A	08/14	UF	CS	0.02	0.04		ND
G-3A	11/15	UF	CS	-0.09	0.05	0.19	ND
G-4A	03/06	UF	CS	0.01	0.04	0.13	ND
G-4A	06/20	UF	CS	0.00	0.04	0.13	ND
G-4A	08/14	UF	CS	0.03	0.12	0.21	ND
G-4A	08/14	UF	DUP	-0.06	0.16	0.27	ND
G-4A	08/14	UF	CS	0.06	0.22	0.37	ND
G-4A	08/15	UF	CS	-0.05	0.04		ND
G-4A	11/15	UF	CS	-0.01	0.05	0.19	ND
G-4A	11/15	UF	CS	-0.07	0.07	0.24	ND

[1]Three columns are listed: the first is the analytical result, the second is the radioactive counting uncertainty (1 standard deviation), and the third is the analytical laboratory measurement-specific minimum detectable activity.

[2]Codes: UF- unfiltered; F- filtered; CS- customer sample; DUP- laboratory duplicate.

[3]ND- nondetect; Detection defined as analytical result $\geq 3 \times$ one sigma uncertainty and $\geq$ minimum detectable activity .

Table 11. Otowi Well Field CY 2000 Strontium-90 Sampling Results[1]

Location	Sample Date	Code[2]		Result	1-Sigma Uncertainty	MDA	Detect?[3]
O-1	06/21	UF	CS	0.07	0.05	0.16	ND
O-1	06/21	UF	DUP	0.19	0.05	0.15	Detect
O-1	06/21	UF	RE	0.02	0.03	0.11	ND
O-1	08/03	UF	CS	0.03	0.43	0.74	ND
O-1	08/03	UF	DUP	-0.04	0.32	0.57	ND
O-1	08/03	UF	CS	0.07	0.04	0.13	ND
O-1	08/03	UF	CS	0.23	0.14	0.23	ND
O-1	08/03	UF	CS	-0.10	0.39	0.68	ND
O-1	08/03	UF	CS	-0.09	0.05	0.17	ND
O-1	08/14	UF	CS	-0.03	0.15	0.25	ND
O-1	08/14	UF	CS	-0.01	0.05		ND
O-1	08/14	UF	CS	0.01	0.05		ND
O-1	08/14	UF	DUP	0.00	0.05		ND
O-1	11/15	UF	CS	-0.09	0.07	0.24	ND
O-4	06/21	UF	CS	0.07	0.05	0.16	ND
O-4	06/21	UF	DUP	0.14	0.05	0.15	ND
O-4	08/14	UF	CS	0.05	0.11	0.19	ND
O-4	08/14	UF	CS	0.05	0.04		ND
O-4	11/15	UF	CS	-0.09	0.08	0.29	ND

[1]Three columns are listed: the first is the analytical result, the second is the radioactive counting uncertainty (1 standard deviation), and the third is the analytical laboratory measurement-specific minimum detectable activity.

[2]Codes: UF- unfiltered; F- filtered; CS- customer sample; DUP- laboratory duplicate.

[3]ND- nondetect; Detection defined as analytical result ≥ 3 × one sigma uncertainty and ≥ minimum detectable activity.

Table 12. Pajarito Mesa Well Field CY 2000 Strontium-90 Sampling Results[1]

Location	Sample Date	Code[2]		Result	1-Sigma Uncertainty	MDA	Detect?[3]
PM-1	02/14	UF	CS	0.01	0.03		ND
PM-1	06/20	UF	CS	0.04	0.05	0.15	ND
PM-1	08/14	UF	CS	-0.02	0.12	0.20	ND
PM-1	08/14	UF	CS	-0.04	0.05		ND
PM-1	11/15	UF	CS	-0.07	0.05	0.17	ND
PM-2	02/14	UF	CS	0.00	0.04		ND
PM-2	06/20	UF	CS	0.13	0.05	0.16	ND
PM-2	08/14	UF	CS	-0.07	0.21	0.37	ND
PM-2	08/14	UF	CS	0.11	0.15	0.24	ND
PM-2	08/14	UF	CS	0.03	0.05		ND
PM-2	11/15	UF	CS	-0.05	0.06	0.20	ND
PM-3	06/21	UF	CS	0.10	0.04	0.13	ND
PM-3	06/21	UF	RE	0.01	0.04	0.12	ND
PM-3	08/14	UF	CS	0.09	0.23	0.39	ND
PM-3	08/14	UF	CS	-0.12	0.13	0.22	ND
PM-3	08/14	UF	CS	0.05	0.05		ND
PM-3	11/15	UF	CS	-0.02	0.04	0.15	ND
PM-4	06/21	UF	CS	0.09	0.04	0.13	ND
PM-4	06/21	UF	RE	0.05	0.03	0.10	ND
PM-4	08/03	UF	CS	-0.11	0.05	0.16	ND
PM-4	08/03	UF	CS	0.22	0.40	0.68	ND
PM-4	08/14	UF	CS	0.09	0.23	0.39	ND
PM-4	08/14	UF	CS	-0.17	0.16	0.28	ND
PM-4	08/14	UF	CS	-0.02	0.04		ND
PM-4	11/15	UF	CS	-0.03	0.06	0.21	ND
PM-5	02/14	UF	CS	0.03	0.04		ND
PM-5	06/20	UF	CS	0.06	0.04	0.13	ND
PM-5	08/14	UF	CS	0.06	0.22	0.36	ND
PM-5	08/14	UF	CS	-1.22	0.14	0.21	ND
PM-5	08/14	UF	CS	-0.02	0.05		ND
PM-5	08/14	UF	DUP	0.10	0.06		ND
PM-5	11/15	UF	CS	0.04	0.06	0.20	ND

