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Informal Report

Geohydrology of the Pajarito Plateau with Reference to Quality of Water, 1949-1972

by

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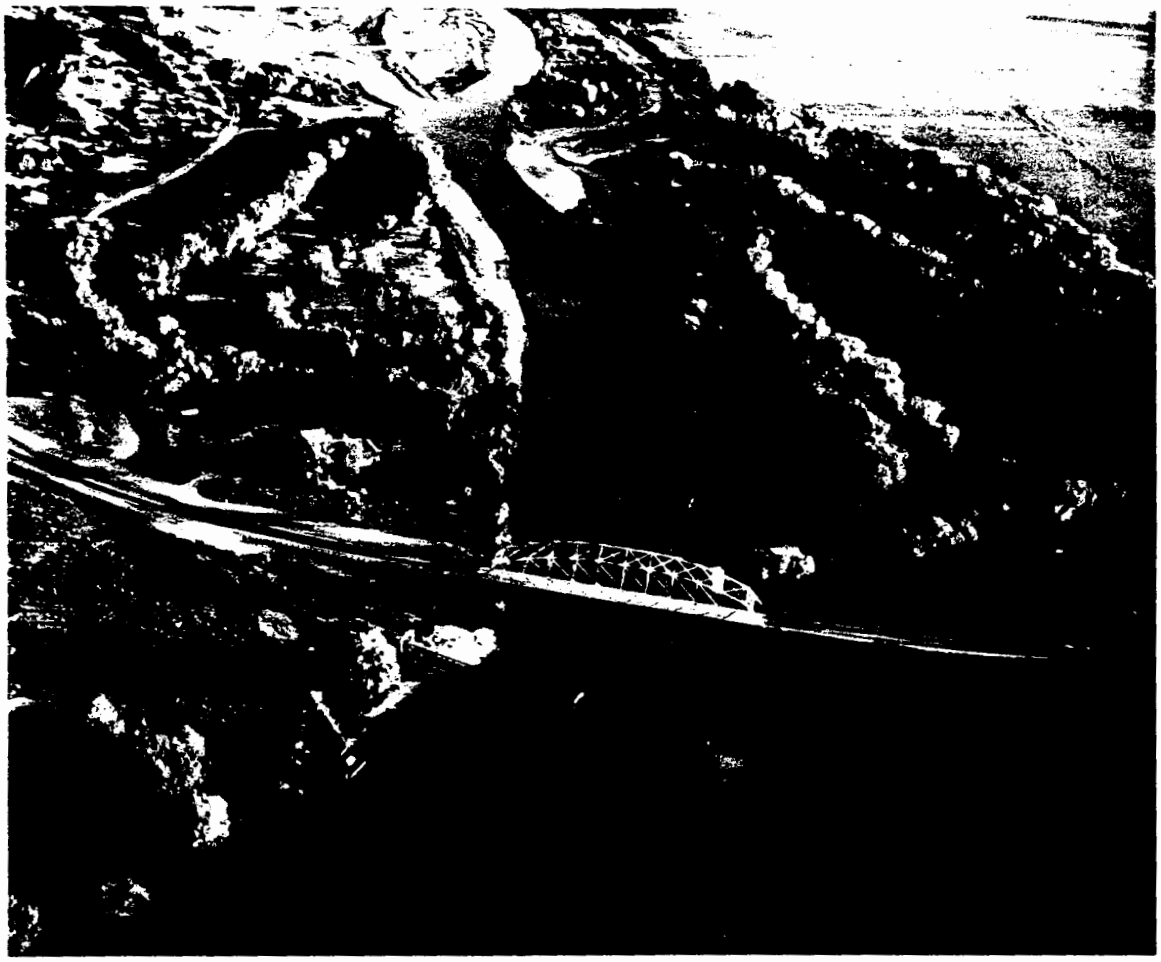

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ABSTRACT

The facilities of Los Alamos Scientific Laboratory are located on the Pajarito Plateau in North-Central New Mexico. The plateau is formed by ashfall and ashflow units of the Bandelier Tuff. The tuff is underlain by volcanic debris of the Puye Formation which in places interfingers with the Basaltic Rocks of Chino Mesa. The Puye Formation is underlain by sediments of the Tesuque Formation.

Southeastward intermittent streams that drain into the Rio Grande have cut deep canyons into the Bandelier Tuff. The intermittent runoff in the canyons occur from storm runoff and the release of treated sewage or industrial effluents. The effluents do not reach the Rio Grande as surface flow.

There are two major ground water systems in the canyons. A near surface ground water system occurs in the larger canyon in the alluvium which is underlain by the tuff. This system is recharged by the intermittent storm runoff or release of effluents. A deep ground water system, the main aquifer, occurs in the lower part of the volcanic debris and sediments of Puye and Tesuque Formation.

The movement of water from the recharge area in the Valles Caldera and canyons cut into the flanks of the mountains and western part of the plateau eastward toward the Rio Grande, where a part is discharged into the river.

There are sixteen drainage areas on the plateau that encompass the Laboratory Reservation. Hydrogeologic data have been collected in twelve of these areas. The remaining four areas are small with no well defined drainage, thus, have not warranted study.

Treated sewage effluents are released into Drainage Area 4 (Acid-Pueblo Canyon), 5 (DP-Los Alamos Canyon), 6 (Sandia Canyon), 10 (Pajarito Canyon) and 11 (Water Canyon). Pueblo Canyon receives the largest volume of effluents from the two community sewage treatment plants. The volume released into the remaining drainage areas are small. The chemical quality of the sewage effluents released into the canyons have dominated the chemical quality of the water in the stream and shallow ground water aquifer in the alluvium of the canyons.

Two drainage areas, 5 (Los Alamos Canyon) and 7 (Mortandad Canyon) are currently receiving effluents from treatment plants that operate to reduce radionuclide concentrations. Drainage Area 6 (Sandia Canyon) receives some effluents as the result of blow-down from the power plant at TA-3. Drainage Area 11 (Water Canyon) receives some water from industrial process at nearby technical areas. These canyons also receive sewage effluent as previously mentioned.

The chemical quality of water in the streams or shallow aquifers in the alluvium of these canyons reflect the chemical quality of the type of effluent released, such as sewage or industrial effluents. The base flow in these canyons are from the release of effluents. In general, the chemical quality of the water improves downgradient from the effluent outfall as the chemical ions in the effluent adjust to the environment.

Drainage Area 4 (Acid-Pueblo Canyon) received industrial effluents containing radionuclides until 1964. Drainage Area 5 (DP-Los Alamos Canyons) received this type of effluents from 1952 to present, and Drainage Area 7 (Mortandad Canyon) also received this type of effluents from 1963 to present.

Residual radionuclides remain in the Acid Pueblo Canyon drainage although the release of effluents ceased in 1964. The radionuclide concentration decreased downgradient in the canyon from the old effluent outfall. The radioactive materials are attached to the alluvial materials in the stream channel. They, in part, are resuspended in water in the stream.

Radionuclides in solution in the stream and shallow aquifer in alluvium and attached to alluvial material are found in DP-Los Alamos Canyon. The concentrations generally decrease down stream from the outfall in DP Canyon and below the junction of DP with Los Alamos Canyon. The radionuclides have an affinity for the alluvial material in the channels of both canyons. There is no high build up of radionuclide near the effluent outfalls. Storm runoff during the summer, transports and disperses the alluvial material and attached radionuclides down the canyon to the Rio Grande.

Radionuclides in solution in the stream and shallow aquifer in the alluvial material are found in Mortandad Canyon. The concentrations also

decrease downgradient from the effluent outfall. Although the radionuclides are dispersed by storm runoff down the canyon, there has been no transport off the Laboratory Reservation. This is due to the small drainage area that results in low volumes of storm runoff and thick sections of unsaturated alluvium that has been able to adsorp all runoff since hydrologic observations began in 1960.

The chemical quality of water from perched aquifers in the Puye Formation and Basaltic Rocks of Chino Mesa in Pueblo Canyon indicate recharge from the stream in Pueblo Canyon. There is no indication of contamination of these perched aquifers by radionuclides released from the treatment plant at TA-45 from 1943 to 1964.

The chemical quality of water from eight test wells completed into the main aquifer have shown no change during the period of study. The quality of water reflects no contamination by sewage or industrial effluents. Radionuclides occuring in the waters are natural and do not indicate any contamination from the release of industrial effluents on the plateau.

I. INTRODUCTION

The Community of Los Alamos and the Laboratories of the Los Alamos Scientific Laboratory are located on the Pajarito Plateau in north-central New Mexico. The community and the Laboratory have grown from a few hundred people in 1943 to over 16,000 with about 4,000 employed in the Laboratory.

Geologic and hydrologic studies began in 1947 to evaluate the water resources of the area and to study the problems associated with the treatment and release of industrial and sewage effluents into canyon disposal areas. The purpose of this report is to evaluate the impact of the Laboratory on the surface and shallow ground water aquifers in the alluvium in canyon drainage areas and to provide compilation of basic data for future reference. The study covers drainage areas that form discharge points from ERDA-LASL controlled property.

The study includes geologic and hydrologic conditions in the drainage areas including channel geology, occurrence and movement of surface and ground water, chemical and radiochemical quality of water, radiochemical analyses of sediments, transport of sediments in storm runoff (in canyons where data is available), particle-size distribution of sediments, and flood-frequency and maximum discharge in the drainage area. The study also includes basic data collected in the surveillance monitoring program, 1949-1972, special studies, and in part develops new data necessary for completion of the study.

A. Geography

The Pajarito Plateau forms an apron 8 to 16 km wide and 32 to 40 km long around the eastern flanks of the Sierra de los Valles

(Fig. 1). The surface of the plateau slopes gently eastward from an altitude of about 2290 m along the flanks of the mountains to about 1430 m along the eastern edge where it terminates along the Puye Escarpment and White Rock Canyon. The plateau is drained by southeast and eastward trending streams that have cut deep canyons into the surface of the plateau.

The Rio Grande lies to the east of the plateau. It drops from an altitude of about 1680 m at Otowi (mouth of Los Alamos Canyon) to about 1630 m at the junction with Frijoles Canyon. North of Otowi the Rio Grande lies in a broad valley, while to the south it is confined in a deep narrow canyon (White Rock Canyon).

