UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

EVALUATION OF MONITORING OF RADIOACTIVE SOLID-WASTE BURIAL SITES AT LOS ALAMOS, NEW MEXICO

By

T. E. Kelly

Open-file report 75-406

Prepared by the U.S. Geological Survey
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ABSTRACT

Burial of solid radioactive waste began at Los Alamos, N. Mex. in 1943. Most of this waste contained a low level of radioactivity; consequently, only limited monitoring of the hydrogeologic environment has been done in the past. This study was based on a file-and-literature search in order to determine the effectiveness of these moitoring activities.

Insufficient data are available to design an effective monitoring program at the present time. Various geologic and hydrologic parameters need to be defined more accurately if an effective system of monitoring is to be designed.

INTRODUCTION

In 1943 the University of California was requested to establish a nuclear research facility at the Los Alamos Boarding School, a private institution located in the Jemez Mountains northwest of Santa Fe, N. Mex. This facility, subsequently named LASL (Los Alamos Scientific Laboratory), has retained its affiliation with the University of California system. Currently (1975) a wide variety of research projects are conducted at LASL, all of which are funded by Federal agencies. The prime agency is ERDA (Energy Research and Development Administration), formerly the Atomic Energy Commission.

In the past, various types of waste have been buried at the LASL reservation. Some of these wastes were radioactively contaminated; other waste consisted of classified materials and nonradioactive chemical wastes. In recent years the interest in environmental impact and control has focused attention on these burial areas, some of which were located near population centers. Consequently ERDA requested that USGS (U.S. Geological Survey) conduct an independent investigation of some of these sites.

This investigation was conducted under contract with the Albuquerque Operations Office of ERDA. The study is part of an ERDA waste-management plan to evaluate the solid-waste-burial methods in use at several sites in the United States and to determine the suitability of burial grounds for long-term storage of solid radioactive wastes.

The investigation was conducted between September 1973 and July 1974. No new data were collected; the study was based on existing records from the files of LASL and on data from previous investigations by ERDA contractors, including USGS. Each disposal site was visited on various occasions and the monitoring and sampling procedures were observed in the field whenever possible.

The author wishes to express his appreciation for the help given by various members of the Health Division of LASL, especially LaMar Johnson, J. A. Mohrbacher, and Margaret Anne Rogers.

Two facets of data collection are necessary to adequately evaluate a disposal site. First, on-site studies are needed to determine the geohydrologic characteristics of each site; this would be a one-time evaluation of features which would remain constant for prolonged periods of time. Second, a continuous monitoring program is necessary to trace ground-water movement and migration of radionuclides.

In some instances the term "monitoring" has been used in reference to periodic sampling and testing of various segments of the environment to detect radiation levels at specific sites without regard for movement. However, in this report the term refers to a continuing program of study and sampling that would ultimately define the rate, direction, and concentration of radionuclide migration in the geohydrologic environment.

Of the material-disposal sites at Los Alamos, eight were selected for study (fig. 1). Six of the eight areas studied are considered conventional solid-waste burial sites. One of the materials-disposal areas, Area T, is a liquid-waste disposal operation; another of the materials-disposal areas, Area D, is two subterranean chambers where experimental devices were detonated.

Although the principal emphasis in this investigation was directed toward solid-waste disposal areas, it is not always possible to identify the source of contamination after the radionuclides have entered the environment. Also, liquid wastes and precipitation have come in contact with the solid-waste products, thus causing the radionuclides to move as a liquid waste. Consequently many of the statements made in this report pertain to the monitoring of liquids as well as solids.

The primary purposes of this investigation, as requested by ERDA, were (1) to determine adequacy of current solid-waste monitoring systems at LASL, and (2) to determine improvements to the monitoring program to assure that radioactivity migration from burial areas could be detected. It was agreed by the cooperating agencies that the efforts in this study be directed toward the tabulation of existing data pertaining to the immediate vicinity of the disposal sites, with suggestions being made for the collection of additional data which would provide the necessary background for the design of a comprehensive monitoring program.

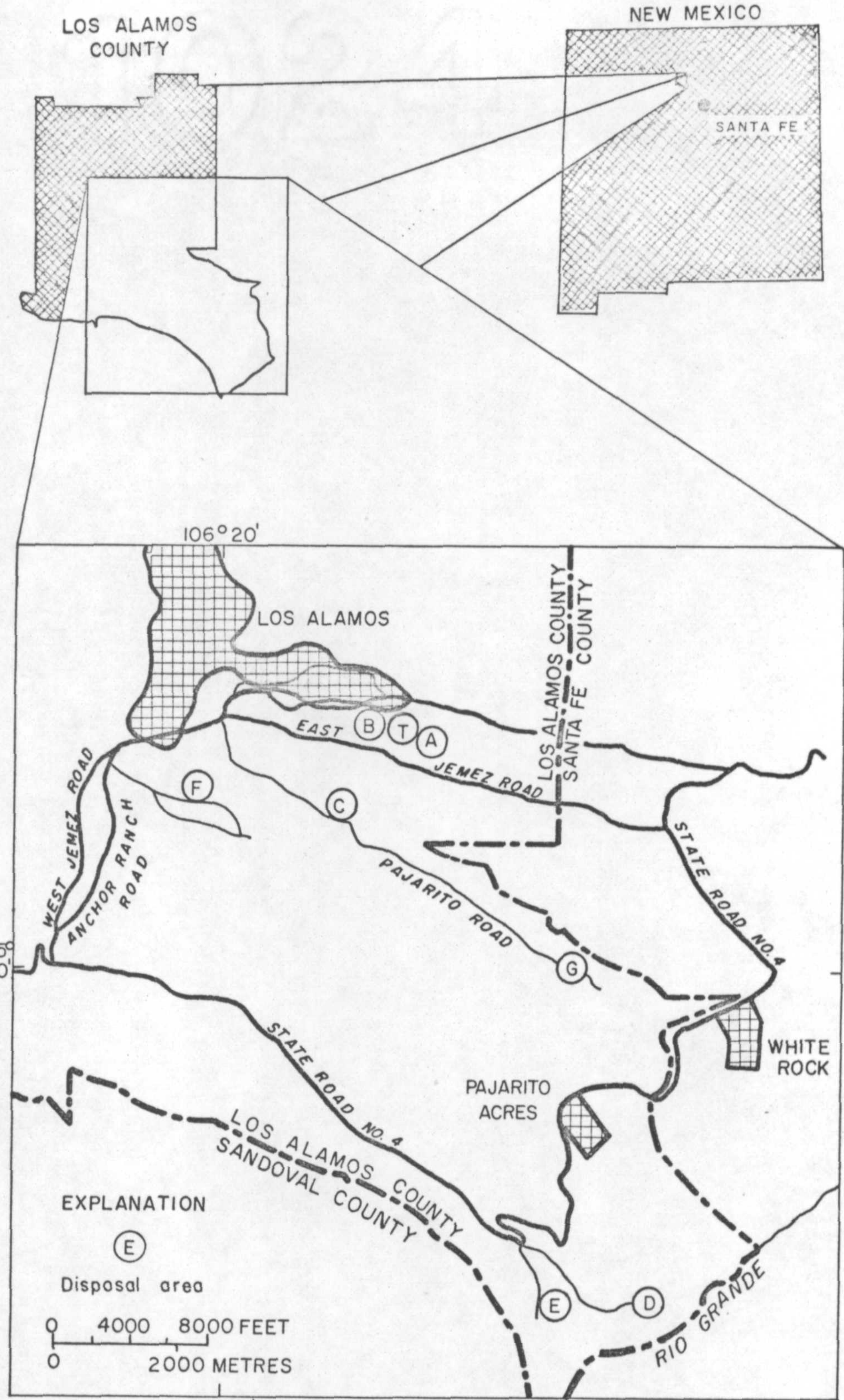


Figure 1.--Location of disposal areas.

The Health Division of LASL has always classified the radioactive wastes disposed to ground as either solid or as liquid, and the monitoring programs have been designed accordingly. Owing to the mobility of the liquid-waste products, most of the emphasis has been directed toward this group. From 1950 through June 1971 a continuous program of liquid-waste monitoring was conducted by the USGS in cooperation with LASL and ERDA. During this interval several thousand surface and ground-water samples were collected in Los Alamos County. Samples were also collected from the Rio Grande and several other major streams in the State. A large number of reports were prepared as a result of these surface-water investigations.

Most of the solid waste is considered to have a low level of activity. These wastes are monitored by LASL during packaging and transportation to the burial grounds; however, no specific site-monitoring program has been established for buried waste.

The types of solid wastes consist of a wide variety of materials originating from different places in a given work area (Fowler and others, 1973, p. 3). These have been subdivided into six categories. (1) Laboratory trash consists of the miscellaneous materials which are used in laboratories or rooms outside the direct-process enclosures. (2) Line-generated trash consists of miscellaneous materials which are used inside processing enclosures; it is usually considerably higher in contamination than that of the room-generated trash. (3) Liquid effluent treatment sludges are the precipitates from various liquid radioactive-waste streams. (4) Oils, greases, and combustible liquids are derived from various machining operations involving radioactive metals. (5) Contaminated equipment and metals which are too large to be handled as laboratory or line-generated trash. (6) Radioactive building debris includes such things as blowers and filter housings, as well as whole buildings which have become contaminated and subsequently dismantled.

During the era of the Manhattan Project of World War II, the responsibility for disposal of radioactive waste was delegated to military personnel. Sometime in early 1945 this responsibility was delegated to the Health Group, CMR-12 (Chemical Metallurgical Research-12). In 1953 CMR-12 was transferred to the Health Division and assigned to Group H-6. Subsequently Group H-6 was redesignated Group H-1. In an office memorandum from G. L. Voelz, M. D., Health Division Leader, LASL, through R. E. Schreiber to H. J. Blackwell, Area Manager, AEC, dated April 27, 1973, the responsibility for collection of solid wastes and management of the radioactive-waste burial grounds was transferred from LASL Group H-1 Health Physics to Group H-8 Environmental Studies effective May 1, 1973. During these numerous changes Dean D. Meyer was Project Leader of the solid waste-disposal programs throughout most of his career with LASL. His tenure with the laboratory extended from 1946 through June 1973. J. W. Enders and others were responsible for the actual field operations during most of this time.

An early description of the disposal sites was given in a LASL office memorandum from Dean D. Meyer to S. E. Russo on January 31, 1952, subject "Location of contaminated waste burial pits." The memorandum is quoted in full below:

"The collection and burial of contaminated waste materials from CMR areas was started by group CMR-12 in 1944. Letters in the CMR-12 files indicate that sometime in 1944 a pit located in the fenced area between the Trailer Court and the CMR Laundry was in use. When this pit was filled two more were dug in the area now known as the General's Tank Area. When these were filled (1945) three more pits were dug in the area between the Trailer Court and CMR Laundry. Space in this area was exhausted in 1948 and new pits were started at the present location on Pajarito Road. Personnel that were attached to the CMR Division during the war think that there was a small pit located on the north side of the DP Site Road, however, records in the CMR-12 files do not confirm the existence of this pit.

"The material in these pits consists of all the contaminated waste from CMR operations. This includes laboratory equipment, building construction material, paper, rubber gloves, filters from air cleaning systems and contaminated or toxic chemicals. Other divisions of the laboratory have also requested that contaminated materials and classified shapes from their operation be disposed of in these pits.

"The contamination on materials in these pits consists of all the types of radioactive materials used at Los Alamos. Some of the known types of activity are: plutonium, polonium, uranium, americium, curium, RaLa*, actinium and waste products from the Water Boiler. No attempt has been made to keep the various materials separated."

*Radium-Lanthanum

In 1973 the Health Division Group (H-8) made a preliminary survey of the radionuclide concentration and composition of solid waste buried at Los Alamos since the beginning of operations at the laboratory in the early 1940's (McCurdy and others, 1974, p. 44). This investigation revealed that, in general, no records were kept until the mid-1950's and that the records are "highly variable" in quality. Detailed records of radionuclide concentration and composition of wastes were not kept until 1959, however the quality of records has improved steadily since that time.

Of the eight sites which were designated for study during this investigation, only three--Areas C, G, and T--have been used since 1959. Therefore specific information concerning the total number of curies of waste are available for these three sites only (table 1).

Table 1.--Radionuclide concentration of materials placed in three subsurface disposal sites as of January 1973[a/]

Isotope	Area C		Area G		Area T		Total of all disposal areas
	Pits	Shafts	Pits	Shafts	Absorption beds	Shafts	
^{3}H	-	49,136[b/]	4	77,661	-	-	147,589
^{22}Na	-	40	-	46	-	-	86
^{60}Co	-	20	-	229	-	-	249
^{90}Sr ^{90}Y	-	31	2,962	306	-	2	3,301
^{137}Cs	-	-	-	6	-	2	8
^{233}U	-	5	-	5	-	7	17
U[c/]	25	< 0.1	48	-	-	-	73
^{238}Pu	-	-	15	4	-	13	32
^{239}Pu	26	-	332	-	10	70	438
^{241}Am	149	-	2,074	-	-	1,256	3,479
Fission products	-	50	-	77	-	-	127
Induced activity	-	200	-	2,458	-	-	2,658

a/ Modified from Tables XIV and XV, Los Alamos report LA-5614-PR; no data given for Areas A, B, D, E, or F.
b/ All values in curies, decay corrected.
c/ Included isotopes 234, 235, 236, 238.

