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Radioactive waste disposal at Los Alamos, New Mexico

by

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Abstract

Liquids and solids containing radioactive materials have been discharged or buried at Los Alamos since about 1943. The U.S. Geological Survey began studies of the general geology and hydrology of the Los Alamos area in 1949 and began investigations of the movement of water and radioactive-waste materials in 1957.

Los Alamos is on the Pajarito Plateau which is part of the Jemez Mountain volcanic pile. The Sierra de los Valles immediately west of the Pajarito Plateau and the plateau itself are dissected by deep canyons that drain eastward to the Rio Grande. The Bandelier Tuff of Pleistocene age caps the plateau and is comprised of ash-flow rocks that drape over the older rocks. The tuff lies unconformably on the Santa Fe Group of middle(?) Miocene to Pleistocene(?) age and the Tschicoma Formation of Pliocene and Pleistocene(?) age.

The main zone of saturation is about 800 to 1,200 feet below the land surface of most of the waste-disposal sites in rocks of the Santa Fe Group and the Tschicoma Formation. The gradient on the piezometric surface of the zone of saturation is east-southeast about 50 feet per mile toward the Rio Grande.

Processed liquid radioactive wastes were discharged in the 1940's into dry canyons or into pits dug into the tuff, and the pits were partly backfilled with gravel. Liquid wastes were discharged into alluvium at one site. Solid wastes were dumped into pits and covered. After about 1950 the liquid wastes, except for laundry wastes, were treated to below off-site tolerances and discharged into canyons. Sludges left after the treatment of wastes were placed in barrels and mixed with cement or vermiculite and then buried systematically between layers of fill in pits dug into the tuff. Solid wastes containing radioactive materials also were buried between layers of fill. The fill over some of the pits containing sludge and solid wastes was compacted and mounded to prevent ponding of water.

The main discharge area after 1962 will be into Mortandad Canyon. The movement of the wastes in alluvium and bedrock will be monitored closely.

Introduction

Untreated chemical and processed radiochemical wastes from facilities at Los Alamos, N. Mex., were discharged into usually dry canyons and pits, or buried in containers, from about 1943 until about 1950, at which time plants for the treatment of liquid wastes were installed. The Los Alamos Scientific Laboratory took over the treatment and burial of wastes in 1953.

The U.S. Geological Survey began cooperative investigations with the U.S. Atomic Energy Commission in 1949 of the geology and hydrology of the Los Alamos area in relation to the movement of radioactive wastes on and below the land surface.

The waste-disposal studies by the Geological Survey are confined principally to the disposal of liquid wastes because the contamination of surface and ground waters by solid wastes and contained sludges probably is more remote than from liquid wastes. Studies generally consist of a geologic investigation, logging of wells drilled, collection of water, soil, and rock samples for chemical and radiochemical analyses, measurements of water levels in wells, pumping tests of wells, streamflow measurements, and site locations for new disposal areas. Studies of limited extent are made where the quantities of liquid waste discharged are small.

Water, soil, and bedrock samples for analysis are collected periodically throughout most of the Pajarito Plateau. The network of sampling points and areas are shown on figure 1. Samples of water

Figure 1.--Map showing locations of waste-disposal areas and the sampling network in Los Alamos County, N. Mex.

are also collected regularly at four points on the Rio Grande (fig. 2).

Figure 2.--Generalized map of the physiographic features of the Jemez Mountain region, New Mexico, and sampling stations on the Rio Grande and Rio Chama.

Airborne wastes have not been studied in detail by the Geological Survey.

A systematic sampling program was started about 1956, and a period of intensive sample collection lasted from July 1957 through July 1959, after which the program was reduced and sampling was done on a less intensive and a more selective basis.

Investigations of the movement of water and radioactive materials after disposal into canyons and into pits are underway. Special equipment and methods were developed to aid in determining the physical and chemical processes involved in movement of wastes through alluvium and through consolidated rocks such as the Bandelier Tuff. These studies, combined with an expanded program of general geology and hydrology, should determine if, how, and where radioactive materials move when placed on or in the ground in the Los Alamos area.

This report describes only the methods and places of disposal of radioactive wastes and of sewage at Los Alamos. Twelve waste-disposal areas and their construction, type of waste involved, manner of disposal, and special problems are described and three sewage-disposal plants discussed (fig. 1). No attempt is made herein to interpret the studies. This report on wastes and waste-disposal sites precedes a series of reports in preparation on studies of waste movement.

Los Alamos is on the Pajarito Plateau which is part of the Jemez Mountain volcanic pile (fig. 2). The altitude of the plateau ranges from 7,800 feet on the west side to about 6,200 feet on the escarpment at the Rio Grande on the east side. The altitude of the Rio Grande in White Rock Canyon is about 5,500 feet near the north end and about 5,300 feet near the south end.