The mountain peaks of the Sierra de Los Valles rise to an altitude of about 3,525 m near the head of Santa Clara Canyon and to an altitude of 3110 m near the head of Frijoles Canyon. The crest of the north-south trending range of peaks and ridges forms a surface water divide. Streams originating on the eastern slopes and Pajarito Plateau flow directly into the Rio Grande. Streams on the western sloped follow a more circuitous course and enter the Rio Grande 48 km to the south.

The climate and vegetation change westward from the Rio Grande to the crest of the Sierra de Los Valles along with the change in altitude. The average precipitation increases from about 23 cm along the Rio Grande to as much as 76 cm along the crest of the mountains. The average precipitation on the plateau is about 46 cm. About 70 percent of this amount occurs in July and August during summer thunder showers.

The average July temperatures at the lower altitude is about 23° C and on the plateau is about 19° C while average January

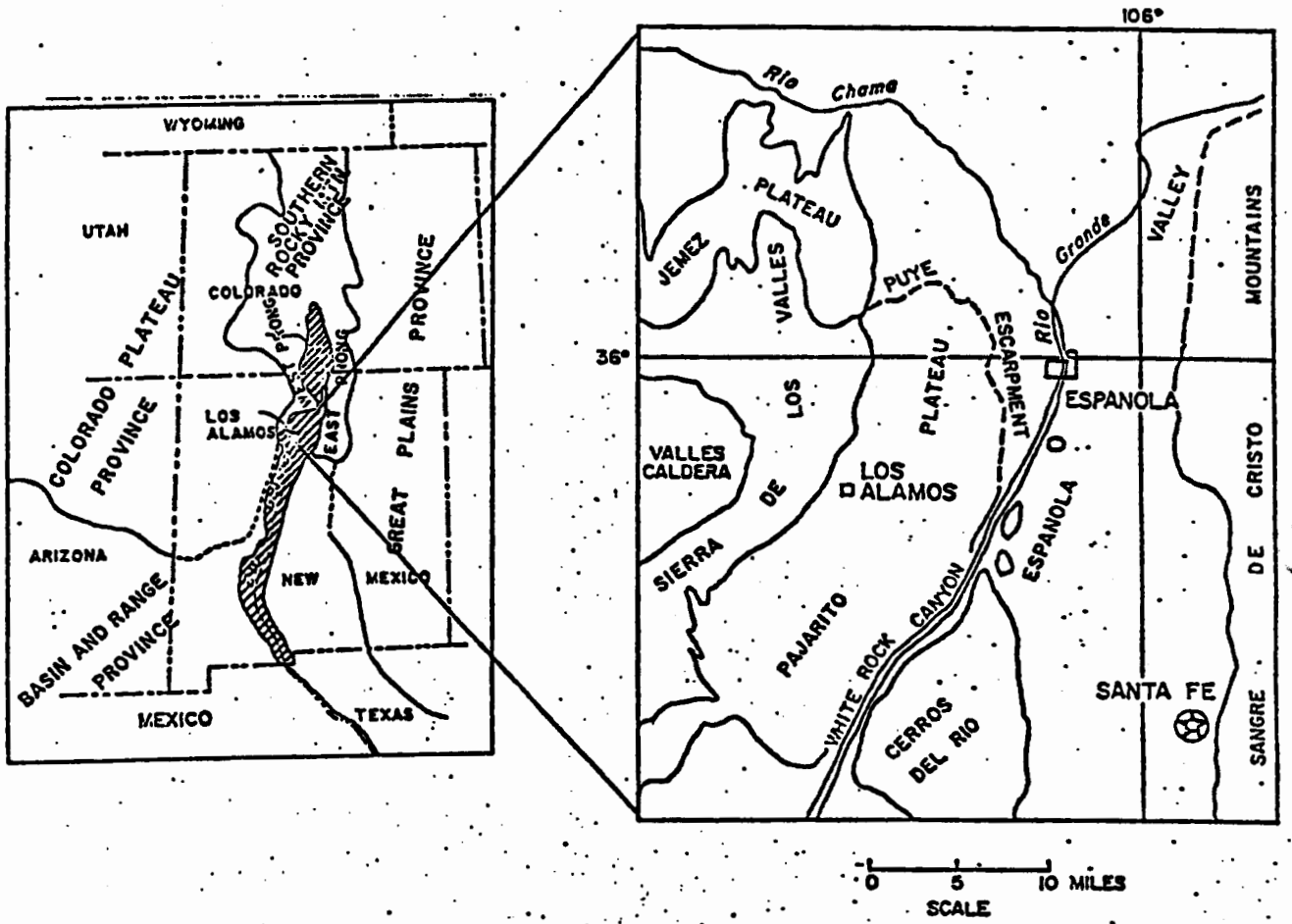


Fig. 1. Physiographic features in North-Central New Mexico.

temperature at the valley is -6° C and on the plateau -7° C. At higher altitudes on the mountain crests, temperatures are lower so that snow on the peaks lasts until late May or early June.

Cottonwoods, willows, and box elders are found along the Rio Grande and in the lower part of the canyons cut into the plateau. The eastern two-thirds of the plateau is covered with piñon and cedar while the western third and lower flanks of the mountains are covered with pine. Spruce, fir, and aspen intermingle with the pine on the upper slopes of the mountains. Alpine meadows are found on some of the south facing slopes of the higher peaks.

The upper surface of the plateau is sparsely covered with gamma grass while a variety of grasses occur in the canyon floors. The banks of the perennial streams are stabilized with this growth of grass.

B. Geology

Drainage areas or streams that head on the flanks of the mountains are cut into the rocks of the Tschicoma Formation. Canyons on the Pajarito Plateau are cut into and are underlain by the Bandelier Tuff. Along the eastern edge of the pleateau, the channel is cut through the Puye Formation into the Tesuque which floors the valley north of Otowi and forms the lower canyon walls along the Rio Grande in White Rock Canyon. The basaltic rocks of Chino Mesa are in places interbedded in the sediments of the Puye Formation.

The rock units described, from oldest to youngest, are the Tesuque Formation, Puye Formation and basaltic rock of Chino Mesa of the Santa Fe Group; the Tschicoma Formation and Bandelier Tuff of the volcanic rocks of the Jemez Mountains, and alluvium and soil of recent age. The generalized stratigraphic relations are

shown on Fig. 2.

A detailed discussion of the geology of the area is presented by Griggs[1] and Bailey et al.[2]

1. Santa Fe Group

The Santa Fe Group in ascending order, consists of the Tesuque Formation, the Puye Formation, and basaltic rocks of Chino Mesa.

The Tesuque Formation is a sequence of light-colored sediments laid down as coalescing alluvial-fan and flood-plain deposits in the Rio Grande depression. These sedimentary rocks were derived from highlands to the north, and possibly in part from the Sangre de Cristo Mountains to the east. The separate beds are composed of friable to moderately well-cemented, light-pink-grey to light-brown siltstone and sandstone that contain lenses of conglomerate and clay. Bedding generally is poorly developed except locally in fine-grained material.

The Puye Formation consists of two members. The lower member is a poorly consolidated, channel-fill deposit. A fanglomerate overlies the lower member and is composed of volcanic debris.

The lower member of the Puye Formation overlies the Tesuque Formation along the Rio Grande and in Los Alamos and Guaje Canyons. It is grey, poorly consolidated conglomerate consisting of fragments of quartzite, schist, gneiss, and granite ranging in size from sand to boulders; well-sorted lenses of silt and sand are present sporadically. The materials making up the conglomerate were derived principally from igneous and metamorphic rocks to the north and northeast. They were deposited on a broad flood plain and in channels of the ancestral Rio Grande. A zone near

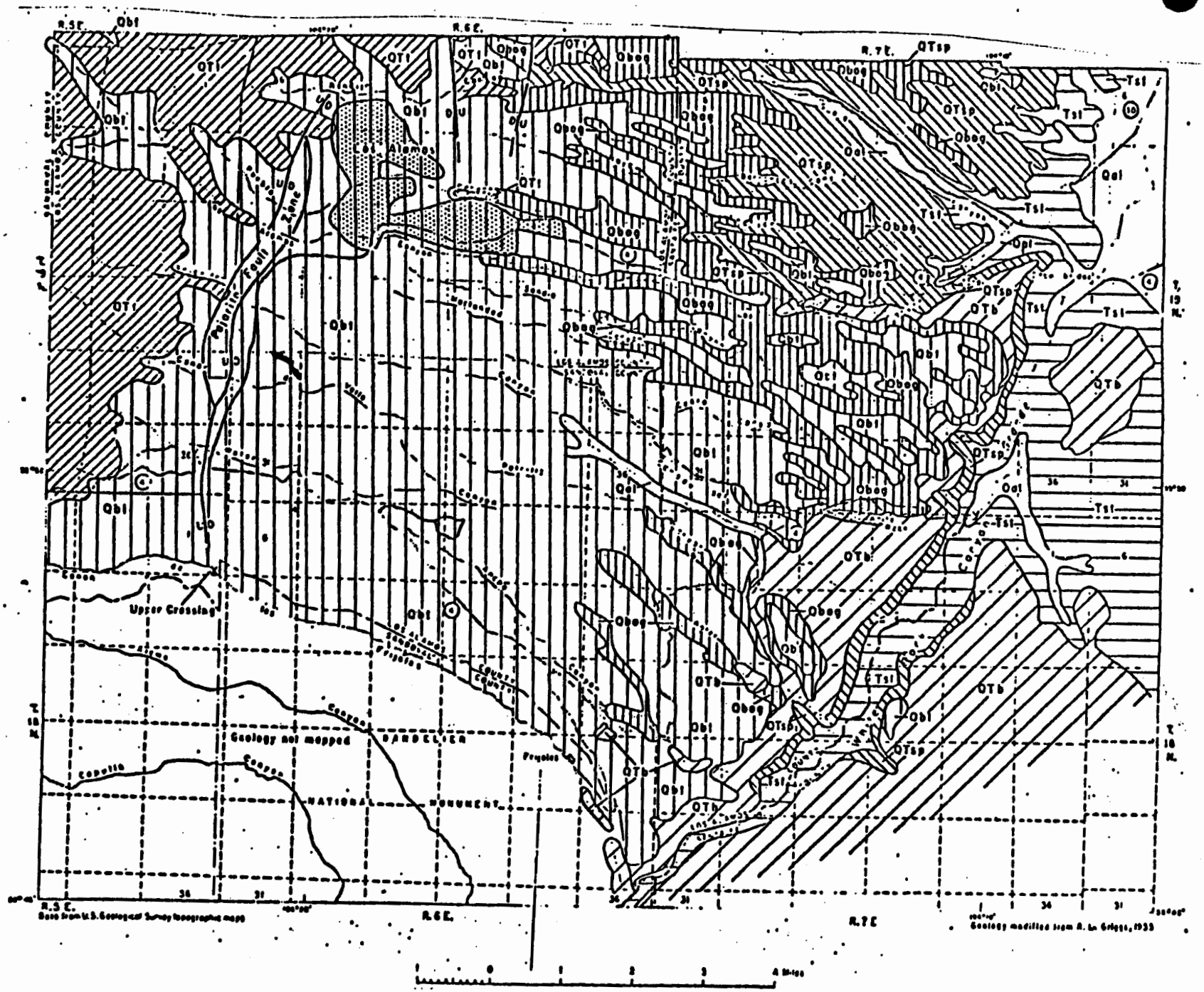


Fig. 2. Geologic map of the Pajarito Plateau

SIERRA DE LOS VALLES - PAJARITO PLATEAU

PAJARITO PLATEAU - RIO GRANDE AREA

Recent

Qal

Alluvium

Gravel, sand, and silt in the Rio Grande valley and eastern parts of canyons of the Pajarito Plateau. Yields small quantities of water to wells and springs during wet weather.