For those readers interested in using the metric system, metric equivalents of English units of measurement are given in parentheses. The English units used in this report may be converted to metric units by the following conversion factors:

From		Multiply by	To obtain	
Unit	abbreviation		Unit	abbreviation
inches	(in)	25.4	millimetres	(mm)
feet	(ft)	0.3048	metres	(m)
miles	(mi)	1.609	kilometres	(km)
square miles	(mi^2)	2.590	square kilometres	(km^2)
cubic feet per second	(ft^3/s)	0.02832	cubic metres per second	(m^3/s)
feet per mile	(ft/mi)	0.3048/1.609	metres per kilometre	(m/km)
acre-feet	(acre-ft)	1233	cubic metres	(m^3)
		1.233×10^{-3}	cubic hectometres	(hm^3)
gallons per minute	(gal/min)	6.309×10^{-5}	cubic metres per second	(m^3/s)
cubic yards	(yd^3)	0.764555	cubic metres	(m^3)
square feet	(ft^2)	0.092903	square metres	(m^2)
gallons	(gal)	0.003785	cubic metres	(m^3)

REGIONAL GEOHYDROLOGIC SETTING

The Los Alamos Scientific Laboratory reservation, approximately 120 mi^2 (310 km^2) in extent, covers most of Los Alamos County, excluding the metropolitan and residential areas--the Los Alamos townsite (1970 population 11,310), White Rock and Pajarito Acres (1970 populations 3,388). Los Alamos County is in north-central New Mexico, approximately 25 mi (41 km) northwest of Santa Fe.

Most of the Laboratory installations have been constructed on the Pajarito Plateau (fig. 2) which is at an altitude of about 7,000 ft (2,100 m). The surface of the plateau has been dissected by many narrow, steep-walled canyons which have been cut by intermittent streams that drain eastward into the Rio Grande at an altitude of approximately 5,500 ft (1,700 m). The western edge of the area is bordered by the Sierra de los Valles, part of the Jemez Mountains, which have many peaks exceeding 10,000 ft (3,000 m) in altitude.

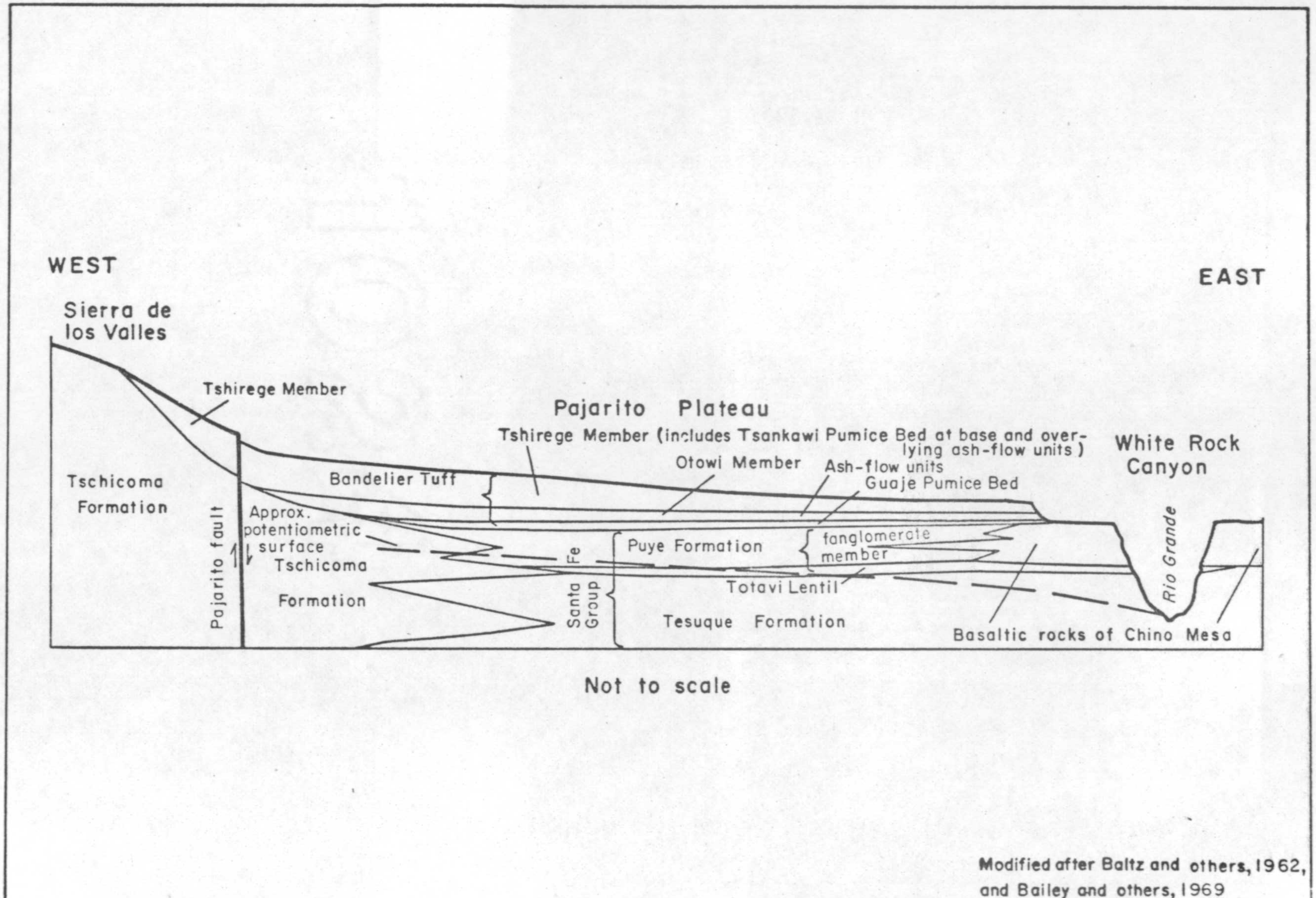


Figure 2.--Diagrammatic section showing generalized stratigraphic relations of the Bandelier Tuff to older rocks in the Los Alamos area.

Meteorological data have been collected at Los Alamos since 1926. Initially this effort was supported by the Los Alamos Boys' School and later by the laboratory. The average annual precipitation of the plateau is about 17 in (450 mm) per year. Approximately 30 to 50 percent of the precipitation falls during local thunderstorms in July and August; about 50 in (1,300 mm) of snow is recorded annually at Los Alamos. The average annual temperature is 9°C (48°F); average July temperature is about 19°C (67°F) and the average January temperature is -3°C (29°F). Evaporation data are not available for Los Alamos.

The oldest exposed Tertiary rocks in the Los Alamos area consist of sand, silt, clay, and some interbedded gravel called the "undifferentiated unit of the Santa Fe Group" by Griggs (1964, p. 20). Spiegel and Baldwin (1963, p. 39) applied the name Tesuque Formation to part of this unit (fig. 2). The Tesuque Formation is overlain by the Puye Formation (Griggs, 1964, p. 28). Although this unit has been divided into two different members, in general it consists of coarse clastics, silt, and minor amounts of basalt. The maximum known thickness is 726 ft (221 m). These rocks grade eastward into the basaltic rocks of Chino Mesa east of the Rio Grande and westward they intertongue with the Tschicoma Formation that comprises most of the volcanics of the Sierra de los Valles. The municipal water supply for Los Alamos is obtained from wells completed in the Puye Conglomerate and underlying Tesuque Formation.

The hydrologic characteristics of these depostis have been described in detail by Theis and Conover (1962), Cushman (1965), and Purtymun and Cooper (1969).

The regional flow pattern of ground water in the Rio Grande basin is parallel to the axis of the river (Kelly and others, 1970, p. 21). However this pattern is locally modified by the inflow of ground water from the various source areas. At Los Alamos the ground water flows eastward toward the Rio Grande from the source areas in the Sierra de los Valles and higher parts of the Pajarito Plateau (Griggs, 1964, p. 95). The regional slope of the potentiometric surface is approximately 70 ft/mi (13 m/km) from west to east. As this slope is less than that of the land surface of the Pajarito Plateau, the depth to the potentiometric surface becomes progressively greater toward the Sierra de los Valles, although few data are available for the region west of Area C. The average depth to the potentiometric surface at LASL is about 1,000 ft (305 m).

Soil moisture which is not retained in perched water zones percolates downward until reaching the main zone of saturation, then migrates eastward toward the Rio Grande. According to Griggs (1964, p. 95), streamflow measurements in the Rio Grande in dry weather indicate that the river gains 500 to 600 gal/min (0.03 to 0.04 m^3/s) per mile in the 21-mi (34-km) reach of the Rio Grande below Otowi Bridge east of Los Alamos. Most of this water probably discharges from the Puye Conglomerate and the Tesuque Formation.

The Puye Formation is overlain by the Bandelier Tuff, a thick sequence of volcanic depostis that forms the Pajarito Plateau. Griggs (1964, p. 46) subdivided the Bandelier into three members: the oldest Guaje Member, the Otowi Member, and the Tshirege Member. Subsequent work by Bailey and others (1969, p. 13) has shown that the formation may be more naturally subdivided into two stratigraphic and genetically equivalent members, the Otowi and Tshirege Members, each consisting of a basal pumice bed overlain by a petrologically related succession of ash-flow units (fig. 2). The Otowi Member, including the Guaje Pumice Bed, is exposed in the deeper parts of the canyons east of Los Alamos. The overlying Tshirege Member is a prominent cliff-forming unit that caps the Pajarito Plateau. The maximum known thickness of the Bandelier Tuff is more than 1,000 ft (305 m).

According to Griggs (1964, p. 47) the present Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff is characterized by unconsolidated white-to-gray, rhyolitic pumice; small phenocrysts of quartz and feldspar crystals are locally present. The overlying ash-flow units generally consist of a single flow of light-gray pumiceous tuff and tuff breccia containing fragments of rhyolite and latite. The conical-shaped erosional remnants, locally called "tent rocks," are characteristic of the weathering of the ash-flow units of the Otowi Member.

The Tshirege Member of the Bandelier Tuff caps the Pajarito Plateau and forms the prominent cliffs which are characteristic of the Los Alamos area and Bandelier National Monument. All of the solid-waste burial pits have been excavated in the Tshirege.

A study of the soil adsorption of radionuclides by the Tshirege Member of the Bandelier Tuff was made by Christenson and others (1958). Three radionuclides were tested: ^{137}Cs, ^{239}Pu, and ^{90}Sr. The lowest percentage retention of ^{137}Cs by tuff was 99.6 and attempts to release the cesium were unsuccessful. It was found that ^{239}Pu is tightly bound within the tuff but that it can be released by the addition of such complexing agents as citric acid, versene, or soap. Strontium-90 was not retained by the tuff as well as cesium or plutonium, and it was much more easily released. These data indicate that each radionuclide has different retention characteristics but only three of the radionuclides commonly buried at Los Alamos were studied. Also, it is possible that there are variations in the retention characteristics of the tuff at different burial sites. Therefore the study by Christenson and others (1958) should not be considered directly applicable to any specific burial site, although it does provide valuable background data.

Jointing is the most significant structural feature of the Tshirege Member of the Bandelier Tuff; it also exerts a significant control on the hydrology of the burial sites. According to Baltz and others (1963, p. 37), joints in the tuff range from hairline cracks to fissures several inches wide. The average density is about one joint per square yard, but in many areas the individual joints intersect or are more closely spaced. Many of these fractures are filled with sediment, caliche, or clay derived from the weathering of the fracture plains. Open joints have been noted in many outcrops and boreholes, and they have been found in both members of the Bandelier Tuff. Baltz and others (1963, p. 41) state that "....it would be reasonable to expect....[that jointing] might allow percolation downward to the Puye Formation if water is able to infiltrate at the surface."

Many of the earlier studies at Los Alamos concluded that the soil which developed on the Tshirege Member produced a relatively impermeable barrier to the downward movement of precipitation (Abrahams and others, 1961, p. 145), (Purtymun, 1966, p. 17), and (Purtymun, 1967, p. 25). It was generally believed that most of the precipitation was returned to the atmosphere from the soil zone by evapotranspiration; a small amount of water moved laterally through the soil,"....this being the path of least resistance," and into the nearby canyons where it infiltrated the more permeable alluvium (Baltz and others, 1963, p. 63). In those cases where precipitation did reach the unweathered tuff, Purtymun (1966, p. 17) suggested that the "Flat-lying to near-vertical open joints probably will perch water and impede the downward movement of water in the tuff, because the water is held in tension in the small pore spaces of the tuff."

Recent work by Purtymun, (1973, p. 6) however, shows that water which has passed through the soil profile will move in the vapor phase, primarily along the horizontal bedding planes in the tuff and secondarily through open joints and through the tuff matrix.

AREA A

History and conditions of burial

Area A, one of the oldest disposal sites at Los Alamos, has been used intermittently since about 1945. This area is located near TA-21, 0.25 mi (0.41 km) east of the end of DP Road and on the north side of the Los Alamos Canyon.