[1]Three columns are listed: the first is the analytical result, the second is the radioactive counting uncertainty (1 standard deviation), and the third is the analytical laboratory measurement-specific minimum detectable activity.

[2]Codes: UF- unfiltered; F- filtered; CS- customer sample; DUP- laboratory duplicate.

[3]ND- nondetect; Detection defined as analytical result ≥ 3 × one sigma uncertainty and ≥ minimum detectable activity.

As of early 2001, eight regional aquifer wells and one intermediate-depth well had been completed and sampled under the Hydrogeologic Workplan (Figure 10). These wells are R-9, R-12, R-25, R-15, R-31, R-9i, R-19, R-22, and R-7. Water samples are collected during drilling in some wells (borehole samples). Borehole samples may be less reliable because they may not come from discrete zones and may include material introduced by the drilling process. Once the wells are completed (that is, casing and well screens are installed), collection of four sets of samples rounds out the groundwater characterization phase for that well.

Only one strontium-90 detection has occurred in samples collected from these wells to date. This was in a borehole water sample (not from a completed well) from R-9, located at the eastern Laboratory boundary in Los Alamos Canyon. The unfiltered water sample from a perched zone in basalt at 180 ft depth gave a strontium-90 activity of 0.47 ± 0.14 pCi/L. Subsequent sampling of this zone in the completed R-9i well has yielded no detection of strontium-90, with a detection limit of 0.5 pCi/L (P. Longmire, personal communication, 2001).

CONCLUSIONS

Since the early 1980s, the Laboratory has decreased the number of locations where radioactive effluents are discharged to the environment. In addition, the total strontium-90 activity contained in Laboratory discharges has decreased significantly. Much of the strontium-90 released by the Laboratory is still present in surface sediments near the discharge locations in Acid Canyon, Los Alamos Canyon, and Mortandad Canyon, so strontium-90 levels in adjacent shallow groundwater and surface water at the Laboratory have remained elevated. The Laboratory now discharges strontium-90 as liquid effluent only into Mortandad Canyon, from the TA-50 RLWTF.

Strontium-90 activities in the 1990s continued to exceed the EPA MCL of 8 pCi/L in surface water or shallow groundwater in Acid Canyon, Los Alamos Canyon, and Mortandad Canyon, where the Laboratory has discharged radioactive liquid effluents. Strontium-90 activities in surface and shallow canyon-bottom groundwater have exceeded the applicable DOE uncontrolled area DCGs of 300 pCi/L (before 1985) or 1,000 pCi/L (after 1985) in these three canyons. In the late 1960s, the strontium-90 activity in DP Canyon surface water exceeded the DOE controlled area DCG of 10,000 pCi/L. Effluents discharged into Ten Site Canyon, a tributary of Mortandad Canyon, exceeded the DOE controlled area DCG of 10,000 pCi/L in 1956 and 1957.

Based on 25 years of environmental monitoring, there has been no strontium-90 impact on the regional aquifer, which supplies drinking water to Los Alamos County. Strontium-90 appears to have been occasionally detected in regional aquifer water supply or test wells beneath areas of past and present liquid effluent discharges. Were strontium-90 present in groundwater, it should be regularly detected because a steady supply is maintained in the adjacent water as strontium-90 desorbs from soils. These apparent detections are more likely the result of analytical outliers than the presence of strontium-90 in groundwater, as the measurements have not been repeated. At values near the analytical detection limit, it is difficult to determine whether an analyte has been detected in an individual sample. Therefore it is important to base a conclusion of whether or not an analyte is present on a large number of samples and to establish an analytical detection limit at a value substantially below any regulatory or health-related limits. Beginning in 2000, for water supply and regional aquifer samples, Los Alamos has obtained detection limits for strontium-90 analysis of 0.2 to 0.5 pCi/L, or 2.5% to 6.25% of the 8 pCi/L EPA drinking water MCL.