Volcanic rocks of the Jemez Mountains

Bandelier Tuff (Pleistocene)

Qbt

Tshirege Member

Mainly welded rhyolite tuff. Yields small quantities of water to a few springs along the flank of the Sierra de los Valles.

Qbog

Otowi and Guaje Members, undifferentiated

Otowi Member, pumiceous rhyolite tuff. May yield small quantities of water to springs from perched zones in the upper part of Guaje Canyon. Guaje Member, lapilli tuff composed of lump pumice, unconsolidated. May contain small quantities of perched water.

QUATERNARY

Volcanic rocks of the Jemez Mountains

Pliocene and Pleistocene(?)

QTt

Tschicoma Formation

Undifferentiated thick flows of latite and quartz latite with large feldspar phenocrysts. Yields small quantities of water to springs and wells from weathered zones and interflow breccias.

Santa Fe Group (Middle(?) Miocene to Pleistocene(?))

QTsp

Puye Conglomerate, undifferentiated

Conglomerate member at top consists of interbedded silt, sand, and pebble-to-boulder conglomerate derived from the Tschicoma Formation. Contains small quantities of perched water locally. Totavi Lentil at base is composed of stream-channel deposits of silty, sandy conglomerate. Yields small quantities of water to springs and wells.

Tst

Tesuque Formation

Slightly consolidated arkosic sand, silt, and some interbedded conglomerates, gravel and lithic volcanic detritus with interbedded basalt flow exposed in White Rock Canyon. Unit yields moderate quantities of water to wells and is the main aquifer of the area.

Santa Fe Group (Late Pliocene(?) and Pleistocene)

QTb

Basaltic rock of Chino Mesa, undifferentiated

Basalt flows and interbedded sediments along White Rock Canyon. Thin flows and breccias south of Los Alamos Canyon with steep sided basalts and breccias in the canyon near the confluence with Pueblo Canyon, cinder cones and local basalts on the Pajarito Plateau between Ancho and Frijoles Canyons. Yields water to springs in Los Alamos Canyon and may yield small quantities of water locally along White Rock Canyon.

TERTIARY(?) AND QUATERNARY

SYMBOLS USED ON MAP

Contact of geologic formation

Fault

Dashed where inferred.
U, upthrown side;
D, downthrown side.

Area of municipality

Fig 2A. Geologic and Hydrologic description of rock units.

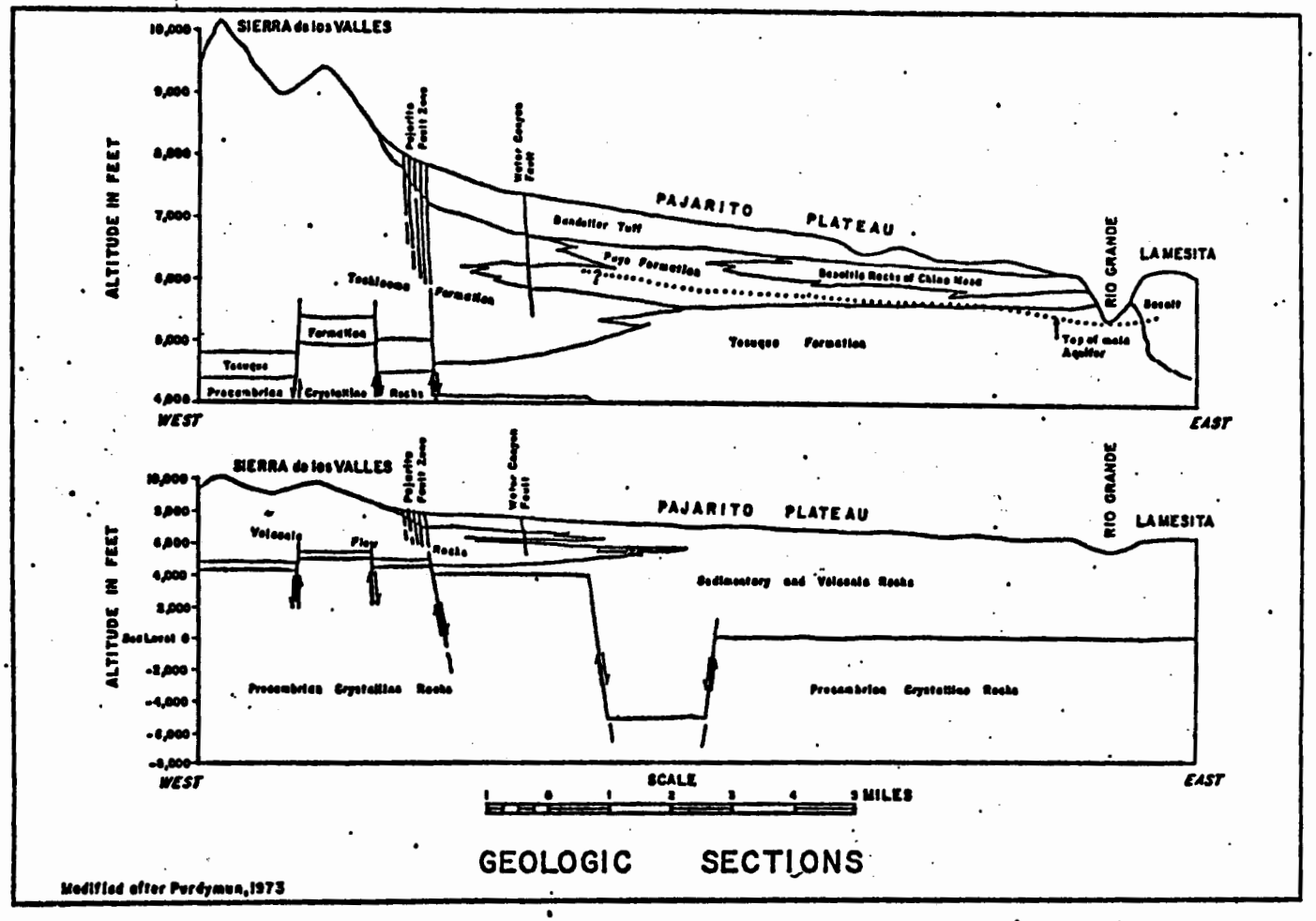


Fig. 2B Geologic sections showing stratigraphic units and basement Precambrian rocks beneath the Pajarito Plateau.

the top is composed of a mixture of pegmatitic rocks and volcanic debris. This mixed zone represents a change in source of sediments from igneous and metamorphic terrane to the north to the igneous and volcanic terrane to the west.

The upper member of the Puye Formation is a fanglomerate composed of pebbles, cobbles, and boulders of rhyolite, latite, quartz latite, and pumice in a grey matrix of silt and sand. These rocks were derived from flows associated with the volcanic rocks of the Jemez Mountains. Sorting is poor, but tongues and lenses of fairly well-sorted pumiceous siltstone and water-lain pumice are present within the fanglomerate. The degree of cementation varies from friable to well-cemented. In upper Guaje and Los Alamos Canyons, the fanglomerate member consists of angular boulders; eastward it grades to silt, sand, gravels, and rounded boulders.

The basaltic rocks of Chino Mesa originated from volcanic vents on the Cerros del Rio to the southeast of the Los Alamos area. The basalts cap the mesas of Cerros del Rio and form the steep walls of White Rock Canyon. The basalts flowed north and northwest into the Los Alamos area interfingering with the Puye Formation.

The basalts consist of five units which range in color from grey to black. They contain varying amounts of olivine, pyroxene, and plagioclase feldspar and range from fine-grained to glassy. Individual flows vary in thickness from a few feet to over 50 feet. Sediments may be found between the individual flows.

The basalts outcrop in the lower parts of the major canyons that drain the Pajarito Plateau from Otowi to Frijoles Canyon in

White Rock Canyon.

2. Volcanic rocks of the Jemez Mountains

Volcanic rocks of the Jemez Mountains along the eastern flanks of the Sierra de los Valles and on the Pajarito Plateau consist of the Tschicoma Formation and the younger Bandelier Tuff.

The Tschicoma Formation is composed of undifferentiated latite and quartz latite flows and pyroclastic rocks that are highly fractured and jointed; some intervals contain weathered zones and interflow breccia. These rocks form the core and flanks of the Sierra de los Valles.

The Bandelier Tuff is composed chiefly of ashfall and ashflow tuff and some thin, water-lain sediments. The formation has been divided into three members: Guaje, Otowi, and Tshirege, from the oldest to the youngest. The Bandelier Tuff forms the upper part of the Pajarito Plateau. Physical characteristics of the tuff are presented as Appendix A.

The Guaje Member of the Bandelier Tuff is an ashfall pumice and water-laid pumiceous tuff that rests unconformably on older rocks. The base of the unit contains grey lump-pumice fragments as much as 2 inches in length. Glass shards and crystals of quartz and sanidine are present in the cellular structure of partly devitrified pumice. Rounded pebble-size fragments of light-red rhyolite are present near the top.