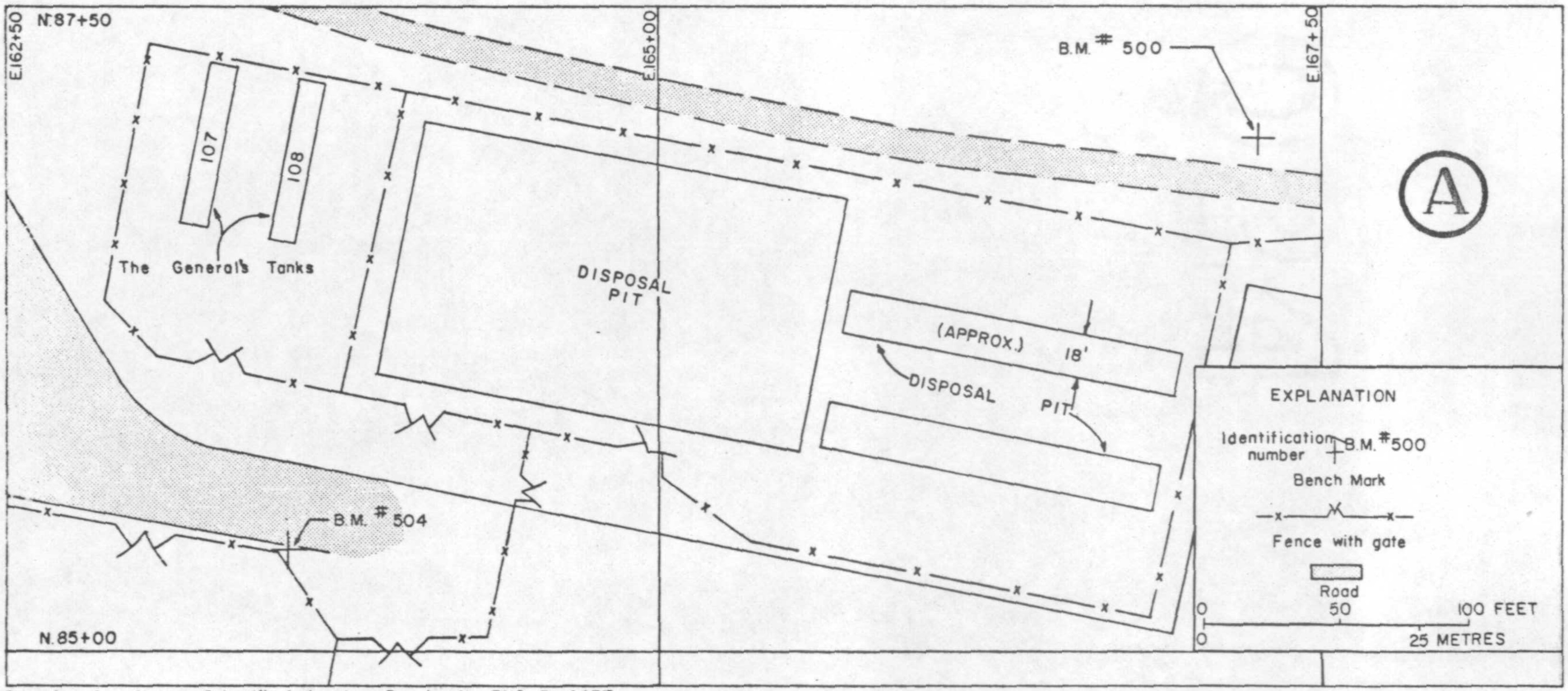
Two structures, TA-21-107 and TA-21-108, locally known as the "General's Tanks," are located in Area A in addition to several solid-waste pits (fig. 3). These structures are 50,000 gal (200 m^3) stainless steel tanks which were used for storing solutions that contained radionuclides. According to office memorandum dated October 30, 1973 from G. L. Voelz, LASL, to E. E. Wingfield, ERDA, the two tanks were constructed in 1945. They were buried about 8 ft (24 m) below grade and covered with an 8-in (200-mm) slab of concrete.

According to the Voelz memorandum, surveillance of these tanks has been minimal, however "The volume of 40,000 gallons in one tank and 9,000 in the other as well as chemical concentrations is comparable to the record data." The amount of radioactive material in these solutions is believed by Voelz to be approximately 230 grams of ^{239}Pu and ^{241}Am.

In an unpublished report to LASL, Jacques Renault of the New Mexico Bureau of Mines and Mineral Resources (written commun., December 3, 1973) reports that moisture has moved through the joints in the tuff and that some rock material may have been transported through the fractures. In several instances desiccation cracks and horizontal structures in open fractures suggests that meteoric water was standing in the joints. Renault also found that the joints are locally filled with montmorillonite, a swelling clay. He stated that, "It is conceivable that expansion of this clay could cause fracture walls to move apart irreversibly. The montmorillonite filled fractures will have a low permeability to gases when wet and high permeability to gases when dry."

These studies suggest that in many instances the soil that develops on the Bandelier Tuff retards the downward movement of much of the precipitation which falls on the Pajarito Plateau. However once the soil moisture has reached the unweathered tuff, movement occurs in both the liquid and vapor phases through joints, bedding planes, and through the highly porous tuff. Furthermore, it is possible that the permeability of the joints and bedding planes may vary throughout the year in response to the amount of moisture available to the montmorillonite.

Perched water bodies have been recognized at Los Alamos for a number of years, and in some cases these have been sampled where they discharge as springs (Purtymun, written commun., 1969). The more important springs include the Ancho Spring, Hamilton Bend Spring, and Basalt Spring. The discharge of these springs indicates that perched aquifers exert some control on the movement of water in the zone of aeration.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-R-4457

Figure 3.--Disposal Area A.

Two disposal pits were originally excavated in Area A; according to engineering drawing ENG-1266 these pits were 125 ft (38 m) long and 18 ft (5 m) wide. A later pit excavated in April 1969 was approximately 200 ft (60 m) long and 80 ft (24 m) wide; the depth was about 20 ft (6 m). Subsequently, in LASL office memorandum dated November 9, 1972 from J. L. Desilets to C. A. Reynolds, subject "Materials Disposal Area 'A', DP-West," it was requested that the existing excavated area be enlarged to provide approximately 6,000 yd^3 (4,800 m^3) of additional space.

Purtymun (written commun., June 30, 1969) described Area A as a northward-sloping land surface on the Bandelier Tuff which breaks into a series of benches and steep slopes into DP Canyon. The disposal pits were excavated into a moderately welded tuff having a soil cover that ranges from 2 to 5 ft (0.6 to 1.5 m) in thickness. Three joint sets are present and all of the joints are filled with dark brown clay or gray clay. The total thickness of the Bandelier Tuff at Area A probably exceeds 800 ft (244 m). The tuff is in the unsaturated zone; the top of the saturated zone in the Puye Formation is at about 1,150 ft (350 m) below the surface.

Previous monitoring activity

The amount and type of radioactive waste, which has been buried at Area A and the level of activity of the waste is not well documented. Abrahams (written commun., February 1963) reported that the disposal pits contained polonium and uranium wastes. In LASL office memorandum from D. D. Meyer to C. W. Christenson dated January 4, 1971, subject "Volume of transuranium wastes buried at Los Alamos," Meyer reported that in the first two pits "....the main radioactive material buried was polonium. There may have been a trace of ^{239}Pu." The latest pit (1969) contains Pu contaminated waste material removed from DP West during the rehabilitation work. Furthermore Meyer estimated that the amount of waste buried at Area A was 12,500 yd^3 (10,000 m^3); this estimation was based on the volume of the pits rather than the actual volume of the waste.

AREA B

History and conditions of burial

The establishment of a burial pit at Area B was requested in a memorandum from David Dow to Col. C. R. Tyler on July 5, 1945. The excavation, which was to replace the burial pits at Area A, was to be located along the south side of DP Road.

Little information pertaining to the quantity and type of radioactive waste buried at Area B is available. The only definitive data were presented in a LASL memorandum dated January 31, 1952 from D. D. Meyer to S. E. Russo, subject "Location of contaminated waste burial pits." In this memorandum Meyer stated that all the early burial pits including Area B contained waste contaminated with all the types of radioactive materials used at Los Alamos. These included plutonium, polonium, uranium, americium, curium, actinium, and waste products from the "water boiler." According to this memorandum, "No attempt has been made to keep the various materials separated."

In a LASL memorandum dated January 4, 1971 from D. D. Meyer to C. W. Christenson, subject "Volume of transuranium wastes buried at Los Alamos," it was estimated that Area B "actually contains very little plutonium. At the time they were in use, Pu was scarce and only that which was present as contamination was buried. I would estimate that the entire pit area contains no more than 100 grams of ^{239}Pu."

The memorandum from Meyer to Russo dated January 31, 1952 defined the type of waste as follows: "The material in these pits consists of all the contaminated waste from CMR operations. This includes laboratory equipment, building construction material, paper, rubber gloves, filters from air cleaning systems and contaminated or toxic chemicals. Other divisions of the laboratory have also requested that contaminated materials and classified shapes from their operations be disposed in these pits."

The exact dimensions of the disposal pits at Area B are unknown. The original memorandum suggested that the excavation be 15 ft (5 m) wide and 300 ft (90 m) long (fig. 4). In a later memorandum it was suggested that the excavation be 12 ft (4 m) deep. It is believed that a series of pits were excavated in Area B instead of a single pit. Purtymun and Kennedy (1966, p. 8) reported that the excavated area was about 250,000 ft^2 (32,500 m^2) and a depth of about 20 ft (6 m).

This disposal site was last used in late 1949 or early 1950. It was then covered by about 3 ft (1 m) of tuff that had originally been removed from the excavation, and subsequently about 60 percent of the pit was paved with asphalt. This paved area remains under ERDA ownership and control. It is used, however, by residents of Los Alamos County for storage of trailers, boats, and automobiles. The area on the east end of the paved area has not been improved.

The geologic environment of Area B is assumed to be similar to that of Area A; no geologic investigations have been made. Depth to the aquifer beneath Area B is approximately 1,200 ft (366 m) below land surface.

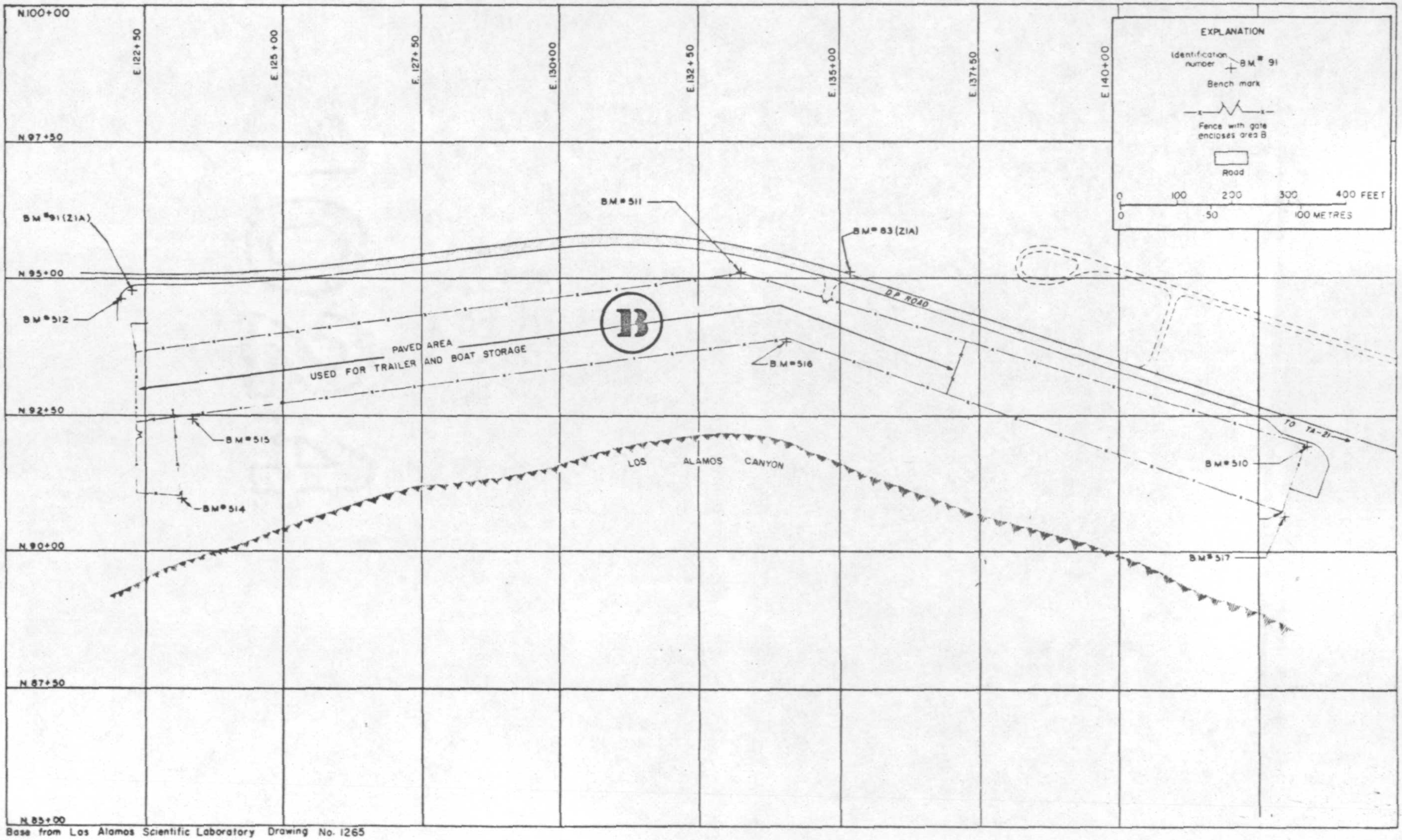


Figure 4.--Disposal Area B

Previous monitoring activity

A number of investigations have been conducted in the vicinity of Area B to determine if the surrounding area has been contaminated by the buried waste. Analyses of soil and water taken from surface samples within the area in 1947, 1953, 1954, and 1957 (written commun. Abrahams, 1963) have consistently shown that the radionuclide concentrations are well below the maximum permissible concentrations (MPC) as outlined in AEC Manual Chapter 0524.