The Sierra de los Valles immediately west of the Pajarito Plateau and the plateau itself are dissected by deep canyons that drain east-southeastward to the Rio Grande. The walls of these canyons are steep and at some places vertical, and the relief along some of the large canyons is 800 to 1,000 feet. Generally, the gradient of the canyon floors in the upper, or western, reaches is steep, and bedrock is exposed between patches of thin alluvium. In the lower reaches of most of the canyons the gradient is relatively flat and the alluvium may be 50 or more feet thick. The relatively undissected areas of the plateau between the canyon form finger-like mesas that extend east-southeastward. A sandy-loam soil, weathered in place (Staritzky, 1949, p. 4) and ranging in thickness from 3 to 8 feet, is on the central and western parts of the mesas. Along the edges and in the eastern parts of the mesas, little or no soil is present.

The Bandelier Tuff of Pleistocene age caps the Pajarito Plateau. It consists of ash-fall and ash-flow rocks that are draped over the older rocks, filling the lows and smoothing out the topography of the older rocks. The Bandelier Tuff consists of three members. In ascending order they are: the Guaje Member, an ash-fall pumice and water-laid pumiceous tuff; the Otowi Member, a friable ash-flow tuff; and the uppermost Tshirege Member, a series of ash-flow tuffs with one thin water-laid bed near the top.

The Tshirege Member is moderately resistant to erosion, but it contains open joints and has many small vertical and horizontal joints filled with weathered material or sediments. The joints may interconnect to the top of the Otowi Member. The Tshirege has an average porosity of 40-50 percent and an average permeability of only 1 to 6 gallons per day per square foot. Pore spaces are small. The ion-exchange capacity of the tuff ranges from about 2 milliequivalents per 100 grams near the surface to about half a milliequivalent per 100 grams at a depth of about 20 feet (Weir and others, in preparation). The tuff is approximately 75 percent SiO_2.

The Bandelier lies unconformably on the Santa Fe Group of middle(?) Miocene to Pleistocene(?) age and the Tschicoma Formation of Pliocene and Pleistocene(?) age (Griggs, 1955, 44-57 and 72-76). The Santa Fe is subdivided into the Tesuque Formation (Spiegel and Baldwin, in press), the Totavi Lentil, and the Puye Conglomerate in ascending order. The general stratigraphic relations of these rocks are shown in figure 3.

Figure 3.--Diagrammatic cross-section showing generalized stratigraphic relations of the Bandelier Tuff to older rocks in the Los Alamos area.

Alluvium in the canyons consists of materials eroded from the Sierra de los Valles and the sides of the canyons on the Pajarito Plateau. It is thin in the headwaters of the canyons, and commonly bedrock is exposed; it may be hundreds of feet wide and as much as 80 feet thick in the lower parts of the canyons. Most of the alluvium is sandy and contains cobbles and boulders, and it is considerably more permeable than the Bandelier Tuff. Small bodies of perched ground water occur seasonally in the alluvium in the thin upper parts and perennially in the thick lower parts in most canyons.

The geology and hydrology in the Los Alamos area is complex, and the movement of water is known only in general. Interpretation of the movement of water through the zone of aeration is complicated by the different rock types and by the structure of the rocks. Pre-Bandelier faulting and jointing also complicate the interpretation because the rate and direction of movement of water and nuclides would be considerably different through jointed and faulted rocks than it would be through the pore space of solid-rock units.

The zone of saturation, or main aquifer, lies about 800 to 1,200 feet below the land surface of most of the waste disposal sites in rocks of the Santa Fe Group and the Tschicoma Formation (fig. 3). The sources of recharge to the main aquifer in the area are not known. The gradient on the piezometric surface of the main aquifer is east-southeastward toward the Rio Grande about 50 feet per mile.

The annual precipitation ranges from about 20 to 25 inches along the extreme western part of the plateau to about 12 to 15 inches at the Rio Grande. Most of the precipitation occurs during the winter.

Vegetation is predominantly ponderosa pine, juniper, and grasses (Isaacson and Lovald, 1935, p. 3). Pinon and juniper grow, generally, on the eastern part of the plateau and merge into pine, which predominates in the western part. Pine grows farther east in the canyons than on the surface of the plateau. Deciduous trees and shrubs are common in the narrow, deep, western parts of most canyons.

Acknowledgements

Data on the quality and quantity of liquid wastes contained in this report were obtained from a letter dated April 30, 1962, from C. W. Christenson and J. P. Hutchinson of the Health Division of the Los Alamos Scientific Laboratory. Much of the data on the solid-disposal areas were obtained by personal communication from John Enders and Dean Meyer, also of the Health Division of the Los Alamos Scientific Laboratory. Detailed information on some of the older disposal areas was obtained from personnel who had worked in these areas. The location and surface area of many of the disposal pits were obtained from drawings numbered ENG-4-102 and ENG-R 185-190 of the Engineering Division of the Los Alamos Scientific Laboratory.

Disposal of radioactive wastes

Radioactive wastes disposed to the ground at Los Alamos consist of solids, liquids, and sludges. The types and quantities of wastes have changed with time at some areas, and the techniques of disposal have evolved from crude uncontrolled dumping to controlled burial or discharge. In early disposal practices solid wastes contaminated with beta and gamma emitters were sometimes dumped into a scrap pile near the various laboratories, and both solid and liquid wastes were dumped outside buildings or down sink drains during emergencies. Liquid wastes were at first discharged untreated into canyons, into underground storage tanks, or into pits filled with gravel.