The Otowi Member of the Bandelier Tuff is a light-grey, non-welded, pumiceous rhyolite tuff that weathers to a gently slope; it is conformable with the underlying Guaje. Quartz crystals, glass shards, minor amounts of mafic minerals, and varying amounts of rhyolite, latite, and pumice fragments included in a fine-grained

ash compose the tuff. Most of the rock fragments are rounded. The Otowi consists of ashflows primarily but it contains several beds of silt and water-laid pumice near the top.

The Tshirege Member of the Bandelier Tuff, is composed of a series of ashflows of rhyolite tuff that contains at least one thin, water-laid bed near the top. The Tshirege unconformably overlies the Otowi and forms the caprock of the fingerlike mesas of the Pajarito Plateau. The rhyolite tuffs range from nonwelded to welded. The thin, water-laid bed is composed of material derived from the underlying tuff.

3. Alluvium and soil

Alluvium from the Sierra de los Valles and the Pajarito Plateau has been deposited in the canyons of the plateau. Near the heads of the canyons bedrock commonly is exposed in the lower parts; but further down the canyons alluvium may be several hundred feet wide and as much as 80 feet thick.

Alluvial deposits in the canyons heading on the flanks of the Sierra de los Valles contain cobbles and boulders with accompanying clay, silt, sand, and gravel derived from the Tschicoma Formation and Bandelier Tuff. Deposits in the canyons heading on the Pajarito Plateau contain clay, silt, sand, and gravel derived from the Bandelier Tuff.

Clayey soil derived from weathering of the Bandelier Tuff covers most of the fingerlike mesas of the Pajarito Plateau.

4. Structure

The Rio Grande depression is a structurally low area that constitutes the valley through which the Rio Grande flows.[3] The Pajarito Plateau is part of the depression although it forms a

topographic high area along the western margin of the valley.

The most prominent structural features of the Pajarito Plateau is the Pajarito fault zone which trends northward along the western edge of the plateau. It is a part of the complex fault system that formed the Rio Grande depression. The fault zone consists of normal faults that are downthrown to the east and displace rocks of the Bandelier Tuff, Puye Formation, and Tschicoma Formation (Fig. 2). The displacement, estimated from the fault scarp west of S-Site, is from 120 to 150 m. The amount of displacement decreases northward where, at a point north of Los Alamos, all visible traces of the fault disappear (Fig. 3). The movement along the fault zone has been in small increments which began prior to the deposition of the Bandelier Tuff and continued into post-Bandelier time. The displacement of the older rocks is greater than the displacement of the younger rocks. The major fault in this zone extends into and displaces the Precambrian rocks.

North of Los Alamos and east of the Pajarito fault zone, two normal faults (Fig. 3) cut the Bandelier Tuff, the Puye Formation, and the Tschicoma Formation. These faults, downthrown to the west, form a graben between them and the Pajarito fault zone. They are a part of the fault system which formed the Rio Grande depression.

Beneath the central part of the Pajarito Plateau a north-trending depositional basin is formed in the Tesuque Formation. The basin is filled with volcanic debris of the Puye Formation, overlain by the Bandelier Tuff. The eastern edge of the basin is formed by thick flows of basalt from Chino Mesa, 3 to 6 km west of the Rio Grande.

A gravity survey indicated that the deepest part of the

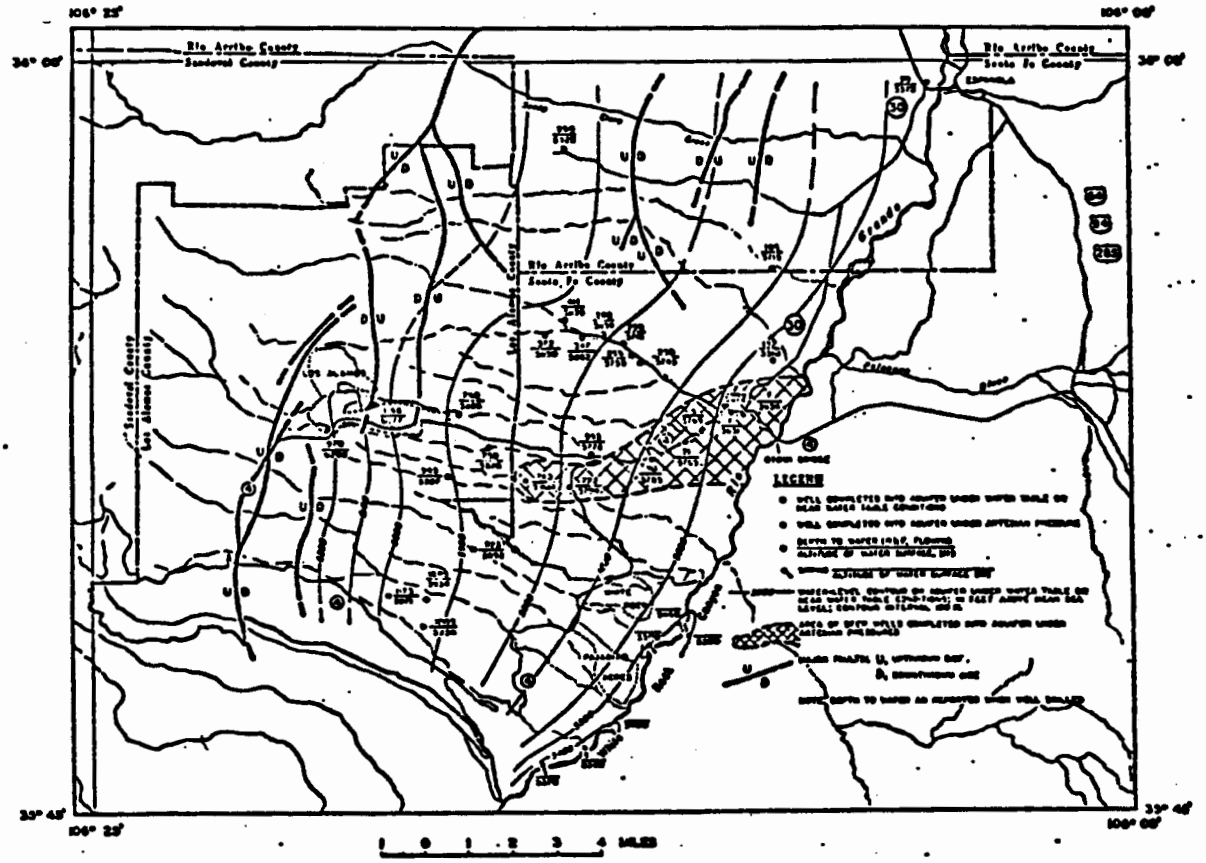


Fig. 3. Major faults and contours on the top of the main aquifer of the Los Alamos area.

Rio Grande depression (top of the Precambrian rocks) is in a north-trending trough near the center of the plateau. The bottom of this sediment-filled trough lies about 1,500 m below sea level (Fig. 2).

C. Hydrology

The master stream of north-central New Mexico, the Rio Grande flows southeastward along the eastern edge of the Pajarito Plateau and ultimately receives all runoff from the eastern flanks of the Sierra de los Valles and Pajarito Plateau. Rito de los Frijoles and Santa Clara Creek to the south and north of the drainage areas studied are the only perennial streams that discharge into the Rio Grande. Intermittent streams that cross the plateau flow into the Rio Grande only during periods of excess precipitation.

Surface flow in the intermittent streams is from either effluents released from industrial waste treatment plants and sewage treatment plants of from precipitation recharge of small aquifers in the alluvium along the canyon bottoms.

A perched water body occurs in the Puye Formation and basaltic rocks of Chino Mesa in lower Pueblo, Los Alamos, and Sandia Canyon. The main aquifer (aquifer capable of water supply) lies at a depth of about 370 m along the western edge of the plateau and at a depth of about 180 m along the eastern edge.

The Bandelier Tuff is above the main zone of saturation and does not contain any known bodies of perched water in the Los Alamos area. Hydrologic characteristics of the tuff are presented in Appendix B.

1. Surface Water

Records from the gauging station at Otowi on the Rio Grande

indicate that for 71 years of record the average discharge is about 43 m^3/sec. The drainage area above Otowi is about 14,300 sq. miles in southern Colorado and northern New Mexico. The maximum discharge of 691 m^3/sec occurred on May 2, 1920 and is the greatest since at least 1884 and probably since 1741. The minimum discharge of 1.7 m^3/sec occurred in July of 1902.[4] Total sediment load passing the gauging station at Otowi during 1969 was 1.6 x 10^6 t. Some extremes listed for chemical quality and sediment loads for the period 1946 through 1969 are listed below.[5]

Dissolved solids: Maximum, 1,030 mg/l Aug. 5, 1963; minimum, 135 mg/l May 1-31, 1969. Hardness: Maximum, 702 mg/l Aug. 5, 1963; minimum, 83 mg/l May 22-26, 1960, June 22-28, 1968. Specific conductance: Maximum daily, 1,310 micromhos Aug. 5, 1963; minimum daily, 165 micromhos June 13, 1952. Water temperatures (1948-69): Maximum 31° C Aug. 4, 5, 1954; minimum, freezing point on many days during winter months. Sediment concentrations (1947-69): Maximum daily, 43,500 mg/l Aug. 21, 1955; maximum daily, 11 mg/l July 27, 1963. Sediment loads (1947-69): Maximum daily, 3.3 x 10^5 t Aug. 23, 1961; minimum daily, 2.7 t July 27, 1963.

Perennial flow occurs in the upper reaches of Los Alamos, Pajarito, Canon de Valle and Water Canyon. The flow is from perched water zones in the Tschicoma Formation and Bandelier Tuff. Perennial flow in sections of Pueblo, Los Alamos, Sandia, and Mortandad are from the release of effluents from industrial waste treatment plants, sewage plants, and blow down water from cooling process. These effluents do not leave the boundaries of

the ERDA property as surface flow but infiltrate to recharge small bodies of water in the alluvium of the canyon bottoms. Only during periods of excessive precipitation, snowmelt, or heavy summer showers, does runoff from most of the stream reach the Rio Grande. Occurrence of surface water is treated in each major drainage area investigated in this report. Hydrology of Santa Clara, Guaje Los Alamos, and Frijoles Canyon as related to low-flow investigations are presented in Appendix C.

2. Water in the alluvium

Water in the alluvium is recharged from surface flow from either effluents, cooling water, or storm runoff. Water in the alluvium occurs in Pueblo, Los Alamos, Mortandad, and Pajarito Canyon and probably is perched seasonally in the upper reach and perennially in the lower parts of other canyons that receive effluents or runoff from the Pajarito Plateau and Sierra de los Valles. The occurrence of water in the alluvium is treated in each of the major drainage areas investigated in this report.