Abrahams (written commun., 1963) reported that soil samples were collected in June 1955, "a short distance downgradient in the canyon south of the pit...." The highest concentration of gross alpha in these samples was 48 (d/m)/g (disintegrations per minute per dry gram). The exact location of this sampling point was not documented, and members of the Health Division now (1974) believe that this sample was collected near the outflow point of discharge from an old laundry facility where contaminated clothing was processed.

Purtymun and Kennedy (1966, p. 11) drilled 13 test holes around the outer perimeter of the area. These ranged in depth from 25 ft (8 m) to 50 ft (15 m). The maximum gross alpha measured in soil and rock samples from the holes was 1.2 (d/m)/g and maximum gross beta was 12.6 (d/m)/g. Most of the moisture profiles illustrated in their report show that the soil moisture generally decreases with depth, then remains constant below an average depth of 23 ft (7 m).

A beta-gamma survey of Area B was conducted on September 16, 1966 by W. F. Romero, H-1. No appreciable readings above normal background of 0.07 mR/hr (milliroetgens/hour) was detected.

There have been several cave-ins on the asphalt in the parking area of Area B indicating that some compaction and settling of waste has occurred. In an office memorandum dated November 10, 1971 from Wilbur Workman to D. D. Meyer, one such cave-in was documented. The memorandum stated that at 5:00 p.m. on November 10, 1971 two monitors were sent to the county trailer parking lot to check out a reported cave-in of the asphalt parking area. An area approximately 5 ft (1.5 m) in diameter and 18 in (460 mm) deep was surveyed using alpha and beta counters. No alpha contamination was detected and the beta count was background.

Vegetation samples were collected on October 24, 1973 by Wayne Hanson at several sites where clover, yucca, and grasses had penetrated the asphaltic cover. These are to be analyzed for tritium concentration. However, the analyses were not available as this report was written (1974).

AREA C

History and conditions of burial

Waste disposal Area C was established in May 1948 when the available space in Area B was being exhausted. The site is located on the north side of Pajarito Road and east of its intersection with Pecos Drive. TA-50, one of the principal waste-processing plants, is located on the north side of Area C.

In a LASL office memorandum dated January 4, 1971 from D. D. Meyer to C. W. Christenson, subject "Volume of transuranic wastes buried at Los Alamos," it was estimated that 118,000 yd^3 (94,400 m^3) of waste were buried in Area C. Much of this waste, however, was classified material which was not radioactive. The last disposal trench was filled by mid 1959; however, the chemical pit in Area C continued to be used until at least July 1, 1964 and the last disposal shaft was not sealed until 1974.

The amount of radionuclides that are reported to be buried at Area C are given in table 1.

Abrahams (written commun., 1963), reported that the soil profile on the Bandelier tuff is about 3 to 5 ft (1 to 1.5 m) thick at Area C. 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 ft (3 m). The disposal site is at the head of Ten-Site Canyon which is a short tributary to Mortandad Canyon, one of the major drainageways in the area. The approximate depth to the main aquifer beneath Area C is 1,000 ft (305 m).

According to Engineering Drawing ENG-R1264 dated December 22, 1970, a total of six pits were excavated for disposal of radioactive waste (fig. 5). Pits 1, 2, 3, and 4 were 610 ft (186 m) long and 40 ft (12 m) wide; depth was not given. Pit 5 was 705 ft (215 m) long and 110 ft (33 m) wide. It had a maximum depth of 18 ft (5 m) and a volume of 43,783 yd^3 (35,026 m^3). These pits occupy most of the two east quadrants of the area. Pit 6, located in the northwest quadrant of Area C, was 505 ft (154 m) long and 100 ft (30 m) wide; maximum depth is approximately 25 ft (8 m) and volume is 34,894 yd^3 (27,915 m^3).

Prior to 1958 all waste chemicals, as well as a large quantity of nonradioactive classified waste, was intermixed with the contaminated waste in Area C. However due to the fire hazard, this practice was discontinued and chemical and classified waste were processed separately. A special pit was excavated in Area C for disposal of uncontaminated chemical wastes (fig. 5).

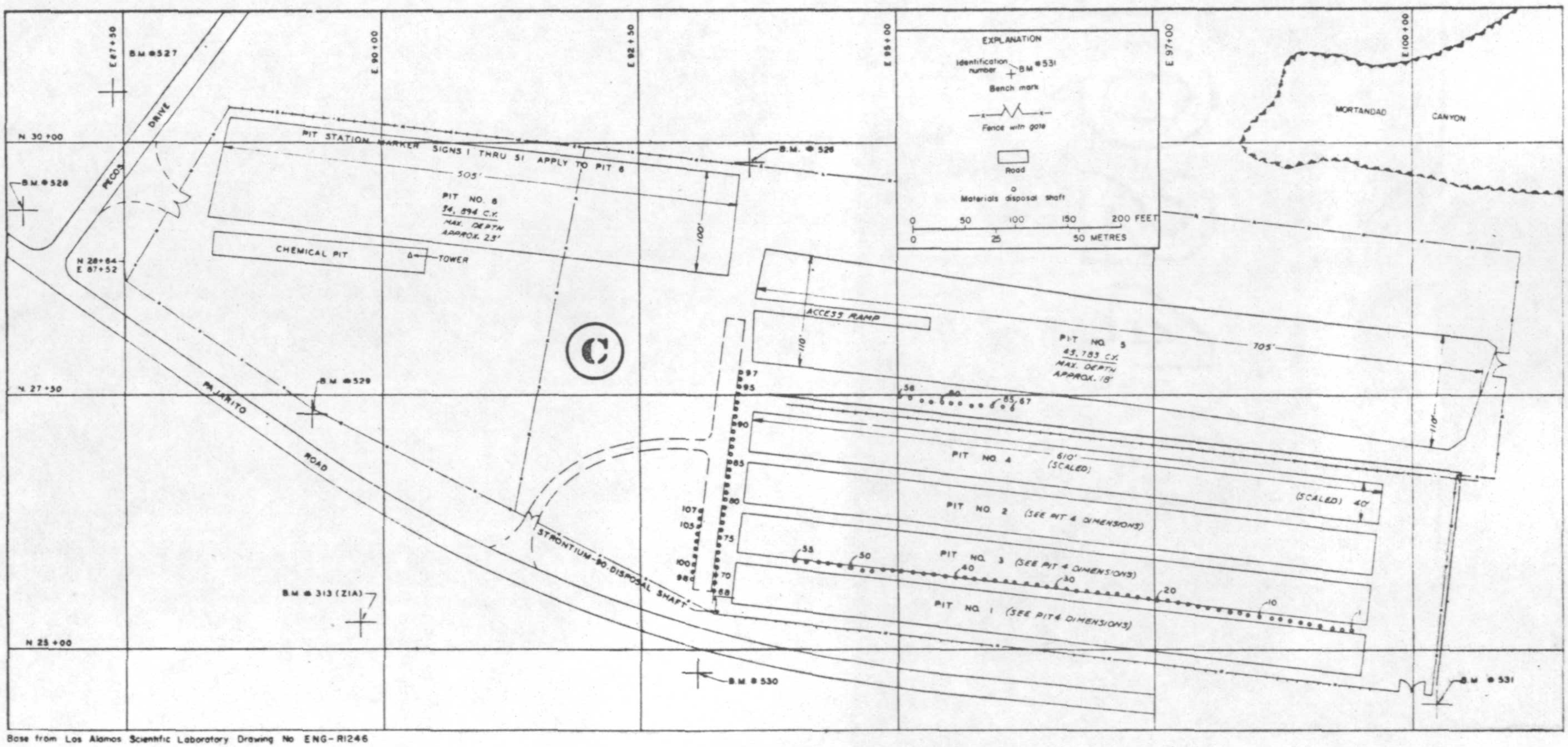


Figure 5.--Disposal Area C.

Disposal of high-activity waste (material contaminated to a greater degree than usual laboratory trash) in boreholes 2 to 3 ft (0.6 to 1 m) in diameter and as much as 25 ft (8 m) deep was first proposed in 1962. Subsequently 107 of these disposal wells or shafts ranging in depth from 10 to 25 ft (3 to 8 m) deep were bored and utilized in area C. Wastes were prepackaged in small containers and then lowered into the disposal shafts. When each shaft was full, the hole was capped with concrete. The contents of each shaft were recorded and the capped hole was then marked by a numbered stake. One hole was used exclusively for disposal of ^{90}Sr.

Nearly all the waste buried at Area C was in the solid state. The great bulk of the buried waste is laboratory trash, much of which is considered to be "suspect" rather than proven to contain contaminants. In many cases this material was packaged in corrugated paper cartons for convenience in transportation and burial. According to the records only a few drums of contaminated oil or other lubricants have been buried in this area; Fowler and others (1973, p. 5) state that these "are frequently mixed with a sorbing solid" such as vermiculite and buried as a solid. However it could also be assumed from this statement that some liquids have been buried at this site, presumably in steel drums.

After each pit had been filled to capacity with waste, it was backfilled to ground level with tuff. There has been subsequent settling of this fill so that some ponding of surface runoff is possible. Area C is within the confines of a small drainage area which would tend to channel runoff across the area rather than away from it; however, no attempt has been made to determine the amount of precipitation which has infiltrated these pits.

Some precipitation probably has infiltrated to the depth of burial, however no information is available to determine the effects of this soil moisture on the contaminated waste. The direction of movement and concentration of radionuclides in the ground water is unknown. Studies by Christenson and others (1958) provide some general information about the adsorption characteristics of the tuff, but detailed studies of samples from Area C are not available.

Previous monitoring activity

No continuing monitoring operations have been conducted within the confines of Area C to determine if radioactivity has migrated from the burial pits and its subsequent movement. In April 1971 a total of 12 test holes were drilled to depths ranging from 5 to 25 ft (1.5 to 8 m) prior to construction of a meteorological tower in the southwest quadrant of Area C. The results of the drilling are summarized in LASL office memorandum dated April 28, 1971 from W. D. Purtymun to V. J. Stephens, subject "Results of test drilling and penetration tests at Area C." Accordong to the memorandum, the cuttings were monitored and no radioactive contamination was detected. However the tower is topographically higher than the disposal sites, and it is unlikely that contaminants would have migrated a significant distance upgradient. A monitoring survey of the land surface by the Health Division near the tower site also failed to reveal any contamination.

The results of a study using honeybees (*Apis mellifera*) as an indicator of environmental radiocontamination are given in Hakonson (1973, p. 46-47). It was found that the honeybees from Mortandad Canyon contained tritium levels as much as 230 times the levels in effluent water readily available to the hive. Hakonson stated that "This is worrisome because there is very little evidence for the biological concentration of tritium. The alternative, that the bees were obtaining tritium from a source other than the effluent water, is also troublesome because such a source has not been located." Subsequently Schiager and Apt (1974, p. 28) postulated that the high level tritium source for the Mortandad Canyon bees was the white clover which is very abundant in Area C. Additional study of the honeybees is planned.