Since about 1950, solid wastes consisting of laboratory or experimental equipment, ranging from glassware and gloves to entire buildings, have been buried in pits. Small articles are sealed in plastic bags or cardboard cartons for handling before burial, and large items, such as buildings, commonly are burned. The pits are filled to land-surface grade by covering each layer of waste with several feet of fill.

The total volume of solid wastes added to the pits each year generally has increased as shown by the following figures.

(From records of the Los Alamos Scientific Laboratory)

1947 through 1953	-	1,500 to 2,000 cubic yards (estimate)
fiscal year 1954	-	3,800 cubic yards
fiscal year 1955	-	2,300 cubic yards
fiscal year 1956	-	2,500 cubic yards
fiscal year 1957	-	3,200 cubic yards
fiscal year 1958	-	3,100 cubic yards
fiscal year 1959	-	4,191 cubic yards
fiscal year 1960	-	5,551 cubic yards
fiscal year 1961	-	6,422 cubic yards (5,671 curies)

Liquids containing chemical and radiochemical wastes in suspension or in solution may pass through the rock onto which they are discharged. The potential contamination hazard to underground water is minimized at Los Alamos by treatment, dilution, or containment of the liquids. A large percent of the radioactive ions are removed from the liquid with resins or by precipitation. The treatment may end with sludges, in which radioactive material is concentrated, or concentrated on the resins. Sludges are mixed with cement or vermiculite, sealed in 55-gallon drums, and buried. Resins are usually drummed directly when they can no longer be regenerated. The supernatant liquid is reduced to off-site tolerances, or below, by normal decay or by dilution before it is discharged into canyons. Small quantities of wastes too low to be measured are sometimes discharged into canyons from several reactor sites.

Small quantities of radioactive wastes are released to the atmosphere in gaseous form through tall stacks at several sites on mesa tops. Most ions are removed by various types of traps and filters within the stacks and the solids commonly buried in pits.

Waste-disposal areas

Waste-disposal areas are numbered 1 through 12 on figure 1. Within any particular disposal area, some sites or types of disposal have been abandoned and replaced with newer methods or pits. Some disposal sites, used during the early days of work at Los Alamos, have been used since about 1950 on a greatly reduced basis. There is no special significance in the order of number of the disposal areas. The older, partially abandoned, areas are discussed first, then the areas with both old and new disposal areas, followed by new disposal areas or areas with little or no problems of waste disposal. Individual disposal sites within a large disposal area are designated by numbers to identify each plot known or suspected to contain or to have contained radioactive materials.

Area 1: Two-Mile Mesa burial area

Area 1 consists of two small fenced shallow disposal sites dug through the soil mantle into the underlying tuff near the center of sec. 20, T. 19 N., R. 6 E. These sites were used during the early 1940's for the disposal of solid wastes. Some containers with beta-gamma emitters are reported to be buried here, and it is not known at what depth the containers are buried. Reliable records of the type or amount of radioactive material that might have been disposed of in Area 1 are not available.

Site 1-1-S, about 2,000 square feet, is on a level surface of the plateau. The sandy soil cover about 2-3 feet thick shows little indication of erosion.

Site 1-2-S is an area of about 50,000 square feet. A mantle of sandy soil about 1-2 feet thick overlies the Tshirege Member. The surface slopes gently northward and contains a sparse vegetative cover of clump grass. Sheet erosion is evident upon this surface, and a small wash has been cut at the west end of the fenced area. Blocky tuff with no apparent joint pattern and a northward slope of less than 5 percent crops out between the fenced area and the south fork of Two-Mile Canyon a few hundred feet north. A shallow-diversion ditch south of the fenced area probably would prevent further erosion that, in time, might exhume and scatter material that is radioactive.

Area 2: Bayo Site

Area 2, in the NE¼ sec. 13, T. 19 N., R. 6 E., was used extensively for disposal of wastes processed in the area until about 1950. Since then, the area has been used primarily as a place to detonate high explosives that contain only small quantities of radioactive materials. Estimates on the quantities of radioactivity of the liquid and solid wastes placed in the area are not available.

Radioactive barium and lanthanum mixtures having a combined half-life of 12.8 days and containing strontium-89 and 90 as impurities were buried at site 2-1-L in stainless-steel tanks and allowed to decay for a certain number of half-lives. The liquid waste then was leached with an acid in covered concrete lined pits which were open-bottomed in the alluvium in Bayo Canyon. The alluvium, about 12 feet thick, lies on the Tshirege Member of the tuff. Although no studies of waste movement have been conducted, some effort should be made to trace the movement of those wastes in the alluvium.