3. Perched Water in the Puye Formation and basaltic rocks of Chino Mesa

Perched water recharged from water in the alluvium occurs in lower Pueblo, Los Alamos and Sandia Canyons. A part of this perched water discharges from springs in Los Alamos and Sandia Canyons. The movement and quality of water in the perched aquifer are treated as a part of this report.

4. Main aquifer of the Los Alamos area

The main aquifer in the Los Alamos area is in the Santa Fe Group. The potentiometric surface (Fig. 3) rises from the Rio Grande westward through the Tesuque Formation into the lower

part of the Puye Conglomerate which interfingers with Tschicoma Formation (Fig. 2). The position of the potentiometric surface in the Tschicoma Formation is not known beneath the western edge of the plateau. Brecciated zones within the Tschicoma Formation may contain water but where encountered in wells such zones have not yielded more than 0.3 to 0.6 l/sec.

The gradient of the potentiometric surface beneath the Pajarito Plateau averages about 370 m along the western edge of the plateau to about 180 m at the confluence of Pueblo and Los Alamos Canyons. Water in the aquifer moves eastward toward the Rio Grande where some water is discharged through springs in the channel and along the banks (Fig. 3). Recharge to the main aquifer occurs on the flanks of the mountain or from the Valles Caldera to the west of Los Alamos.[6] The movement of water in the supply wells in lower Los Alamos Canyon is estimated to be about 110 m/yr.[7] Aquifer tests in the main aquifer south of Los Alamos also indicates slow movement of water in the range 55 m/yr to 220 m/yr. The transit time from recharge of the aquifer to discharge along the Rio Grande is unknown; however, tritium age dating of water from supply wells in Los Alamos, Guaje, and the Pajarito well field indicate that the water has been in transit from the recharge area for periods much greater than 50 years. Tritium analyses (electolysis enrichment method) were below limits of detection (0.5 tritium units).

The main aquifer is separated from water in the alluvium in canyon bottoms and from the perched aquifers in lower Pueblo. Los Alamos, and Sandia Canyons by from 200 to over 300 m of

of unsaturated volcanics and sediments. Geologic and hydrologic data collected during testing and monitoring of test holes penetrating the main aquifer are considered in a latter part of the report.

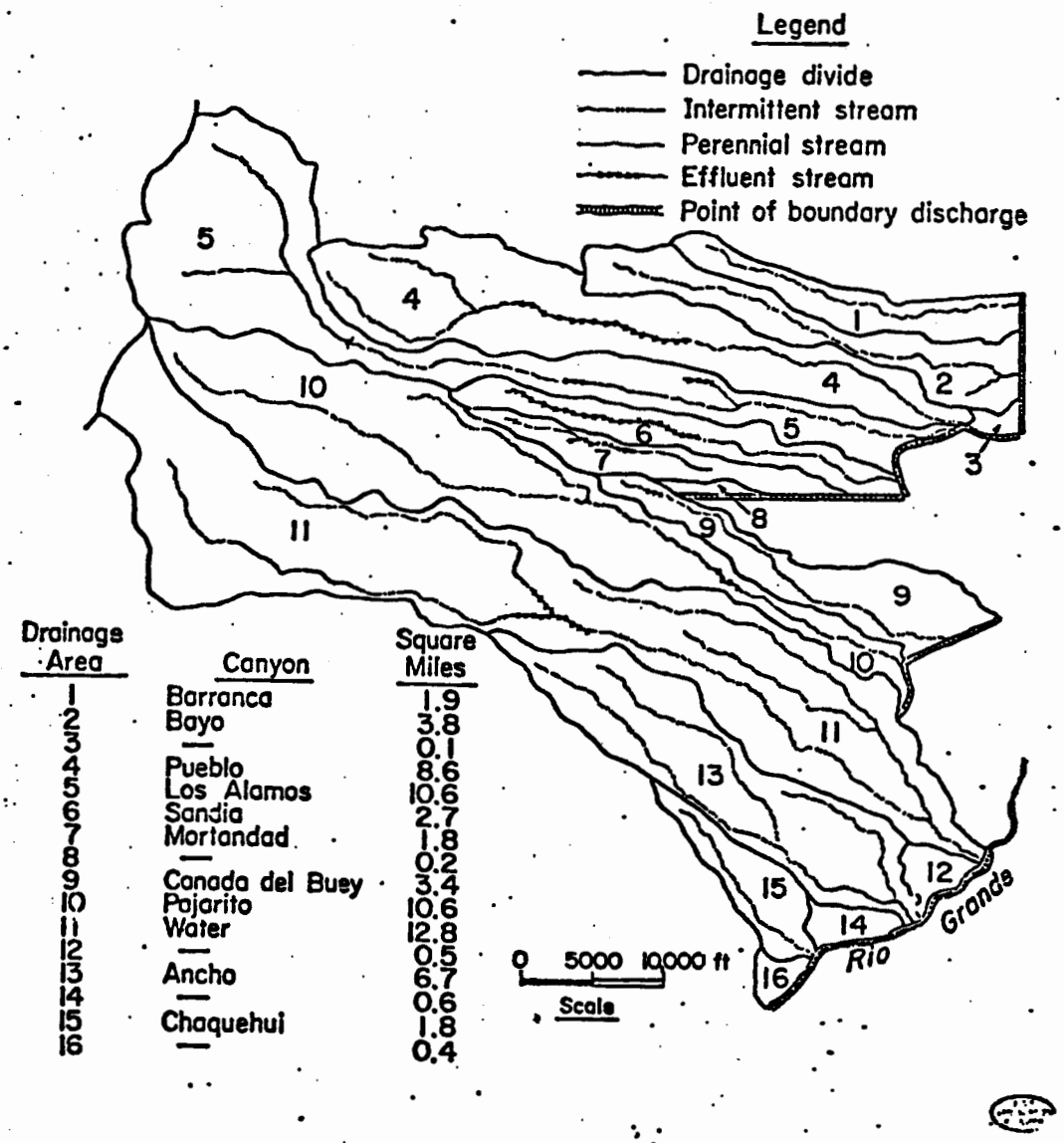
D. Method of Investigation

The study areas include all drainage areas on ERDA controlled property. The drainage areas were outlined on the basis of point of discharge at ERDA-LASL boundary (Fig. 4). All data that was available concerning the geohydrology of surface water, shallow ground water in the alluvium, and transport of sediments was used. List of published and unpublished reports that were used are found in Appendix D.

1. Chemical analyses of water

The chemical quality of surface and ground water in the alluvium was determined by methods as outlined in "Standard methods for examination of water and waste water"[8] and "Methods for the Collection and analyses of water samples."

The average concentration of sodium (Na), Chloride (CL), fluoride (F), nitrate (NO_3), total dissolved solids (TDS), specific conductance, and pH of a number of analyses for a sampling station is used in the tables in the text of this report to show trends in concentration in the disposal area, and over a period of time at a single station. These specific ions and chemical characteristics were used as they will readily reflect quality of water change that may occur. Complete chemical analyses from each station for the period 1967-1972 is presented in Appendix E for the drainage areas.



Drainage Area	Canyon	Square Miles
1	Barranca	1.9
2	Bayo	3.8
3	—	0.1
4	Pueblo	8.6
5	Los Alamos	10.6
6	Sandia	2.7
7	Mortandad	1.8
8	—	0.2
9	Canada del Buey	3.4
10	Pajarito	10.6
11	Water	12.8
12	—	0.5
13	Ancho	6.7
14	—	0.6
15	Chaquehui	1.8
16	—	0.4

Fig. 4. Drainage areas and points of intermittent stream discharge.

2. Radiochemical analyses of water

The radiochemcial data is presented in two parts for each hydrologic regime, surface water, water in alluvium, perched aquifers and main aquifer, covering the periods 1958 through 1967 and 1968 through 1972. During the period 1958 through 1967 analyses were made for gross beta and plutonium. The procedures for analyses for plutonium used Bismuth Phosphate Coprecipitation Method. This method had a limits of detection of 0.5 pCi/l (picocuries per liter). The limits of detection for gross beta activity during this same period was 14 pCi/l and total uranium 0.5 μg/l.

During the period 1967 through 1972, analyses were made for gross alpha and beta, ^{238}Pu, ^{239}Pu, ^{3}H, and total uranium. Procedures used for sample preparation and gross alpha, beta, and gamma screening are outlined in Radioassay Procedures for Environmental Samples.[10] The determination of specific alpha emitters was performed using an alpha spectrometer and internal tracers for recovery corrections. Purification and concentrations were done by ion exchange and electrodeposition or by coprecipitation. Uranium was determined fluorometrically unless specific uranium isotopes were required. The methods used in the period 1967 through 1972 were better in that the limits of detection were lower. Limits of detections for gross alpha and beta activity were 1 pCi/l, plutonium 0.05 pCi/l and total uranium 0.4 μg/l.

The average concentration of a number of analyses for a sampling station is used in the tables in the text of this report to show general trends in concentrations in the disposal area.

Many of the individual analyses are below the limits of detection. The limits of detection rather than zero has been used to compute the average. Complete radiochemical analyses from each station for the period 1967-1972 is presented in Appendix C for the drainage areas.

3. Radiochemical analyses of sediments

Stream channel bed material is referred to as sediments. These sediments were collected with 7.6 cm scoop across the main channel to a depth of about 3 cm. Suspended sediments are classed as having a mean diameter less than 6 mm and are those sediments that remain in suspension in water for a period of time without contact with the bottom. The suspended sediments were collected with a single-stage sampler, cumulative sampler, or a DH-48 sampler during flood or storm runoff.

The procedures used for radiochemical analyses of channel bed sediments and suspended sediments are outlined in "Standard Analytical Procedures for Soil."[11] Plutonium was analyzed by using an alpha spectrometer after concentration and purification by ion-exchange chemistry with internal tracers added for recovery corrections.

4. Particle-size Distribution of Sediments

The particle-size distribution was made by mechanical shaker (Ro-Tap) through a series of different size mesh screens. The size distribution was made of the sediments having a particle size diameter of less than 3.96 millimeters, according to the Wentworth Grade Scale. The particle-size distribution

Grade	Size Range (Millimeters)
Granules	2.36 - 3.96
Sand	
Very Coarse	1.17 - 2.36
Coarse	.589 - 1.17
Medium	.295 - .589
Fine	.147 - .295
Very Fine	.074 - .147
Silt and Clay	Less than .074

is expressed as percent by weight of the channel bed sediments.