AREA D

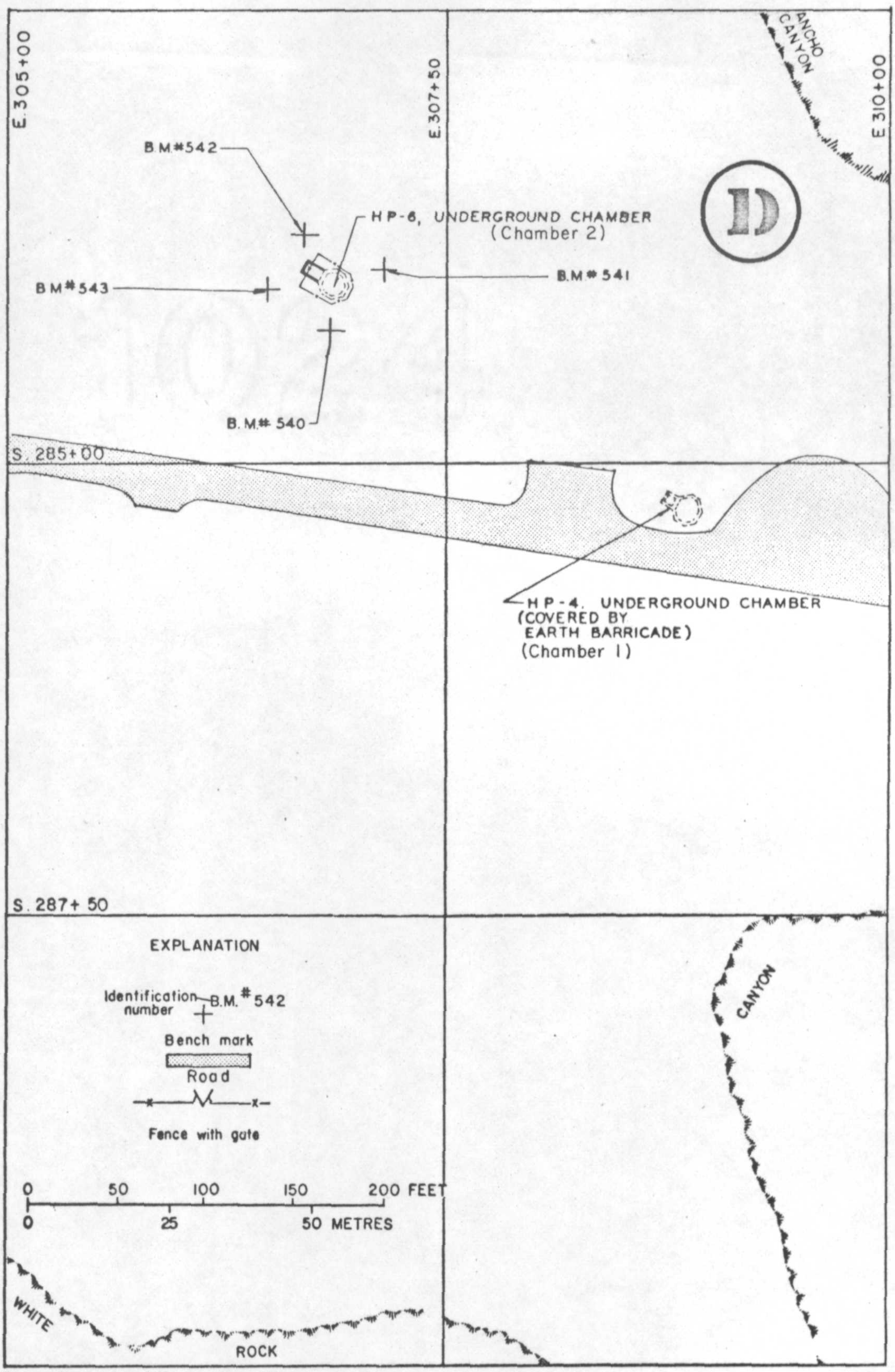
Area D (fig. 6) consists of two abandoned subsurface chambers located 1.8 mi (2.9 km) east of the security gate at TA-33. They are located in a bunker area on a topographic point of Pajarito Plateau overlooking Ancho and White Rock Canyons.

Chamber HP-4 was never used; HP-6 was contaminated by the detonation of chemical explosives containing radionuclide tracers. One LASL employee reported that polonium was the contaminant but the specific isotope was not identified; Abrahams (written commun., 1963) reported that the chamber contained ^{238}U.

A description of the original chamber was obtained from ENG-3, LASL: "Built on Contract HT (29-1)-Gen 481, Contractor R. E. McKee. Started 8/23/48. Completed 10/15/48. Lab Job 174. Reinforced concrete construction octagonal shaped, 18'-0" x 18'-0" x 16'-0" high with a metal door; 30'-0" below grade."

"Destroyed by experimental shot approx. Dec. 1948."

Chamber HP-6 was opened for inspection in 1952. During the 1952 inspection the chamber was found to be contaminated with polonium. A charge was detonated to close it, and the resultant small crater backfilled with tuff. A summary of the use of HP-6 was given in LASL memorandum dated 4-23-52 from Chas. D. Blackwell to D. D. Meyer, subject "Excavation and shot in Chamber #2 at 'Hot Point'."



Base from Los Alamos Scientific Laboratory
Drawing No. ENG-R3643

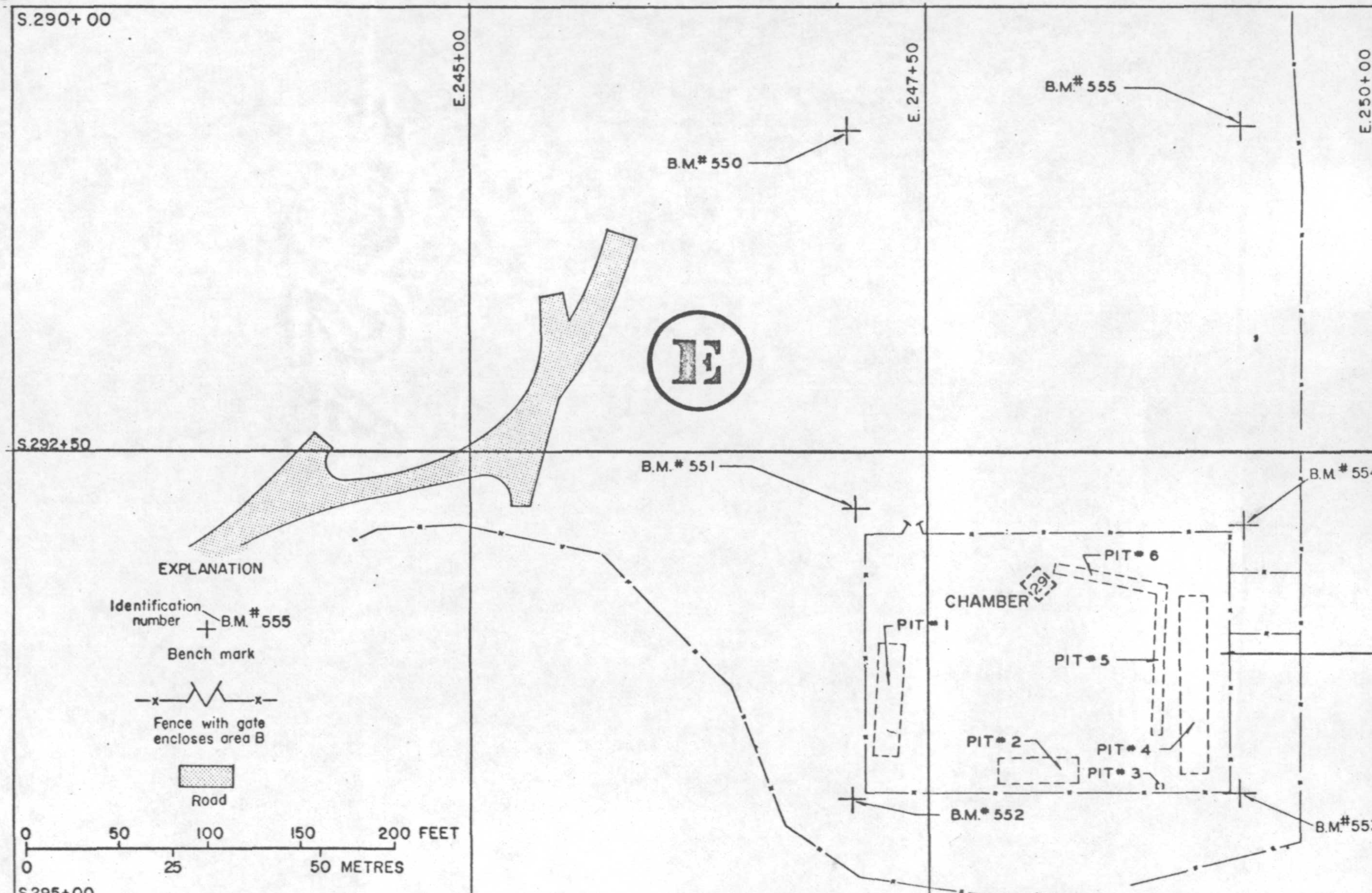
Figure 6.--Disposal Area D.

AREA E

This disposal area is located within TA-33 about 1.2 mi (1.9 km) south of the gate and guard post. The site is on an outcrop of the Tshirege Member of the Bandelier Tuff approximately 60 ft (18 m) north of the rim of Chaquehui Canyon.

Few data are available relating to the establishment and use of Area E for waste disposal. This area was established for disposal of waste that was generated in Technical Area 33 which is located on the periphery of Los Alamos and a considerable distance from the other burial sites (fig. 1). The waste generated at Area E was not the responsibility of the Health Division and no records of the waste were available during this study; and, as far as Group H-8 can determine, there are no records.

In 1961 LASL employee Harlow Russ described the area as having 4 pits, each about 6 ft (2 m) deep which were used from early 1949 through 1955 (Abrahams, written commun., 1963). He estimated that the pits contained a total of several hundred kilograms of ^{238}U. About 80 percent of the usable volume of the pits had been backfilled in 1961. The undated engineering drawing ENG-R3644 shows that six pits were excavated at the site, as well as one underground chamber identified as structure HP-29 (fig. 7). Pit 1 is shown to contain miscellaneous polonium beryllium fired targets. This pit reportedly contained 240 curies of radioactivity and was inactive in July 1951. Pit 2 reportedly contained 60 curies of ^{210}Po. This excavation was not used after July 1950. Pit 3 probably was a hand-dug hole in which a 5-gallon container was buried in September 1951. This can contained "Beryllium dust immersed in kerosene." Pit 4, listed as active on the drawing, was a miscellaneous "hot"-material dump. Depleted uranium and tungsten alloys of polonium may also have been buried in one or more of these pits. The contents of Pits 5 and 6 were not given; possibly they were never used.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-R-3644

Figure 7.--Disposal Area E.

No geologic investigation has been made at this site. A brief reconnaissance of the area indicated that although the Bandelier Tuff is weathered at the surface, the soil profile is thin or absent in the immediate vicinity of the disposal area. The absence of a well-developed soil profile is due to the topographic location which exposes the tuff to surface runoff from adjacent slopes and the strong wind currents from nearby White Rock Canyon. Joints in the tuff are numerous and well exposed at the surface. Basalt of Chino Mesa displays prominent columnar jointing in Chaquehui Canyon directly below Area E. Doe Springs, which has been periodically sampled (Purtymun and Kunkler, written commun., 1969), is located at the mouth of Chaquehui Canyon where it joins the Rio Grande approximately one mile east of Area E.

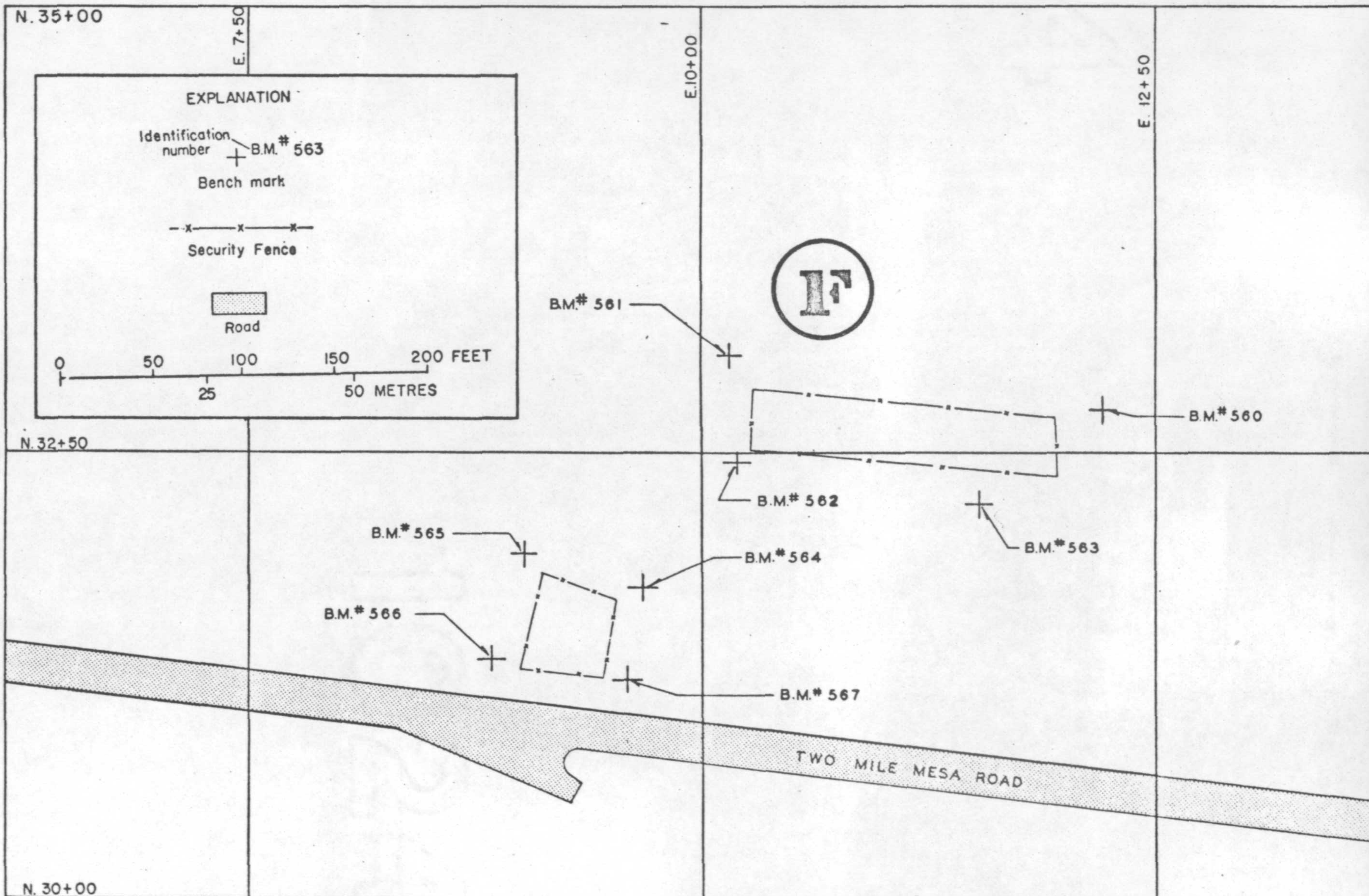
AREA F

This solid-waste burial site is located on the north side of Twomile Mesa Road about 1.3 mi (2.1 km) east of the security gate. Two areas appear to have been excavated (fig. 8), and both are evident on aerial photographs dated November 1, 1960.