Radioactivity of as much as about 20 mr/hr (milliroentgens per hour) at 2 feet were found on the surface soil near the tanks and leach pits and near some old laboratory sites in August 1961. Radioactivity within the covered leach pits was high. Samples of the alluvium collected near those pits in July and August 1956 contained the following activity:

(Counts per minute per dry gram--
analyses by the Los Alamos Scientific Laboratory)

Depth	Gross alpha	Gross beta	Gross gamma	Strontium
Surface	1.4	37,270	39	3,120
12 inches	1.9	5,460	10	719
20 inches	2.1	6,770	20	818
30 inches	.5	220	4	18
45 inches	1.9	250	8	45

Two firing pads at site 2-4-L were used extensively in the past but were used only occasionally in 1961. In the late 1940's, the pads were washed with water and swept after each shot. The wash water seeped into natural surface and artificial drainage in the alluvium, and the sweepings were dumped at site 2-3-S. Radioactivity of the pads was about 2 mr/hr in 1961 and could not be reduced by washing. A sample of soil collected in June 1956 from one of the drainage channels that had received wash water from the pads contained 31,260 c/m/dry g (counts per minute per dry gram) of gross beta, 10,040 c/m/dry g of gross gamma, and 3,470 c/m/dry g of strontium. Some debris from the shots undoubtedly fell on the walls in the upper part of Bayo Canyon and some activity washed into the alluvial material in the canyon. The canyon is 300-400 feet deep at this point.

A sample of soil collected in June 1956 from the dump area at site 2-3-S contained no gross beta and 10 c/m/dry g of gross gamma. The wastes in the dump were burned during 1957 which probably dispersed some of the activity into the air. The ashes were dumped in area 3 and the pit backfilled. No wastes have been dumped at site 2-3-S since 1957.

Starting in 1957 solid wastes were placed in pits in area 3 on the plateau. In 1961, radioactivity at site 2-3-S measured about normal background count, which is 0.01 to 0.03 mr/hr with several spots being as high as about 0.6 mr/hr.

A partially filled wood-lined open-bottomed pit about 6 feet by 8 feet square and 6 feet deep in the alluvium at site 2-2-S contained activity of as much as 10 mr/hr in 1961. Liquid wastes drained directly into alluvium through the pit bottom. Mostly solid wastes were disposed in this pit.

Area 3: Pajarito burial pits

Area 3 is on a mesa in the E½ sec. 22, T. 19 N., R. 6 E. The surface of the mesa slopes gently eastward. Ten-Site Canyon heads a short distance northeast of the pits. The soil covering the tuff is about 3-5 feet thick. The canyons about 1,000 feet north and south of the pits area are about 100-150 feet deep. Two prominent vertical joint patterns in the tuff are oriented about 60 degrees to each other. Spacing of the major joints, most of which are filled with sediments or altered material, is about 10 feet.

Two rectangular disposal pits are 100 feet by 600 feet by 20 feet deep at site 3-1-S, and four small rectangular disposal pits each 40 feet by 600 feet by 20 feet deep are at site 3-2-SL. Shafts 2 feet in diameter and 12 to 20 feet deep between the pits in Area 3 do not have a site number. Shafts 2 feet in diameter and 20 to 60 feet deep will be constructed in tuff during 1962 or 1963 at site 3-3-S for disposal of materials which are slightly contaminated. The pits were mostly filled with waste and backfilled by 1960. The fill probably should be compacted and mounded to minimize erosion and ponding of water on its surface.

A record of radioactive wastes placed in the pits and holes since 1954 has been kept; however, records prior to 1954 are incomplete. The total activity of solid wastes buried in the area cannot be estimated. The west pit in area 3-1-S was filled with about 10,000 cubic yards of waste between February 1956 and the end of 1959. A building containing several grams of plutonium was buried in the east pit in area 3-1-S in 1957 along with some machinery.

Sludges from treatment plants contain gross-alpha activity, short-lived beta- and gamma-emitting isotopes, and some strontium-90. Plutonium and americium sludges are mixed with vermiculite or cement in 55-gallon drums and buried.

Barium and lanthanum wastes are placed in steel casings and buried in the 2-foot diameter holes.

Area 4: Technical Area 33

Area 4 is in secs. 19 and 20, T. 18 N., R. 7 E., and sec. 24, T. 8 N., R. 6 E. The surface of the plateau at site 4-1-S slopes gently to Chaquehui Canyon about 20 yards to the south. The soil is thin and supports little or no vegetation. The joint pattern of the tuff is variable, and the joints are not prominent or persistent.

Explosives involving radioactivity were fired in the 1940's in pits and on pads in the south and east parts of the area. Wastes were disposed of locally because of the great distance to centralized disposal pits. Current disposal problems, greatly reduced in scope, are centered in the western part of the area.

Four pits, each about 6 or 7 feet deep, comprising a total area of about 5,000 square feet were used from early 1949 through 1955 and contain an estimated several hundred kilograms of uranium-238 (Harlow Russ, 1961, oral communication). About 80 percent of the useable volume of the pits have been backfilled. The fill probably should be compacted and mounded to minimize erosion and ponding of water around the pits.