The sediments are derived from chemical and mechanical weathering of the acid volcanic rocks (Tschicoma and Puye Formations and Bandelier Tuff). The granules are composed principally of tuff, pumice, latite, and rhyolite rock fragments with minor amounts of quartz and sanidine crystals. The fractions of fine to coarse sand consist mainly of quartz and sanidine crystals and crystal fragments with minor amounts of rock fragments. The silt and clay fraction are composed mainly of clay minerals montmorillonite and illite.

5. Inventory of Plutonium in Sediments of Drainage Area 4, 5, and 7

Drainage Area 4 (Acid-Pueblo Canyon), Drainage Area 5 (Los Alamos -DP Canyon) and Drainage Area 7 (Mortandad Canyon) have received treated liquid effluents that have contained some plutonium. An inventory was made to determine the amount of plutonium released into the canyon in preceeding years.

Plutonium in the waste when released is adsorbed or retained with the finer material in the channel alluvium. The concentrations of plutonium tend to build up at the point of effluent discharge in the channel during the fall through the spring. This large concentration is reduced by transport during storm runoff, especially the heavy summer showers.

The fine particle in the alluvium in the channel have the greater affinity for the plutonium; however, most of the plutonium is in the coarser alluvium as it is more abundant. The finer sediments in the alluvium are carried out of the canyons (Acid-Pueblo and DP-Los Alamos) as suspended sediments with the storm runoff, while the larger materials are being transported as bed material. The bed material lags behind, moving short distances with each succeeding runoff event.

Storm runoff reaches the Rio Grande from Acid-Pueblo and DP-Los Alamos Canyons. There has been no runoff in the drainage area of Mortandad Canyon to the Laboratory boundary (Santa Fe-Los Alamos County Line) since hydrologic investigation began in the canyon in 1960. This is due to the small drainage area and the thickness of unsaturated alluvium in the canyon.

The inventory is based on (1) mass of sediments in a section of the channel, and (2) the average concentration of plutonium in sediments in that section.

The annual amounts of plutonium released from the Treatment Plants into the canyon were compiled from records furnished by H-7. The estimate from the TA-45 Plant 1943-1950 was taken from LA-5282-MS. The mass of sediments is compiled from channel width,

length of section, a thickness of 0.15 m, and a specific gravity of 1.57. The mass of the sediments and concentration of plutonium were used to compute the amount of plutonium in the section. The inventory in the canyon was made from data collected in 1968, 1970, and 1972 and is presented in the Drainage Areas 4, 5, and 7 sections of the report.

6. Flood-Frequency and Maximum Discharge

The sixteen drainage areas considered in the study contain only intermittent streams at the ERDA Boundary, with the exception of Drainage Area 13 (Ancho Canyon). The lower reach of Ancho contains a perennial stream fed by springs from the main aquifer in the lower part of the Puye Formation and upper part of the Tesuque Formation.

There are three gauging stations on the plateau; mouth of DP Canyon, mid-reach of Los Alamos Canyon and upper Mortandad Canyon. There are no gauging stations on the channels of the sixteen drainage areas, thus, theoretical flood-frequency and maximum discharge were compiled from a method devised by Scott.[12] The methods used, consist of defining the relationship between existing flood data and the physical and climatic characteristics of the gauged sites or drainage basin. The data was extrapolated by use of regression analyses using this relationship and basin characteristics to determine flood frequency and maximum discharge.

The peak discharges of 2, 5, 10, 25, and 50 year recurrence intervals were determined for each of the drainage areas containing a well defined channel from nomographs presented by Scott for Region 1 which includes the Rio Grande water shed in north central New Mexico.

The climatic data used with the nomographs as determined at Los Alamos was a mean minimum January temperature of 8° F and a maximum 24 hour 2 year rainfall of 4.3 cm. The area of each drainage area, in square in km^2 above the ERDA-LASL Boundary was determined by use of a planimeter. The main channel slope, was compiled from elevations taken from topographic maps. Using points at 10 and 85 percent of the distance from discharge point at the boundary and drainage divide. The difference in altitude between those two points divided by the distance between the points was used to compute the main channel slope for drainage areas. The channel slopes are present as dimensionless ratios of average vertical distance change (negative to horizontal distance traversed).

The flood frequency or "recurrence interval" is the average interval of time between floods of a given magnitude. A flood with a recurrence interval of 50 years is the annual flood that is equaled or exceeded once in 50 years, with long term average. The concept implies no regularity in the time of recurrence of a given magnitude flood. It is possible for two or more 50 year floods to occur within a short period of time, or many more than 50 years may elapse before the occurrence of one 50 year flood.

Frequencies may be expressed in terms of probabilities, i.e. the probability of the occurrence of a 10 year flood in any given year is 1 in 10 or 0.1; the probability of a 50 year flood in any given year is 1 in 50, or 0.02.

II. DRAINAGE AREA 1 (BARRANCA CANYON)

Barrance Canyon contains an intermittent stream. Runoff occurs during heavy summer thunder showers and possibly some snow

melt in the upper reaches of the canyon. There is no effluent discharge into the canyon from either sewage or industrial waste treatment plants. No data is available on chemical or radiochemical quality of the storm runoff.

A. Radiochemical analyses of sediments

Samples of sediments from the stream channel were collected in Barranca Canyon above the junction with Guaje Canyon, about 0.5 miles east of the boundary (Fig. 5).

Particle size distribution of sediments in the stream channel was made of the sample collected in 1965. The sediments were derived from the Bandelier Tuff and Puye Formation.

Particle-size Distribution of Sediments

Grade	Distribution (percent by weight)
Granules	10
Sand	
Very Coarse	17.5
Coarse	27.0
Medium	21.0
Fine	11.5
Very Fine	5.5
Silt and Clay	7.5

Radiochemical analyses were made of sediments collected November 24, 1965 and February 5, 1970. No activity found in the sediments were in the range as would be expected from world wide fallout.

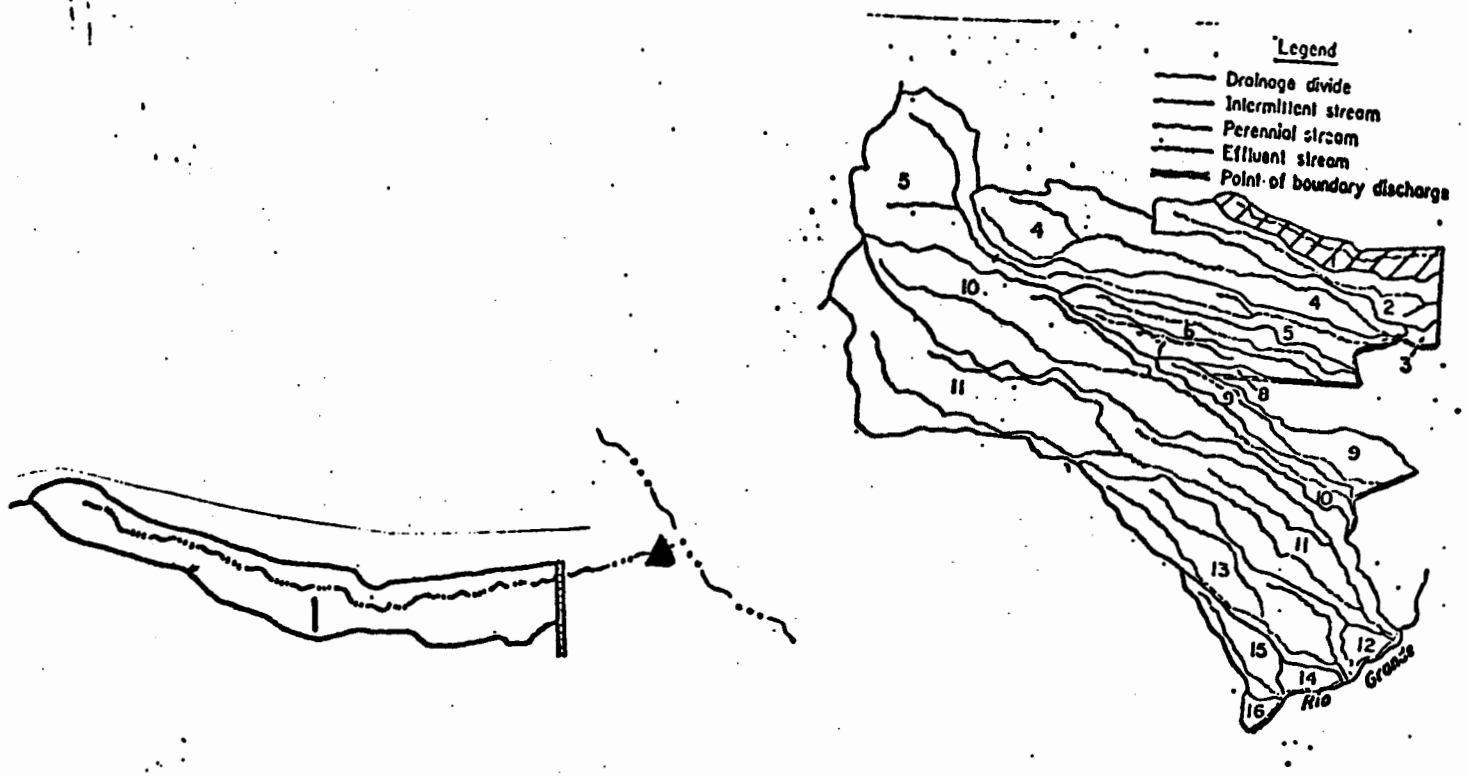


Fig. 5. Drainage Area 1 (Barranca Canyon) showing location of sediment sampling station.