Records of the type and amount of radioactive material that might have been buried in Area F are not available. D. D. Meyer (oral commun., 1973) believes that this area was set aside in 1946 for the one-time burial of wastes from TA-6, contaminated with ^{90}Sr and ^{137}Cs. The sources probably were electronic devices, possibly glass tubes.

In a memorandum dated May 15, 1946 to Division and Group Leaders, subject "Disposal pit at TD Site," N. E. Bradbury suggested that "An obsolete material pit for the disposal of classified objects and shapes had been prepared at TD Site (Area F) where such material will be made secure by burying. This pit will be open until 1 June. It is urged that divisions and groups 'clean house' of obsolete, non-usable, but classified material by the use of this pit."

Area F was found with considerable difficulty only after H. Hidy, ENG-1, provided information about benchmarks which were located near the disposal area. Several fence posts and a strand of barbed wire indicated that two separate areas originally had been enclosed by a single-strand barbed wire fence. A small area near Twomile Mesa Road was about 44 ft square (4 m^2); there was no indication of the excavations except that the soil profile had been disturbed and there was a sparsity of vegetation.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-R3645

Figure 8.--Disposal Area F.

In 1973-74 Margaret Anne Rogers, LASL, attempted to contact the different individuals who were associated with the burial of waste in this area. The investigation was largely unproductive owing to the lack of available records and the wide dispersal of these employees. Rogers (oral commun., 1974) concluded that if radioactively contaminated material is present at Area F, it makes up a very small percentage of the volume of various classified materials that were buried there. It is also possible that a small amount of conventional high explosives may have been buried at one of the sites at Area F.

According to informal documents in the files of ENG-3, a number of pits were dug on Twomile Mesa during the years 1949 through 1951. However the exact location of these pits was not given, and there were several active Technical Areas on Twomile Mesa. Therefore it is unclear whether any of these were excavated in Area F.

Area F is located on a rather level surface of the Pajarito Plateau where a sandy soil about 2 to 3 ft (0.6 to 1 m) thick has developed. The north boundary of the area slopes toward Twomile Canyon. Exposures of the Tshirege Member in this canyon indicated that the joint system is similar to that at Area C, however no detailed geologic evaluations have been made of this site.

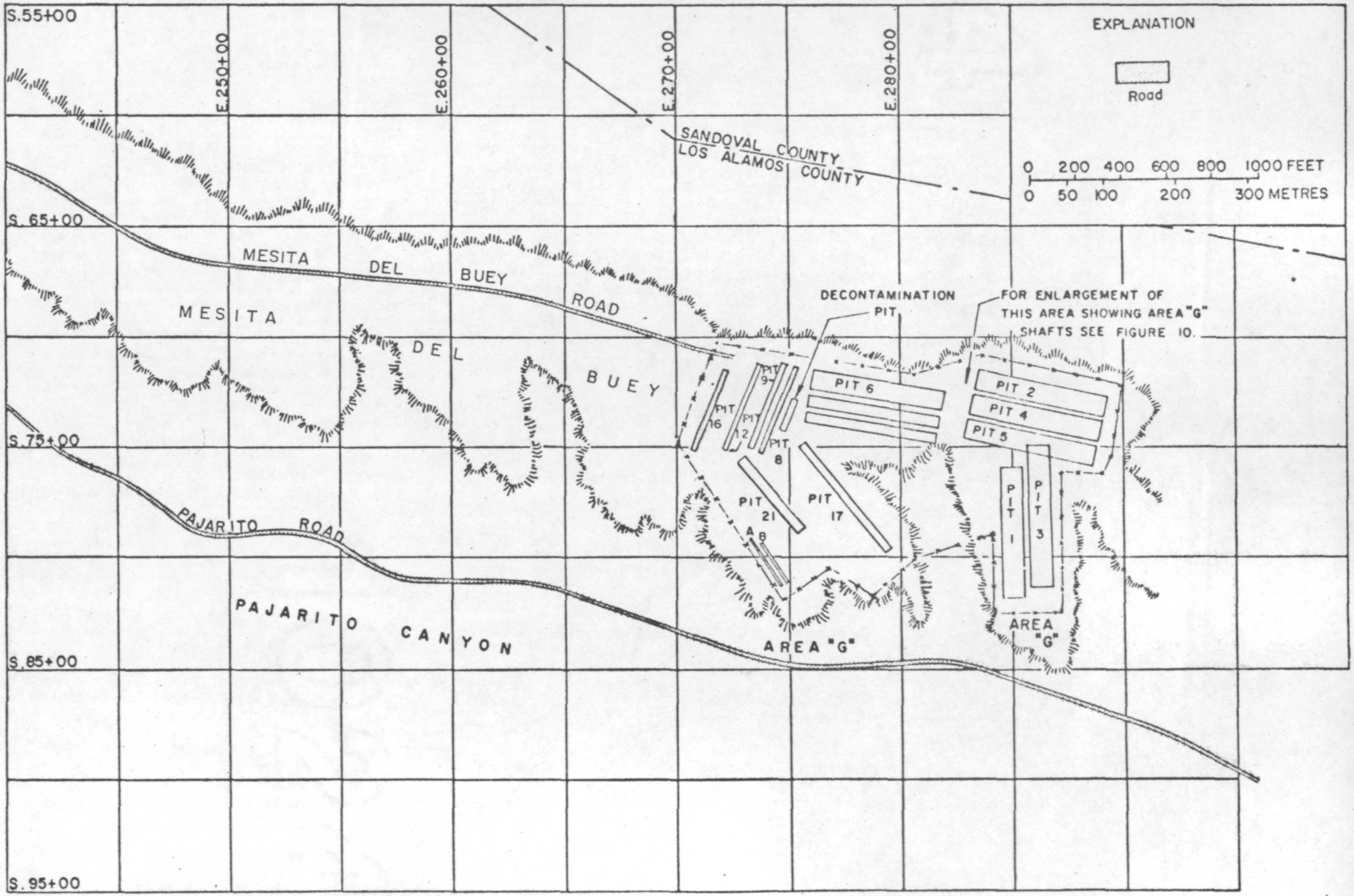
Approximately 120 ft (37 m) northeast of Area F was evidence of an elongate trench about 30 ft (9 m) wide and 300 ft (91 m) long. A spoil bank is located along the south edge. Nearly the entire length of this trench showed evidence of settling and a dense growth of grasses and other plants, including small pines, are growing in the shallow depression. There is evidence of considerable sheet erosion on the north side of this trench. There were no signs warning of radiation hazards or indicating that the area has been used for disposal of radioactive waste.

AREA G

History and conditions of burial

A part of Mesita del Buey was designated Area G (fig. 9) in 1956 after most of the available space in Area C had been utilized. The area was selected by LASL because it was relatively isolated from populated and Technical Areas, and it was sufficiently large to meet the anticipated disposal requirements for 10 or more years. As the result of a geological reconnaissance made on December 7, 1956, at the request of ERDA, the U.S. Geological Survey presented a general summary of the geology of the mesa and possible locations for disposal pits in a letter from C. S. Conover to Robert Dunning, ERDA, dated December 14, 1956. The U.S. Geological Survey investigated the possible use of Mesita del Buey as a burial site in a letter from F. C. Koopman, U.S. Geological Survey, to S. E. Russo, LASL, dated June 30, 1965. Subsequently all the disposal pits excavated at Area G have been examined by a geologist of the U.S. Geological Survey or of LASL.

The method of solid-waste disposal at Area G depends upon the physical state of the waste, amount of radioactivity in the waste product, and the type of radionuclide.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-R-4463

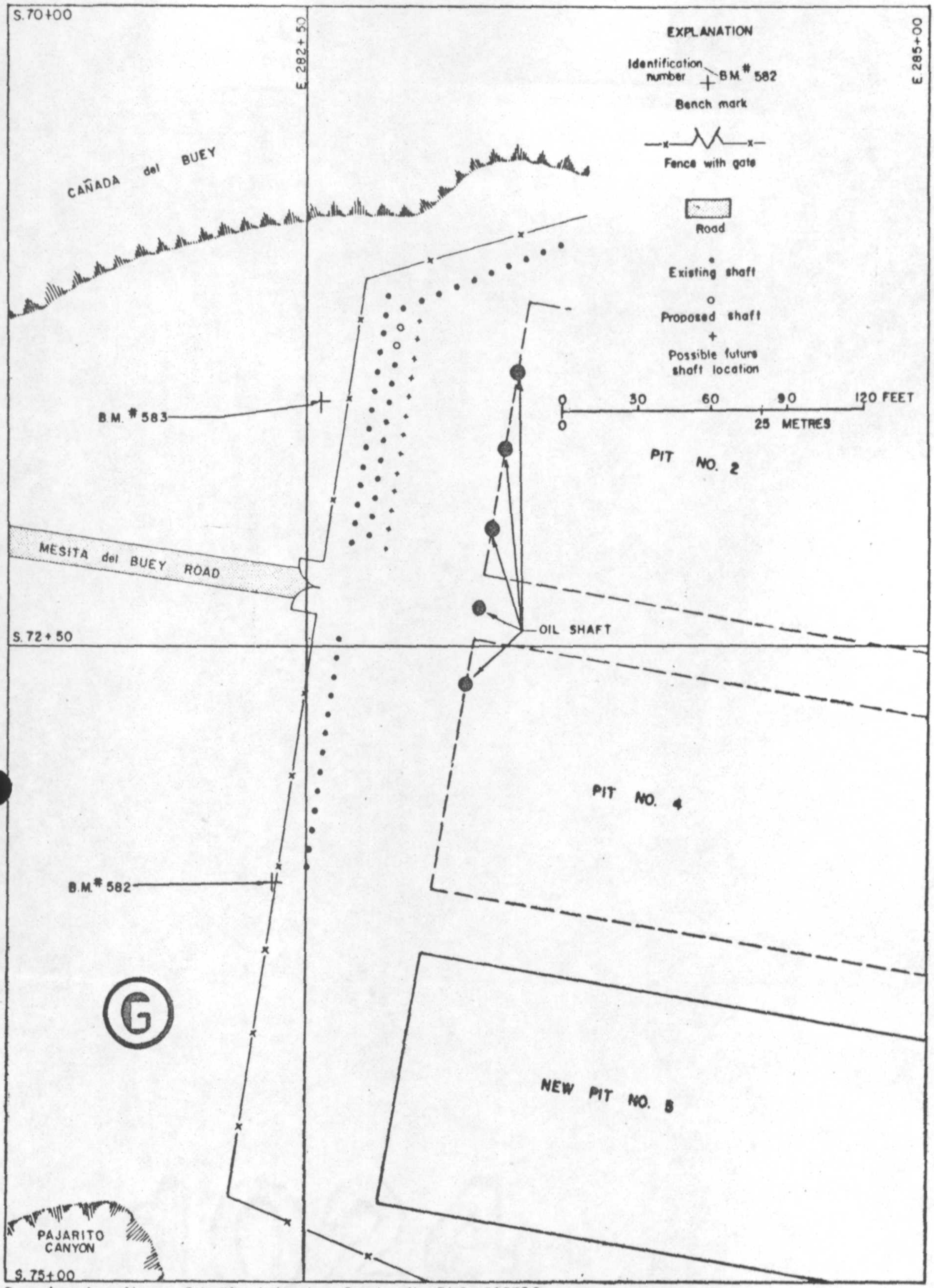
Figure 9.--Disposal Area G.