Shafts about 12 feet by 15 feet square and 50 feet deep were constructed in tuff. The walls were lined with wood, and about 2 feet of concrete was poured on the floors. One shaft was constructed at site 4-1-S, one at site 4-2-S, and two at site 4-3-S. Explosives containing uranium-238 were fired at sites 4-2-S and 4-3-S. The shafts were last used about 1949. They were opened for inspection in 1954 and then backfilled with tuff.

Several firing pads at sites 4-1-S and 4-2-S contain some uranium-238.

Site 4-4-S is a target into which projectiles containing radioactive materials were fired. The target is cut into a cinder cone on top of the north wall of Chaquehui Canyon. Tuff abutts the cone on the west side and weathers into blocks; it contains few joints.

A pit about 10 feet square and dug into the tuff about 5-10 feet at site 4-5-L was used to dispose of solutions contaminated with tritium from 1950 through 1959. Samples of tuff obtained several feet beneath the pit in 1957 did not contain measurable amounts of tritium. Another pit at site 4-5-L contains a septic tank into which uranium-235 and 238 were discharged in 1961. The soil cover at these sites is thin.

Two emergency releases of liquid containing plutonium were washed into a septic tank less than 50 feet from the north wall of Chaquehui Canyon.

Area 5: Mesita del Buey

Area 5 is an elongate area on a mesa between Pajarito Canyon and Canada de Buey and extends about 1 3/4 miles through sec. 36, T. 19 N., R. 6 E. and sec. 36, T. 19 N., R. 7 E. The surface of the mesa at Area 5 is relatively smooth and slopes gently southeastward toward the canyons paralleling the mesa. The soil cover along the axis of the mesa is about 1 to 2 feet thick but thins toward the canyons. The tuff crops out on the mesa along the canyons. Erosion of the soil is slow because of the small drainage area. Vegetation is mostly clump grass, small caci, and pinon and juniper trees.

Area 5 is to be a long-term disposal area. The U.S. Geological Survey cooperated with the Atomic Energy Commission in the selection of the area and recommended that disposal pits be no closer than 50 feet to the canyons, be no more than 50 feet deep, and that open joints in the pits be sealed with fine-grained material. The area was selected because it is relatively isolated and probably is large enough for disposal of solid wastes for 10 or more years.

The disposal pits at sites 5-1-S and 5-2-S were dug in 1957 and 1958, respectively. These pits, which are 100 feet by 600 feet square, 29 to 30 feet deep, and have a ramp on each end (Enders, 1960, p. 153), are dug in tuff. Among the first items burned and buried in these pits were buildings containing unknown quantities of plutonium, uranium, and mixed fission products. The pit at site 5-1-S was filled to capacity and about 60 percent of the pit of site 5-2-S was filled by the middle of 1962. Estimates for wastes buried in these pits are shown below:

(From records of the Los Alamos Scientific Laboratory)

1959 - 4,838 cubic yards

1960 - 5,777 cubic yards

1961 - 7,170 cubic yards

1962 - 3,976 cubic yards (1st half)

Three shafts 6 feet in diameter and 60 feet deep were constructed in tuff at site 5-3-S during March 1960 for uncontaminated classified shapes.

Area 6: DP - West

Area 6, one of the oldest disposal areas in continuous use at Los Alamos, lies mostly in the S½ sec. 14, T. 19 N., R. 6 E. The formation, fabrication, and recovery of plutonium metal (Christenson, 1959, p. 818) and the disposal of the resultant liquid wastes are accomplished here. Solid wastes placed in Area 6 prior to about 1947 have been transferred to storage in Area 3. Sludges from Area 6 also have been transferred to Area 3 since 1951.

A pit dug into the tuff at site 6-1-S has an area of about 200,000 square feet. The south side of the pit is about 100 feet from a canyon that is tributary to Los Alamos Canyon. The pit was filled between 1945 and 1947 with solid wastes mostly from DP site and TA 1. The surface of the material in the pit and the surface of the 100-foot interval on the south slope toward the tributary canyon. The 100-foot interval is partly grass covered and contains some outcrops of tuff. Several small erosion channels originate in the surface of the pit's fill and extend across the natural surface between the pit and the canyon. The tuff, which crops out on the north wall of the canyon, has a blocky structure and no prominent joint system.

The highest concentration of gross alpha in soil samples collected in June 1955 a short distance downgradient in the canyon south of the pit was 48 disintegrations per minute per dry gram.

Solid-waste pits and stainless-steel storage tanks containing liquids are at site 6-2-SL. The pits contain plutonium and uranium wastes. Liquids have not been added to the storage tanks since about 1949. The level of the radioactivity in these tanks, checked in the early 1950's, was ~~an~~ estimated to be 160 to 1,000 grams of plutonium.