11-5-65	
Gross alpha	3 c/m/g
Gross beta	1 c/m/g
Gross Gamma	28 c/m/g
2-5-70	
Gross alpha	2 pCi/g
Gross beta	3 pCi/g
Gross gamma	1 pCi/g
Plutonium-238	0.005 pCi/g
Plutonium-239	.007 pCi/g

B. Flood-frequency and Maximum Discharge

Barranca Canyon heads on the Pajarito Plateau at an altitude of about 2, 195 m. The flood frequency and maximum discharge are based on the following data:

Drainage Area - 4.9 km^2
Main Channel Slope - 0.039

Frequency	Maximum Discharge (m^3/sec)
2-year	1.5
5-year	4.1
10-year	6.7
25-year	12
50-year	14

III. DRAINAGE AREA 2 (BAYO CANYON)

Bayo Canyon contains only an intermittent stream. Runoff occurs during heavy summer thunder showers with some possible snow melt in the upper reaches of the canyon. There is no effluent discharge into the canyon; however, prior to 1965, a technical area used for testing, was located in the canyon. The site was abandoned and the area was cleaned up in 1965.

A. Chemical analyses of storm runoff

Chemical analyses was made of storm runoff that occurred at Station 1 in August 22, 1957 (Fig. 6).

Determination	Concentrations
Chemical (mg/l)	
Sodium	4.8 mg/l
Carbonate	0 mg/l
Bicarbonate	117 mg/l
Chloride	8.0 mg/l
Fluoride	1.0 mg/l
Nitrate	2.0 mg/l
Specific Conductance (μmhos)	227
pH	7.2

No radiochemical analyses were performed on the sample.

B. Radiochemical analyses of sediments

Two sediment sampling stations were established in the canyon. They are located near the middle of the canyon (Station 1) and the other about Bayo Canyon above the junction with Los Alamos Canyon about 2.4 km east of the boundary (Station 2).

Particle size distribution of the sediments at the two stations are shown below. The sediments are derived from the Bandelier Tuff and Puye Formation:

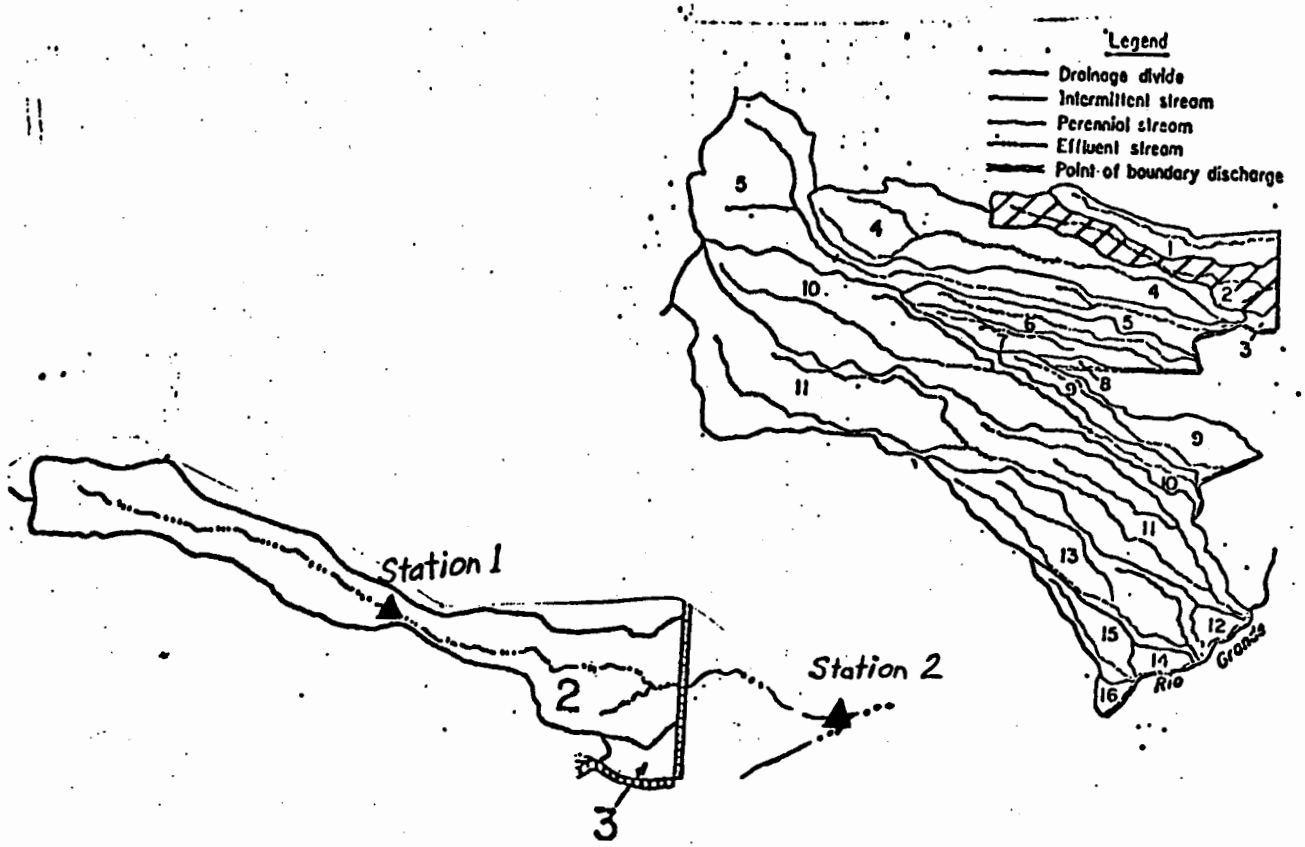


Fig. 6. Drainage Area 2 (Bayo Canyon) and Drainage Area 3 showing locations of sampling stations.

Particle-size Distribution of Sediments

Grade	Distribution (percent by weight) Station 1	Station 2
Granules	2.0	2.0
Sand		
Very Coarse	40.5	24.5
Coarse	40.5	46.5
Medium	10.5	16.0
Fine	3.5	6.5
Very Fine	1.5	1.5
Silt and Clay	2.0	2.5

Radiochemical analyses were made of sediments from the two stations collected November 24, 1965 and February 5, 1970. The activity is in the range that would be expected from world wide fallout.

Determination	Station 1 11-24-65	Station 1 2-5-70
Gross alpha	1 cm/g	<1 pCi/g
Gross beta	<1 cm/g	<1 pCi/g
Gross gamma	<1 cm/g	<1 pCi/g
Plutonium-238	--	<0.001 pCi/g
Plutonium-239	--	.004 pCi/g

Determination	Station 2 11-24-65	Station 2 2-5-70
Gross alpha	3 cm/g	<1 pCi/g
Gross beta	21 cm/g	<1 pCi/g
Gross gamma	<1 cm/g	<1 pCi/g
Plutonium-238	--	< .001 pCi/g
Plutonium-239	--	.004 pCi/g

C. Flood-frequency and Maximum Discharge

Bayo Canyon heads on the Pajarito Plateau at an altitude of

about 2,036 m. The flood-frequency and maximum discharge at the boundary is based on the following data:

Drainage Area - 9.8 km^2
Main channel slope - 0.028

Frequency Frequency	Maximum Discharge (m^3/sec)
2-year	2.4
5-year	6.1
10-year	8.5
25-year	17
50-year	19

IV. DRAINAGE AREA 3

Drainage Area 3 is on the south facing wall of Los Alamos Canyon. No major drainage channel developed in the 0.25 km^2 drainage area. No data are available on chemical or radioachemical quality of storm runoff.

V DRAINAGE AREA 4 (ACID-PUEBLO CANYON)

Stream flow is perennial in the upper and lower reaches of Pueblo Canyon from the release of treated sewage effluent from the Pueblo and Bayo Plants (Fig. 7). Storm runoff adds to the volume of flow either from winter snow melt or summer thunderstroms. During the period 1951 through 1963, industrial effluents from TA-45 were released into Acid Canyon, a small tributary to Pueblo Canyon. The Central Sewage Treatment Plant released effluents into the middle reach of the canyon from 1947 through 1966.

The stream flow in Pueblo Canyon recharges a shallow body of ground water in the alluvium. As the water in the alluvium moves downgradient, water is lost to evapotranspiration while some moves into two shallow perched water bodies in the Puye Formation and

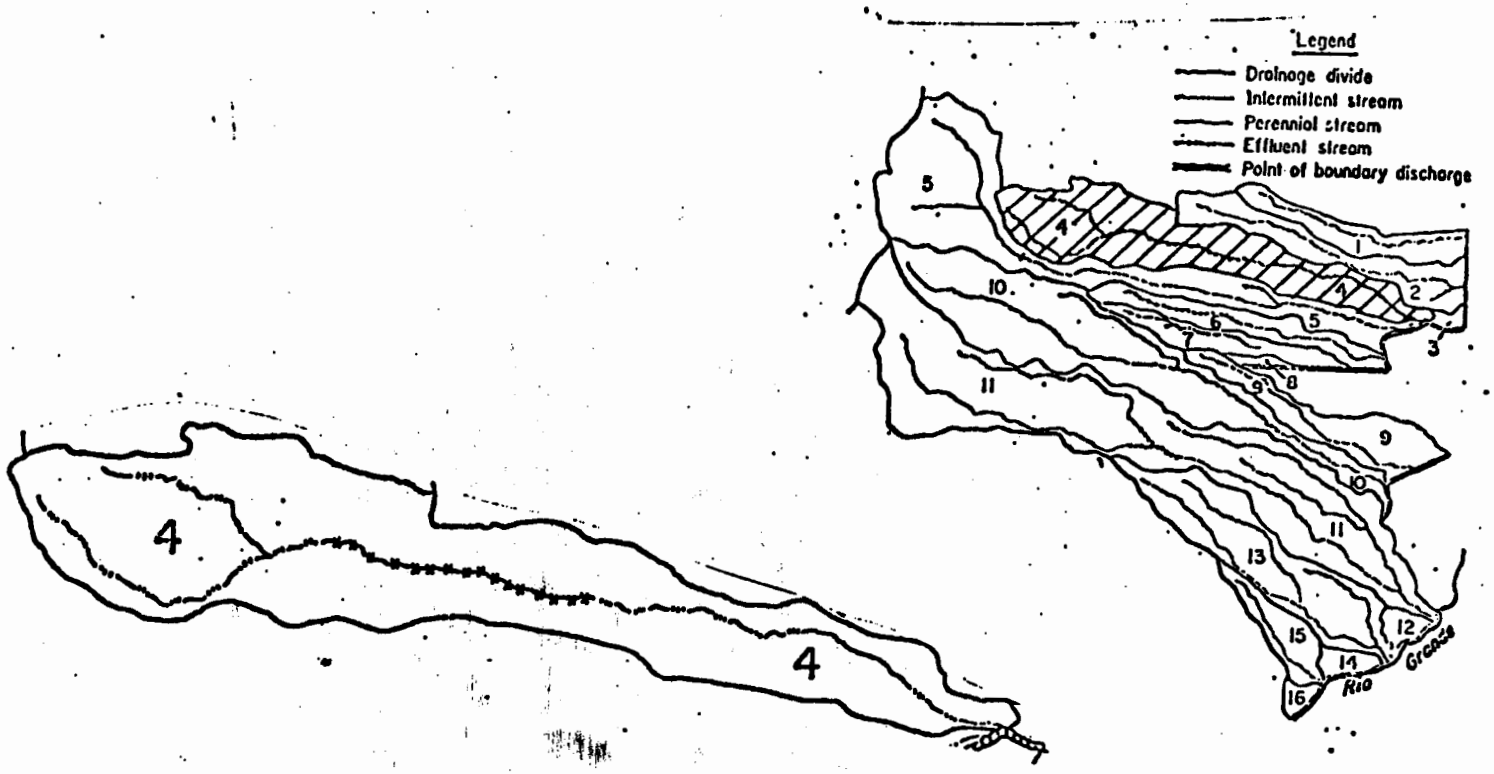


Fig. 7. Drainage Area 4 (Pueblo Canyon).