By early 1971, a total of 11 pits had been excavated in Area G. The solid waste was placed into whichever pit was then in use. However an ERDA Immediate Action Directive (IAD) AEC-IAD-0511-21, dated March 20, 1970, requires ERDA wastes contaminated with transuranic radionuclides (TRU wastes) be segregated and that wastes containing more than 10 nCi/g (nanocuries per gram) of transuranic nuclides must be packaged and stored. The method of segregation was outlined in an office memorandum dated April 26, 1971 from J. W. Enders to D. D. Meyer. Pit 8 was used for the storage of 55-gal (0.2 m^3) drums containing sludge from liquid-waste treatment plants. According to L. A. Emelity (oral commun., 1974) this dewatered sludge contains 60 to 70 percent water. In 1971 this waste was considered by the Health Division to be retrievable. Pit 17 was used for storage of plutonium contaminated boxed waste; Pit 12 is now used for disposal of crated plutonium-contaminated hardware. Subsequently two additional pits, 7 and 24, have been excavated for burial of low-level transuranic waste and low-level uranium waste; Pit 9 and trenches A and B are used for retrievable storage.

The volume of radioactive waste buried in Area G is approximately 8,000 yd^3 (7,200 m^3) annually. Although the records describing the solid waste generally do not provide data on the curie concentration of the waste, the radioisotopes and approximate weights are given. Data compiled by McCurdy and others (1974, p. 44) for Area G are given in table 1.

Approximately 80 disposal shafts have been drilled in Area G since 1967 (fig. 10). Most of these shafts are 2 or 3 ft (0.6 or 0.9 m) in diameter and between 20 and 25 ft (6 and 8 m) deep; some of these have been lined with concrete. Four bored shafts are 6 ft (2 m) in diameter and 60 ft (18 m) deep; these shafts were used primarily for the disposal of packaged tritium-contaminated wastes. In an office memorandum dated July 5, 1973 from J. W. Enders to J. E. Herceg, H-8, subject "Current disposal practices for T^2 (sic) contaminated material," it was estimated that from January 1967 through June 1973 the curie count of tritium buried at Area G was 69,963. This represented a volume of 513.5 ft^3 (15 m^3) of waste.

Mesita del Buey is an elongate mesa sloping gently toward the southeast and bordered by relatively deep canyons. The soil cover along the axis of the mesa is about 2 ft (6 m) thick. The soil thins toward the canyons where Tshirege tuff crops out. According to Purtymun (1966, p. 11), the Tshirege is about 95 ft (29 m) thick at Area G. Numerous ash flows comprise the Tshirege in this area, and in several pits a pumiceous zone marks the contact between separate tuff units. Also exposures of tuff on the canyon walls bordering the mesa indicate that each ash flow has different weathering characteristics. These weathering phenomena probably are due to degree of welding and amount of pumiceous material within each ash flow.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-C25700

Figure 10.--Disposal Shaft field, Area G.

Three major joint systems were mapped at Area G and the joint frequency averaged about 1 joint per 7-ft (2.1 m) length of pit exposure (Purtymun, 1966, p. 13). However in exposures of tuff in Pajarito Canyon which borders the area, the joint frequency appears to be much greater. Thus it is possible that the unweathered tuff exposed in disposal pits may be considerably more jointed than is evident in the pits.

In November 1973, Jacques Renault of the New Mexico Bureau of Mines and Mineral Resources examined disposal Pits 7 and 24 which has recently been excavated. A summary of his findings was given in a letter to M. A. Rogers, H-8, dated December 3, 1973. Renault reported, "Field relationships, microscopic observations, and X-ray mineralogy demonstrated that the fracture fillings exposed on the walls of disposal Pits 7 and 24 are due to alteration of the Bandelier Tuff by meteoric water. There are three zones of alteration: (1) an upper zone of caliche filled fractures, (2) an intermediate zone of fractures filled with mixed caliche and montmorillonite, and (3) a lower zone of montmorillonite filled fractures. In recent times water has been stationary in some of the open fractures that indicate (1) water can gain access to the fractures, and (2) some of the fractures are plugged at depth. Porosity of the caliche filled fractures appears to be less than that of the monmorillonite filled fractures."

The Tshirege Member of the Bandelier Tuff is underlain by volcanic deposits of the Otowi Member and the Guaje Pumice Bed; these two lower units have a combined thickness of about 160 ft (49 m). At Area G the Bandelier overlies the Puye Formation and, at a depth of about 300 ft (91 m), basaltic rocks of the Chino Mesa. Although perched water is present locally, the principal water-bearing deposits are located at a depth of about 900 ft (274 m) below Area G.

Previous monitoring activity

Miscellaneous studies have been conducted at Area G whenever there was evidence to indicate that radioactivity had been released. On two different occasions fires have started in waste stored in disposal pits at Area G. Following each fire the area was monitored to determine the extent of airborne contaminants. Water samples were collected from Pit 8 after runoff from heavy rains accumulated in this pit. The analyses of these samples were not completed as this report was written. Several holes recently were augered in the bottom of Pit 8 for future use in determining whether radioactive contaminants will migrate downward through the disturbed tuff into the bottom of the pit.

A hole that was augered into the top of Pit 1 produced cuttings containing 297,000 pc/ml (picocuries per millilitre) tritium. This pit was covered in about 1960. Records show that little or no tritium was buried in this pit.

During the course of installing additional disposal shafts at Area G in 1970, a number of samples were found to contain high levels of tritium. Subsequently a drilling program was initiated to define the limits of the tritium-contaminated "plume." Purtymun (1973) showed that the contaminants had migrated about 105 ft (32 m) to the west in a period of 5 years and the vertical movement may have been considerably more. The areal extent of the plume was not traced to its limits, but it seems likely that the contaminants would have reached the outcrops of tuff along the walls of Cañada del Buey on the north.

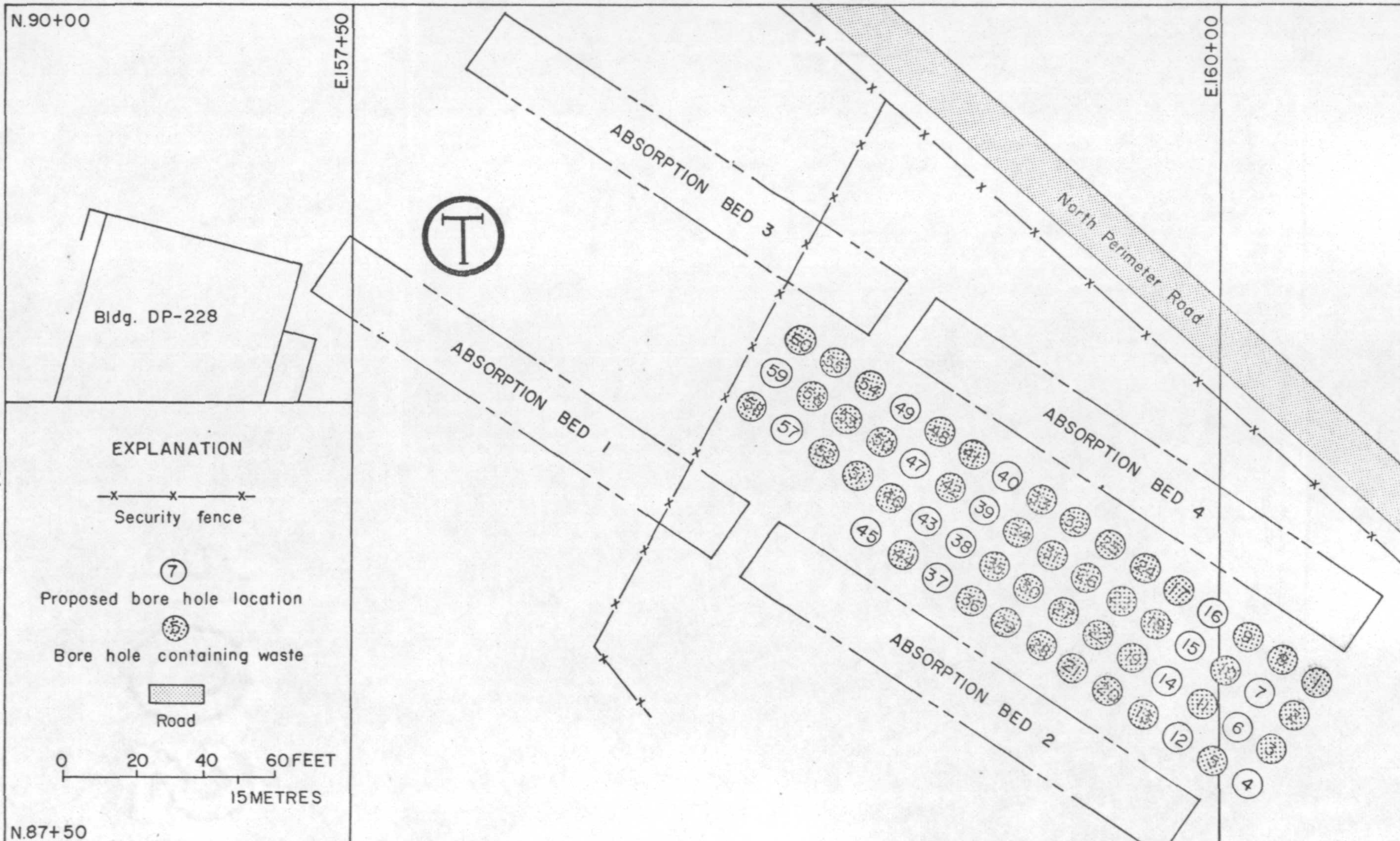
The Los Alamos Scientific Laboratory has never had a specific geologically-oriented solid-waste site monitoring program. Since July 1, 1973 a number of special studies have been initiated by the Waste Management Section of Group H-8 with the objective of providing better assurance of isolation of solid waste from the human environment.

AREA T

History and conditions of burial

This disposal area (fig. 11), which is within TA-21, is located on the west side of Area A near the east end of DP Road. It is the oldest active disposal area at Los Alamos.

Initially Area T was established to dispose of liquid waste, and it was used for this purpose from 1945 until about the middle of 1952. Four pits were excavated about 120 ft (37 m) long, 20 ft (61 m) wide, and about 6 ft (2 m) deep. The pits were filled with about 4 ft (1.2 m) of sand, gravel and boulders, and a berm was constructed around each pit.



Base from Los Alamos Scientific Laboratory Drawing No. ENG-R-4475

Figure 11.--Disposal Area T.

LASL has proposed that a routine environmental monitoring program be established around all waste burial or storage areas. This will include the following actions: Obtain data on general dust loadings of the atmosphere resulting from waste-burial operations. Migration and dispersion of moisture through filled pits and the surrounding tuff will be evaluated. This will include installation of access tubes for measurement of soil-moisture profiles and the collection for radiochemical analysis of moisture and cutting samples from each test hole in a burial pit. Access tubes were constructed at pits 7, 8, and 24 by March 1974. The moisture balance at or near the surface of filled disposal pits will be studied. Vegetation on the filled pits will be sampled to determine whether or not any of the contaminants have migrated to the surface and are being absorbed by plant tissues.

LASL has also proposed that a major effort be made to determine the soil properties and activity concentrations directly under and around each waste-disposal pit.

Effluents were released through a distribution system into Pits 1 and 2, and through overflow pipes into Pits 3 and 4. The amount of waste released into the pits from 1945 to 1952 has been estimated to range from 2 to 3 million gal (7,560 to 11,340 m^3) per year. The concentration of plutonium in the effluents during this period has been estimated at 60 counts per minute per millilitre; the average fluoride concentration, which was derived from hydrofluoric acid, was about 160 mg/l (Christenson and Thomas, 1962, p. 258). In addition, 10,450 gal (39 m^3) of effluent highly concentrated with ammonium citrate, an efficient complexing agent, was released into the pits from June 1951 to July 1952. The plutonium concentration of this waste averaged about 7,000 counts per minute per millimetre and the fluoride concentrations were about 200 mg/l. The pits were not used from 1952 through 1964. However between January 1965 and 1967, Pits 1 and 2 received an average of 74.3 thousand gal (280.8 m^3) per month of low-level radioactive effluent from treatment facility DP-East.

A new method of waste disposal was initiated in May 1968. Radioactive sludge was mixed with a cement slurry in a pub-mill operation and pumped into a series of holes that were bored within the unused part of Area T. Each hole was 8 ft (2.4 m) in diameter and bored to a depth of about 60 ft (18 m) whenever possible. However due to zone of reworked boulders which made augering difficult, a number of these holes could not be drilled to the 60-ft (18-m) depth. The holes were bored on 12-ft (4 m) centers (fig. 10). These holes were bored by employees of the Zia Co. under the supervision of the Health Division of LASL.

In an office memorandum dated August 20, 1969 from C. W. Christenson to D. D. Meyer, subject "Status of waste disposal to pits at Building-257," the disposal operation was described as follows: "Various wastes such as the neutralized americium, 'strip,' alkaline fluoride, and plant sludge are being mixed with cement in a pug-mill operation and the slurry is being pumped to deep holes on the site. This procedure was started on May 1, 1968."

The gross alpha activity of the feed is monitored and reported as equivalent ^{239}Pu. However this includes activity due to ^{239}Pu, ^{238}Pu, ^{241}Am, ^{235}U and "probably other alpha emitters."