Site 6-3-L consists of three interconnected pits 200 feet long, 25 feet wide, and 8 feet deep. The pits were dug into the tuff along the south edge of a finger mesa adjacent to a tributary of Los Alamos Canyon during the summer of 1945. The pits were constructed as filters and were filled to a depth of about 5-6 feet with large gravel at the bottom and layers of small gravel, soil, and tuff above. The capacity of each pit is approximately 60,000 gallons. Some laundry waste water was discharged into the pits from about 1943-1945, but continuous discharge was started in October 1945. Consequently, all types of wastes from clothing used during laboratory operations at Los Alamos may have been discharged to this site.

The average discharge of laundry waste water per working day since October 1945 has been 6,000 to 8,000 gallons and has averaged about 2 million gallons annually. The waste water was discharged into pit 1, where the water moved into and through the gravel and soil filter. Some water remained in pit 1, and some moved through overflow pipes into pits 2 and 3. The volume that reached pit 3 is not known but is believed to be relatively small, although at one time water was reported to have overflowed pit 3. A pond which now contains cattails and various marsh reeds formed in pit 1 in the early 1950's because the overflow pipes from pit 1 became partly clogged and also possibly because of the clogging of the pores in the underlying tuff.

The activity in samples of tuff collected beneath pit 3 in June 1957 was as follows:

(Counts per minute per liter--
analyses by the Los Alamos Scientific Laboratory)

Depth	Gross alpha	Gross beta	Radioactive strontium
5 feet	2.2	11	--
10 feet	.8	5	63
15 feet	1.1	8	76

From 1945 to 1955, samples were obtained occasionally of the waste-water discharge from the laundry for radiochemical analysis. Starting in 1955, a weekly radiochemical analysis was made from a composite of samples collected daily during normal operation of the laundry. Data in table 1 show that plutonium accounts for about one-third to one-half of the gross-alpha activity and that radioactive strontium accounts for about one-tenth to one-twenty-fifth of the gross-beta activity.

Discharge of waste to the three pits at site 6-3-L ceased in 1961. The pits probably should be backfilled to prevent water from ponding in the pits to a level that the walls would be breached and the contents drained into the nearby canyon.

Table 1.--Average of weekly composite samples of raw waste discharged into pits from laundry at Los Alamos, 1955 through 1960, site 6-3-L

(Analysis by Los Alamos Scientific Laboratory)

Year	Gross alpha (counts per minute per liter)	Plutonium (counts per minute per liter)	Gross beta (counts per minute per liter)	Radioactive strontium (counts per minute per liter)
1955	1,907	655	-	-
1956	1,920	763	-	-
1957	1,282	539	25,682	563
1958	861	412	16,624	1,898
1959	1,244	715	3,088	234
1960	2,313	1,053	22,636	887

Site 6-4-L consists of four pits 100 feet long, 20 feet wide, and about 6 feet deep located between the axis and the north rim of a finger mesa. The pits are dug in tuff. The pits are among the oldest used for disposal of liquid wastes at Los Alamos and, as at site 6-3-L, were backfilled with layers of gravel, soil, and tuff to a depth of 4 to 5 feet. The pits were used from about 1943 to about the middle of 1952, at which time a waste-treatment plant was put into operation. A strong solvent, such as hydrofluoric acid in plutonium wastes, may have reacted with the tuff along joints in the floors and walls of the pits and caused some of the joints to enlarge. The average concentrations of fluoride and plutonium discharged into the pits was 160 parts per million and 60 counts per minute per milliliter respectively (Christenson and Thomas, 1962, p. 258) in the 1943-52 period.

Flow of waste water into these pits probably averaged about 2 to 3 million gallons annually from 1943-52. The wastes flowed into a distribution box, then presumably flowed from the distribution box into pits 1 and 2, and through overflow pipes into pits 3 and 4, respectively. Reportably more water moved into pits 1 and 3 than moved into pits 2 and 4, and at times some of the pits became clogged and overflowed, the overflow moving northward towards a canyon.

The radiological quality of the raw waste discharged into the pits from 1943-52 is probably similar to that now entering the waste-treatment plant at site 6-5-L. The pits probably should be backfilled to prevent water from ponding in the pits.

Operation of the treatment plant at site 6-5-L began in 1952. Most of the radioactive ions from plant wastes are precipitated into sludges which are buried in Area 5. The liquid derived from de-watering of sludges that contain plutonium is stored in tanks for several hours or days for control analysis and then is discharged from the tanks into a nearby canyon. Chemical wastes, such as the hydrofluoric acid used in processing the plutonium, are neutralized and also discharged into the canyon.

The approximate volume of wastes processed at the plant annually and the gross alpha and plutonium are shown in table 2. The highest concentration of gross alpha in soil samples collected in August 1954 a short distance downgradient from the point of discharge into the canyon was 184 disintegrations per minute per dry gram.

Site 6-6-L consists of a culvert that drains storm runoff from around several buildings in which radioactive wastes are created. Samples of this runoff have not been collected, but small quantities of radioactive materials may be washed into Los Alamos Canyon through the culvert.

Area 7: Waste treatment

The disposal facility at Area 7 consists of a treatment plant that has been in operation since January 1951 and which discharges treated waste water into Acid Canyon. From about 1943 to 1951, raw wastes were discharged into the canyon.