Although no strontium-90 has been found in existing regional aquifer monitoring or water supply wells, concern over possible impact on the regional aquifer has prompted DOE and the Laboratory to embark on an expanded groundwater characterization program at Los Alamos, known as the Hydrogeologic Workplan (LANL 1998).

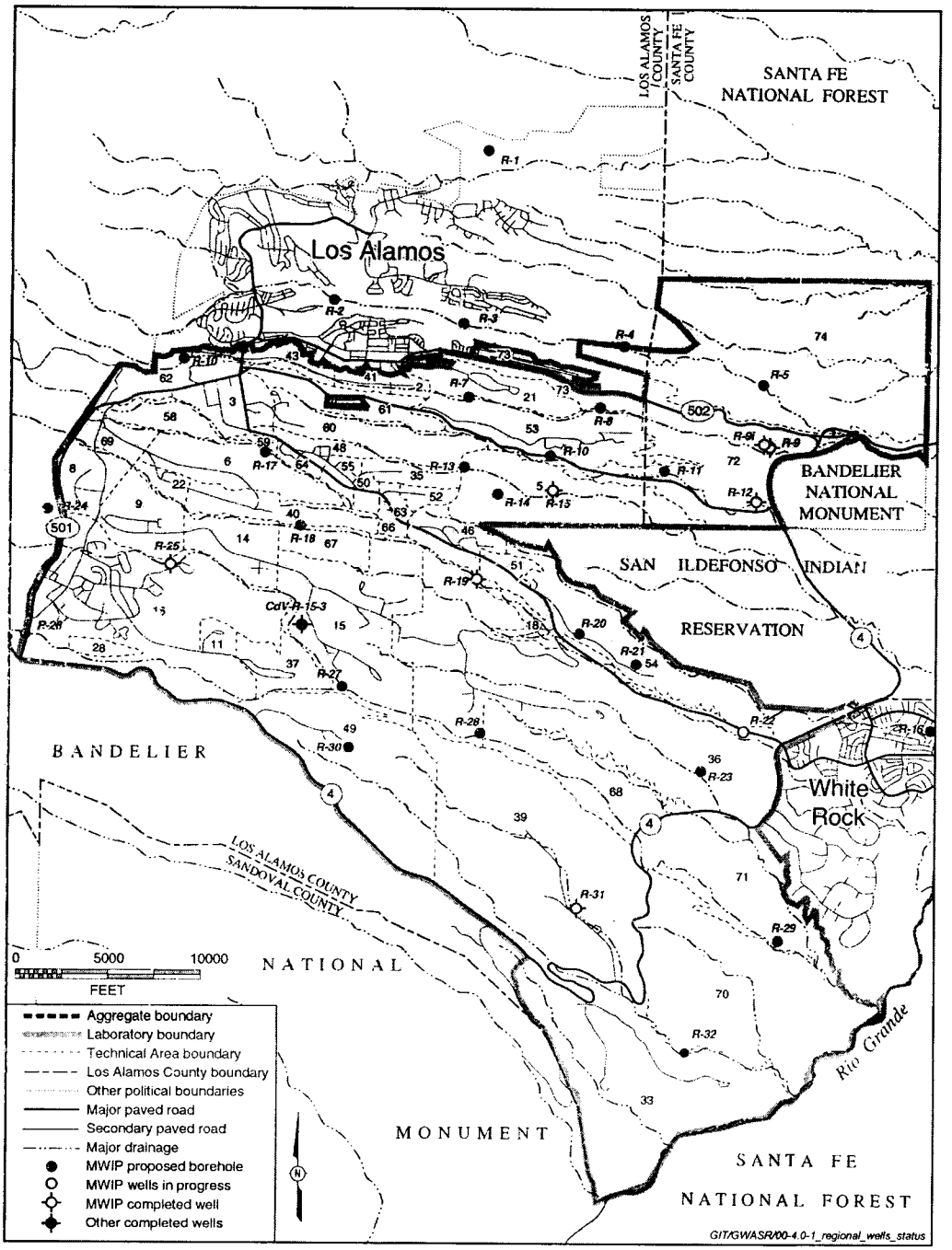


Figure 10. Completed, in progress, and proposed Hydrogeologic Workplan wells at the end of FY 00.

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