"The wastes contain some mixed fission products, mostly strontium and cesium....

"The bathyspheres are usually placed three to a layer and are located at various depths in the pits." These bathyspheres are containers of very high-activity waste that are placed in one of the active boreholes and then covered with 'cold' (nonradioactive) concrete. Each borehole is filled to within 2 ft (0.6 m) of the top, then capped with cold concrete.

Thirty-three boreholes have been utilized since this method of disposal began; the maximum depth of a hole was 67 ft (20 m) and the minimum depth was 15 ft (5 m). Slightly more than 3,000 yd^3 (2,280 m^3) of concrete-sludge mixture has been buried to the present (1974).

The disposal area is situated on the flank of a mesa capped by the Tshirege; there is a moderate slope on the land surface across the disposal area toward nearby DP Canyon. Two lithologic units of the Tshirege can be distinguished in this area. The upper unit is a light brownish gray, moderately welded tuff which is broken by numerous joints. Most of the joints are vertical or near vertical. The lower unit is a light gray tuff that is not as densely welded as the overlying unit; jointing is less common in the lower unit. These two units are separated locally by a zone of reworked tuff including cobbles and boulders of latite and some pumice. The reworked tuff has an average thickness of about 10 ft (3 m); the top of the zone ranges from 10 to 20 ft (3 to 6 m) below land surface.

Boreholes constructed since about 1970 have been examined by a geologist of the Health Division who was lowered into each completed hole on a boatswain's chair suspended from the augering rig. Lithologies, structures, and other geologic feathres were noted and samples were collected from the walls of the hole for geologic and radiochemical analysis.

On September 18, 1973 the author examined Hole 55 in this manner. It was noted that the walls of the hole were coated with pulverized tuff during the boring process making examination of in situ wall rock difficult. However, numerous joints were obvious throughout the total depth of 66 ft (20 m) although none of the joints were continuous from surface to total depth. At a depth of about 20 ft (6 m), a brecciated zone was apparent which contained loose fragments as much as 6 in (150 mm) in diameter. When several of these fragments were dislodged, a sizable void developed. This vertically oriented brecciated zone may have resulted from augering action near the intersection of two joints. It was not related to the reworked tuff zone noted in some of the holes.

Roots were found in joints at depths of more than 15 ft (5 m). According to Purtymun (oral commun., 1973), after the visual examination of each borehole, the interior is coated with asphalt. Cement slurry containing radionuclides is then pumped into the hole. After each operation, the pumping system is flushed with water into another borehole. The wash water is allowed to evaporate or infiltrate, and this borehole is later used for sludge disposal.

Previous monitoring activity

Several attempts have been made to determine the extent of contamination outside the actual disposal sites in Area T. In 1961 a caisson 30 ft (9 m) deep was constructed near Pit 1 and horizontal holes were cored beneath the pit. Christenson and Thomas (1962) concluded from the study that plutonium had penetrated to a depth of at least 28 ft (8 m) in the tuff beneath the pits; this penetration at depth takes place mainly along joints. In a 1967 study, Purtymun concluded that although most plutonium is retained by adsorption in the upper 20 ft (6 m) of the tuff, some may move to greater depths through open joints. He calculated that during the period August 1961 through January 1967 there was vertical penetration by liquid waste of about 28 ft (9 m) near Pit 1.

Attempts to drill holes adjacent to the slurry-filled disposal holes have not been very successful (Purtymun, oral commun., 1974).

Periodically samples are collected from the concrete produced by the pug-mill operation. Various tests are conducted to determine different physical characteristics including leaching. No published data are available which describe the findings of these studies.

CONCLUSIONS

The methodology for burial of radioactive solid waste now used by Los Alamos Scientific Laboratory has gradually evolved in response to various Federal, State, and internal demands for safety. These demands have greatly increased in recent years. In general, the level of activity in waste has been closely monitored prior to burial, however little emphasis has been placed on post-burial monitoring. Consequently a conclusion of this investigation is that currently (1975) there are insufficient data available to design an effective monitoring program.

In order for buried waste to become a contaminant, the radionuclides in the waste must become capable of migrating into the biosphere. This would occur when one or more of the following conditions are met.

1. The waste must be either soluble or suspendable in water.

2. There must be an adequate source of water entering the burial trenches so that the waste will be in contact with water.

3. The geologic media must be sufficiently permeable to allow water to move away from the burial site.

Any effective monitoring program would need to evaluate flow patterns and rates of nuclide transport.

As used in this report, the term "monitoring" refers to a continuing program of study and sampling that would ultimately define the rate, direction, and concentration of radionuclide migration. In order for a monitoring program to be completely effective, it needs to be based on well-defined geologic and hydrologic parameters. At Los Alamos these parameters have not been adequately defined. Therefore, the general discussion below considers possible studies that would provide information that could be used to more accurately define geologic or hydrologic parameters and outlines preliminary steps in a monitoring program as defined above.

Test holes could be drilled to the main aquifer at each disposal area for obtaining detailed lithologic and geophysical logs. All drilling would need to be conducted with extreme caution, using air wherever possible, to minimize the problem of sample cross-contamination. Each hole would need to be planned to obtain the maximum amount of hydrogeologic information. The holes would help delineate zones of perched water and variations in lithology. Any observed perched water zones could be further delineated by additional drilling. All holes could, be drilled and completed so that they can be used as monitoring wells.

Additional drilling, based upon data obtained from the above, could be designed to more accurately define the depth and configuration of the potentiometric surface beneath the Pajarito Plateau. Special emphasis could be placed on exploration along the western margin of the Plateau in the vicinity of the Pajarito fault zone, and in possible areas of recharge.

Variations in lithology of the Bandelier Tuff are believed to be important factors in infiltration and runoff of precipitation. Therefore, detailed geologic maps of each disposal site would be useful in predicting the most likely zone along which radionuclides might travel in the subsurface. The geologic mapping would need to include the depth, thickness, and variations in the caliche zone. Inasmuch as the strontium ion is frequently found in association with calcium, the principal cation of caliche, a detailed study of the caliche might provide information relating to the migration and deposition of strontium waste.

The ion-exchange capacities for rock samples from each burial site could be determined using those radionuclides that have been buried at the respective sites. These studies also could include an evaluation of the "source materials"--the types of fluids in which the radionuclides are entrained. Large scale measurements could be made either in field tests or large-batch laboratory tests because conventional laboratory ion-exchange capacity measurements do not necessarily relate well to field-scale problems.

A study could be made to determine the feasibility of constructing horizontal or angle holes beneath selected waste-disposal pits. Cuttings or cores from these holes would be retained for radioactive by-products examination. Repeated radioactive surveys might then be made in such holes if provision could be made for tracking the sonde along the axis of the hole.

A field air-permeability test could be considered in order to obtain regional formational permeability values. The location of test wells for such a test as well as the instrumentation needs of such studies would require very good control on the geohydrology of the area to obtain meaningful results.

Although none of the above would independently provide adequate information for establishing a monitoring system, it would be possible to design a reasonably adequate monitoring program when all of the types of data indicated are available. However, a fail-safe monitoring program would be impossible to design until the microhydrologic environment of each disposal area is known in detail.

Currently (1975) Los Alamos Scientific Laboratory is collecting and analyzing a large number of samples from various springs, test holes, and municipal wells. This program needs to be continued. Also, those springs and wells that would provide additional data on the radiochemistry of water in perched aquifers near the disposal areas could be added to the monitoring program. The sampling methods and frequency need to be reviewed and modified as additional data become available.

Attempts could be made to obtain soil moisture measurements from the bottom of the disposal pits. Soil moisture profiles could be run at frequent enough intervals, perhaps monthly, until the seasonal fluctuations can be predicted with reasonable accuracy. The soil moisture could be sampled and analyzed for radionuclides.

In those areas where the quantity and physical nature of the waste are questionable or unknown, site excavations and exhumation studies could be made. It may be discovered that some sites need little or no monitoring or that some sites are of critical concern and need some immediate and intensive attention.

Those types of deep-rooted vegetation, such as white clover, that are growing in the disposal areas and making the contaminants more available to the biosphere need to be eradicated. Vegetation which has established itself on some of the burial sites could be sampled on a regular basis in order to determine which radionuclides, if any, are being released to the biosphere through plant uptake.

An evaporation station could be incorporated with the already extensive climatological station now in use at Los Alamos. Although evaporation is considered to be a major factor in water loss from precipitation on the Pajarito Plateau, there are no evaporation data available at present (1975) to substantiate this.

A berm could be constructed around the upslope side of each disposal pit. This would reduce surface runoff into the pits such as was noted during the summer of 1973.

In addition to the above, certain specific steps need to be taken to provide remedial action or input that would make a monitoring program more effective at a particular burial site.

The contents of the "General's Tanks" at Area A could be sampled and analyzed. The tanks themselves could be checked for physical condition and corrosion. Even if it is found that the tanks contain fluid at the present time, it is still possible that some leakage could have occurred. Therefore, it is important that monitoring installations be constructed regardless of the present condition of the tank contents.

Several test holes could be augered near the perimeter of the tanks. Samples could be collected at 5-ft (1.5 m) intervals or less for a minimum depth of 50 ft (15 m). The samples could be analyzed for plutonium, nitrates, ammonia, or pH, any one of which would give an indication of leakage from the tanks. If it is determined that leakage has occurred, additional drilling could be conducted in order to define the rate and distance of movement. Monitoring could continue as long as the contaminants continue to move.

Considering the lack of information available relative to the amount and type of waste that has been buried in the disposal pits of Area A, site excavations and exhumation studies need to be made. In addition, it would be advisable to auger several test holes around the area. Samples could be analyzed for both plutonium and polonium. Inasmuch as liquid contaminants have been emptied into DP Canyon which borders Area A on the north, the auger holes should not exceed 75 ft (23 m) in depth so that the contaminants from the two sources would not be confused.

Certain steps need to be taken in order to better evaluate the present condition of Area B with respect to potential migration of activity. Test holes could be augered around the perimeter of the area to a depth of approximately 100 ft (30 m) and samples collected at 5-ft (1.5 m) intervals. These could be analyzed for various radio-muclides that may have been buried at this site. Data from both the paved and unpaved portions of the disposal pit would serve as a valid comparison for the effectiveness of a relatively impermeable cover on a disposal pit. Furthermore, these data could be used in conjunction with those collected by Purtymun and Kennedy (1966) in order to determine the amount and rate of migration that has occurred within a specified length of time.

Because the hydrologic characteristics of the Bandelier Tuff are poorly known, it is difficult to determine sampling methods that would be reliable indicators of the transport of radionuclides away from Area C. Hopefully the horizontal drilling program and evaluation of the tuff permeability would provide information which would be useful in establishing a monitoring program at Area C. Should these type studies prove unsuccessful, a vertical augering program could be implemented around the perimeter of the area, especially on the north and east boundaries.

In addition to these exploratory drill holes, a series of moisture-access tubes to facilitate neutron logging would provide data pertaining to the movement of soil moisture near the disposal pits. Ideally these would be constructed at different depths and at different distances from the pits. The location and depth of these holes would be dependent upon the information obtained from exploratory drilling. Also, access tubes could be installed beneath the pits if possible. Continued monitoring of these holes would provide data on seasonal fluctuations in soil moisture.

Studies of ion-exchange capacities of the tuff could be made of samples collected from Area C; those isotopes most commonly buried at this site could be used in the studies.

An effort needs to be made to determine the nature of the radionuclides in the chamber utilized at Area D and this information be made a matter of record. Also, at least one test hole could be augered near the chamber. Sufficient samples could be collected and analyzed to ascertain whether or not radionuclides have migrated away from the point of detonation and to determine the areal extent of the contamination.

The lack of a soil profile and the topographic location of Area E are both conducive to invasion of the disposal pits by precipation and runoff. Furthermore, the close proximity of Chaquehui Canyon provides a ready discharge point for ground water. An effort could be made to ascertain the amount of radioactive waste that was buried at Area E, the quantity of activity involved, and the isotopes. Site excavation and exhumation would be helpful. Several auger holes could be drilled near the area and rock samples could be analyzed to determine whether they have been contaminated by radionuclides.

Seemingly no records are available describing the type of waste that was buried at Area F, however, it might be possible to determine this by contacting various persons that were active at TA-6 at the time this burial site was in use. Considering the small amount of waste that apparently was buried at Area F, it might be possible to excavate the waste and transport it to another active burial site. This has been done previously at several other sites at Los Alamos.

If the type of contaminant and location cannot be identified, a number of test holes could be augered along the flanks of the pits. Samples could be analyzed for beta-gamma emitters. If contaminants are found, additional drilling could be done to define the depth and areal extent of contamination.

An extensive augering program could be undertaken to define the limits of tritium migration from the disposal-shaft field in Area G. The "plume" of tritium could be traced to its fullest extent and monitoring could continue indefinitely.

The long history of liquid waste disposal near Area T probably would preclude differentiation of the liquid and solid waste contaminants. Therefore, the horizontal drilling and air-permeability tests mentioned earlier, would need to be concluded prior to establishment of a monitoring program at Area T.

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