Table 2.--Volume of flow into the treatment plant, and the concentrations of the influent and effluent of gross alpha and plutonium, sites 6-4-L and 6-5-L

(Analyses by the Los Alamos Scientific Laboratory)

Year	Volume (thousands of gallons)	Gross alpha		Plutonium		
		Influent (thousands of counts per minute per liter 1/)	Effluent (counts per minute per liter 1/)	Influent (milli-grams)	Effluent (counts per minute per liter 1/)	Total equiv. to plant (mg)
1952	2,683.0	58.2	35	8,781	35	8,781
1953	4,043.6	421	52	92,378	79	92,378
1954	3,226.8	187	73	33,560	93	37,836
1955	2,894.5	218	116	30,004	97	36,555
1956	3,801.1	90	60	18,490	59	23,683
1957	4,712.9	58.5	65	14,883	65	21,030
1958	2,658.8	163	64	23,949	62	38,017
1959	2,496.4	236	114	32,532	98.8	56,541
1960	2,294.1	626	310	81,159	223	a/ 427,829
1961	2,488.2	661	695	99,154	639	173,938

1/ Weighted average

a/ Includes 1.141 grams of plutonium 238

Discharge into Acid Canyon is estimated to have been about 10,000 gallons daily between 1946 and 1951. The volume of discharge generally increased from 1951, when records were started, to 1961 (table 3). Waste was released from the treatment plant during each working day in slugs of 15,000 to 20,000 gallons each.

Acid Canyon is a deep "V" shaped canyon cut into the Tshirege Member of the tuff. It has a steep gradient and contains water only during floodflow, spring snowmelt, and during discharge from the plant. Acid Canyon discharges into Pueblo Canyon, which has a larger drainage area and generally contains a small stream which originates at a sewage-treatment plant upstream. The treatment plant in Area 7 probably will be replaced in late 1962 or early 1963 by a new plant, which will discharge wastes into the upper part of Mortandad Canyon.

The radiological quality of the raw wastes entering the plant and of the treated wastes discharged from the plant is shown in table 3. Most of the radioactive ions are precipitated into sludges which are de-watered before burial at Area 3. The liquid wastes are discharged at approximately one-tenth of drinking-water tolerance. Regular washing of contaminated vehicles, through 1957, in the parking lot at Area 7, and a spill of sludge in the parking lot apparently did not add measurable radioactivity to the canyon. However, an accidental discharge of sludge from the plant, in November 1958, increased the gross alpha of the surface material in the stream channel for a period of several months.

Reportedly, the radiological quality of the raw waste discharged into the canyon before 1951 was similar to that entering the treatment plant during the period 1951 through 1961. The pH of the raw wastes ranges between about 6.6 and 11.8.

Table 3.--Volume of flow into the treatment plant, and the concentrations of the influent and effluent of gross alpha and plutonium, Area 7.

(Analyses by the Los Alamos Scientific Laboratory)

Year	Volume (thousands of gallons)	Gross alpha		Plutonium	
		Influent (α/ counts per minute per liter) [1]	Effluent (α/ counts per minute per liter) [1]	Influent (milli-grams)	Effluent (α/ counts per minute per liter) [1]
1951	4,009.7	2,380	95.8	539.3	95.8
1952	7,538.9	1,845	42.8	745.7	42.8
1953	6,900.0	4,900	105	1,940	49
1954	10,730.0	3,300	222	2,600	60
1955	10,428.7	2,670	167	1,029	61.5
1956	10,653.4	2,100	113	794	29.0
1957	11,538.5	3,580	125	1,429	22.6
1958	10,374.5	4,920	154	1,567	26.2
1959	11,619.4	7,250	160	3,577	30.9
1960	10,850.5	13,200	123	5,296	71
1961	13,962.3	9,767	195	5,686	111.6

[1] α/ Weighted averages

Area 8: Ten-Site

Area 8 is in the E½ sec. 22, T. 19 N., R. 6 E. and is at the head of a small flat-bottomed canyon tributary to Ten-Site Canyon. Clay, about 3 feet thick in the channel of the tributary canyon, is weathered in place from the Tshirege Member of the tuff. The treatment plant in this area processes large amounts of radioactive barium and lanthanum containing some strontium-90 impurities. The treated supernatant liquids are discharged into the tributary canyon.

Operations in the early 1950's consisted of the storage of radioactive wastes in four 50,000-gallon tanks for several months prior to their discharge into the tributary canyon.

A summary of waste discharged from Area 8 from January 1956 to January 1, 1961 (except December 1959 to June 13, 1960) is shown in table 4. The first phase, January 1956 through February 1957, consisted of ion-exchange processes with resins, which were later made a part of regular plant operation. The resins were regenerated and the sludges buried in Area 3. The second phase, February 1957 through November 1959, was a series of pilot plant studies for the removal of strontium-89 and 90. Both processes were used in the plant after June 13, 1960. In addition to the normal discharge of treated wastes into the canyon, a spill of relatively high beta-gamma sources occurred in February 1956, when a storage tank overflowed.

The quantity of water discharged to the canyon is relatively small. The average discharge of radioactive material is about one-tenth of the off-site tolerance.

Table 4.--Volume of flow and concentrations of gross beta and radiostrontium discharged into a canyon in Area 8, January 1956 through November 1959 and June 13, 1960 to January 1, 1961.

(Analyses by the Los Alamos Scientific Laboratory)

Dates	Volume (gallons)	pH	Gross beta (counts per minute per milli-liter)	Radioactive strontium (counts per minute per liter)	Gross beta (counts per minute)	Radioactive strontium (counts per minute)
January 1956 through February 1957	188,600	-	-	-	[a] 20.78×10^{10}	[a] 8.95×10^{10}
March 1957 through December 1957	430,570	-	-	-	-	[a] 10.81×10^{10}
January 1958 through December 1958	370,755	-	-	-	-	[a] 6.08×10^{10}
January 1959 through November 1959	560,234	-	-	-	-	[a] 14.89×10^{9}
June 13, 1960 through January 1, 1961	719,359	[a] 2.6	[a] 685	[a] 2.75	-	-

[a] Weighted averages

Area 9: Omega and OWR (Omega West Reactor) Sites

Area 9 is in the SW$\frac{1}{4}$ sec. 15, T. 19 N., R. 6 E. Liquid and airborne wastes from the operation of two reactors in Los Alamos Canyon are discharged here. Coolant water containing induced activity with a short half-life is discharged into the stream channel at site 9-1-L. Several curies of short-half-life chromium, zinc, and antimony from the ion-exchange column of the OWR (From records of the Los Alamos Scientific Laboratory) are dumped periodically into the stream channel at site 9-3-S. Materials were cleaned quarterly from the trap of a stack at site 9-2-S. Until early in 1961, the wastes were dumped on the alluvium on the floor of the canyon. They contained an average of about 12 uc (microcuries) of cesium^{137} and iodine^{131}.

Area 10: Technical Area 49

Area 10 is in the NW$\frac{1}{4}$ sec. 3, T. 18 N., R. 6 E. It was an active experimental site in 1960 and 1961, and it is expected to be used again in late 1962 or early 1963. Some plutonium is present but the extent cannot be estimated (Phillip Belcher, August 30, 1961, oral communication).

The Geological Survey cooperated with the Atomic Energy Commission in the selection of the area and conducted and extensive geologic and hydrologic study concurrent with construction. Approximately 55 to 60 holes 6 feet in diameter were augered into the Tshirege Member of the Bandelier Tuff to a maximum depth of 110 feet. Three test holes, drilled to depths ranging between 1,409 and 1,821 feet, entered the main aquifer. The water levels in these wells range between 1,004 and 1,172 feet below the mesa. In addition, numerous small-diameter holes within the site and adjacent to the site were drilled for the collection of samples and for the study of the movement of water within the tuff.

Area 11: Mortandad Canyon

Area 11 is in the NW$\frac{1}{4}$ sec. 22, T. 19 N., R. 6 E., mostly in Mortandad Canyon. Liquid wastes treated to below off-site tolerances will be discharged from a central waste-treatment plant into a canyon tributary to Mortandad Canyon. This plant will replace the treatment plant of Area 7.

The Geological Survey cooperated with the Atomic Energy Commission in the selection of Area 12 and conducted and extensive geologic and hydrologic study. One deep test well to the main aquifer was drilled and several series of wells were drilled to measure the water level in the alluvium in the canyon, to collect samples, and to measure the moisture content of the alluvium and underlying rock. The alluvium in the upper part of the canyon is thin and contains many boulders but widens and thickens down the canyon (Baltz and others, 1962, p. 30). The movement of water in the alluvium and into the underlying tuff is being followed so that the step-by-step movements of wastes can be followed from their source.

Area 12: Pajarito

Area 12 is in the NE$\frac{1}{4}$ sec. 35 and the NW$\frac{1}{4}$ sec. 36, T. 19 N., R. 6 E. in Pajarito Canyon. The canyon floor is flat and consists of gravelly alluvium 20 to 25 feet thick. Small quantities of wastes are discharged here occasionally.

Sewage-disposal plants

Sewage is discharged from the Pueblo, Central, and Sandia sewage plants. These wastes generally are high in phosphates and nitrates. Pueblo and Central sewage plants discharge into Pueblo Canyon, and the Sandia plant discharges into Sandia Canyon. During the warm months, about 90 percent of the sewage from the Pueblo sewage plant is pumped onto the golf course for irrigation. For several years in the mid-1950's, part of the sewage from the Central sewage plant was pumped to the main power plant for cooling purposes and then discharged into Sandia Canyon. The discharge creates small streams in Pueblo and Sandia Canyons. Discharge from the Pueblo sewage plant averages about 9 million gallons monthly and from the Central sewage plant about 4 million gallons monthly. Data are lacking on the discharge from the Sandia sewage plant.

Sewage from isolated technical areas generally is discharged into local tile systems which are entrenched in tuff.

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