Basaltic Rocks of Chino Mesa (Fig. 8)

A. Sewage and Industrial Treatment Plants

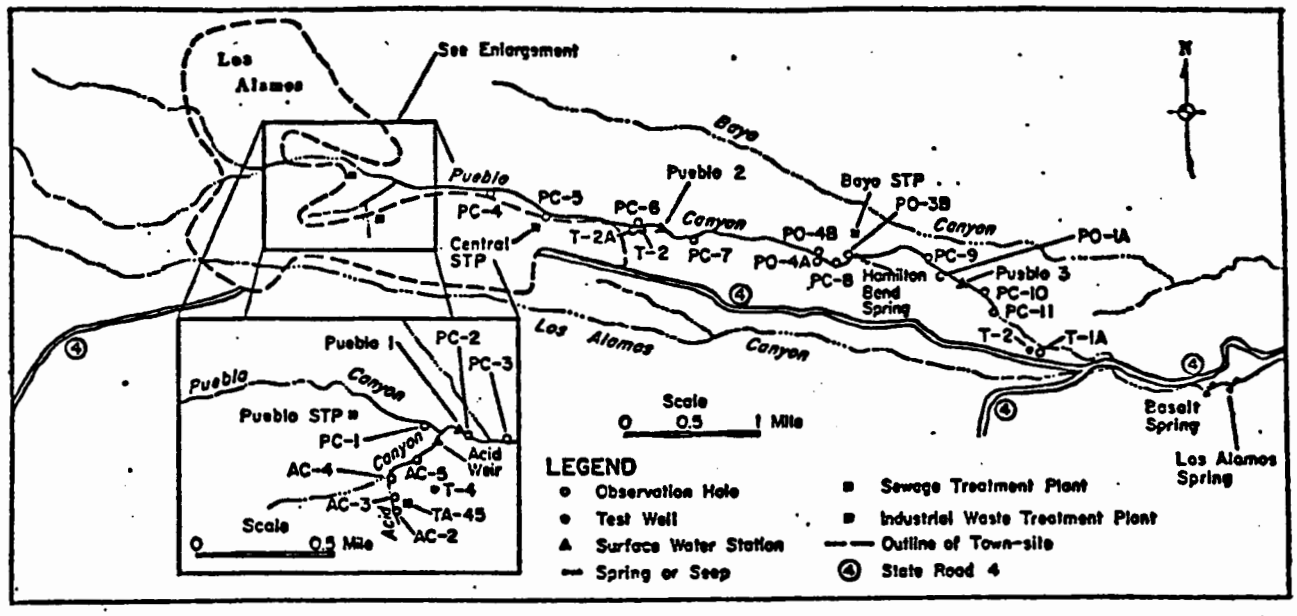
Sewage has been treated and released at three plants in Pueblo Canyon during the interval between 1951 and 1971. The oldest plant in operation is the Pueblo Plant which began operations in the mid 1940's and is still in operation. The yearly volume of sewage effluent released increased from 375 x 10^3 m^3 in 1956 to 875 x 10^3 m^3 in 1961.

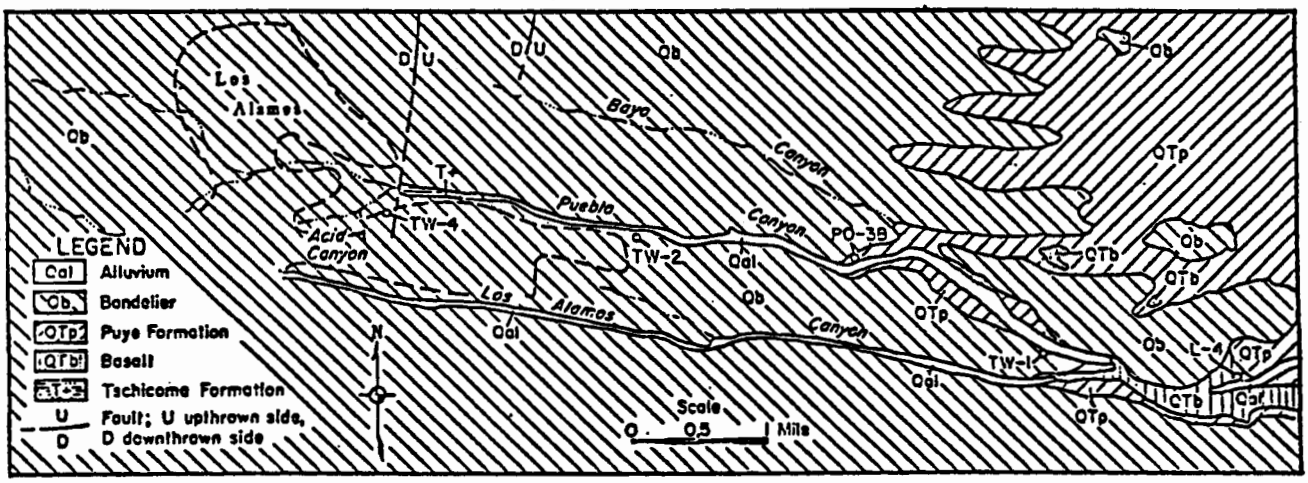
The release in 1970 was about 780 x 10^3 m^3. From April through September, about 90 percent of the effluent is pumped to the golf course for irrigation.

The central treatment plant operated from the late 1940's to about 1966 when the effluent was then treated at the Bayo Plant. The earlier release from the plant ranged from 570 x 10^3 m^3 to 760 x 10^3 m^3 annually; however, after 1954, when a part of the effluents were pumped to the power plant for use, the releases into Pueblo Canyon dropped, ranging from 75 x 10^3 m^3 to 150 x 10^3 m^3 per year to 1966 when all the effluents were then treated at Bayo Plant.

The Bayo Plant became operational in 1963 with the effluent released into Pueblo Canyon. The plant was enlarged and in 1966 began treating sewage previously processed at the central treatment plant. The release in 1972 was about 900 x 10^3 m^3.

The industrial waste treatment plant at TA-45 was in operation from January 1951 through June 1963. Several small batches of waste were treated until June 1964 prior to complete abandonment of the plant. Plutonium, the major waste contaminate, was removed





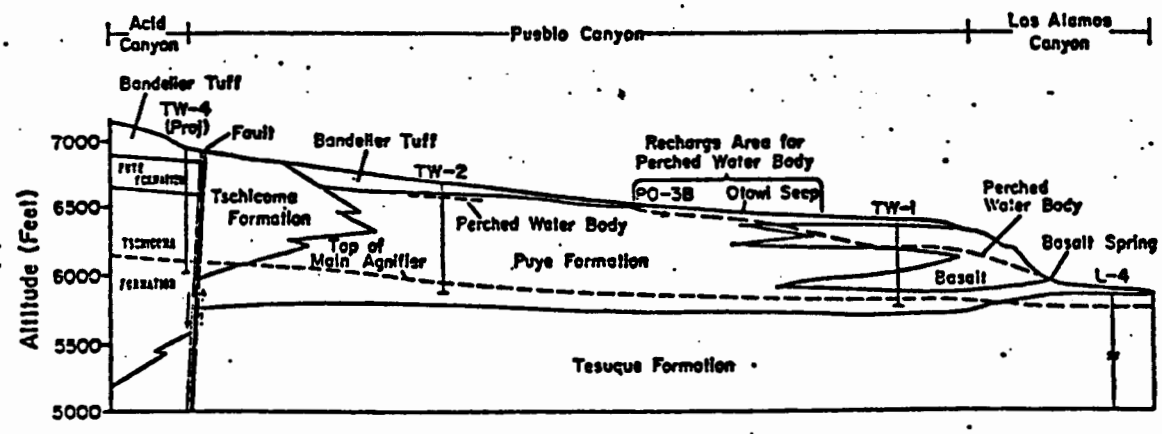


Fig. 8. Sampling stations, geologic map, and cross-section of Drainage Area 4 (Pueblo Canyon).

from liquid wastes by chemical treatment with ferric sulfate and lime, which forms a flocculent that precipitates to the bottom of settling tanks. The precipitate (ferric hydroxide) carries nearly all of the plutonium with it. The sludge is removed from the bottom of the tank, packaged, and buried in pits.

An average of 9×10^3 of waste were released into Acid Canyon between 1946 and 1951. The volume of waste released increased from 15×10^3 m^3 in 1951 to a maximum of about 65×10^3 m^3 in 1962, then decreased to about 0.7×10^3 m^3 in 1964 as the new plant at TA-50 became operational. The wastes were released from the treatment plant in batches of 55 m^3 to 75 m^3 rather than by continuous flow. The effluents were released into Acid Canyon. The effluents made up the bulk of the flow in the canyon except some occasional runoff from storms.

1. Chemical quality of sewage and industrial effluents

The chemical quality of effluents from the Pueblo, Central (now abandoned), and the Pueblo Sewage treatment plants have remained about the same over the years.

Chemical Quality of Sewage Effluent

(Average of a number of samples, analyses in mg/l except as noted).

Plant	Pueblo				Central		Bayo	
Year	1952	1961	1971	1972	1952	1961	1971	1972
Number of Samples	1	1	2	4	1		2	4
Calcium	--	--	26	14	--		13	14
Magnesium	--	--	3	6	--		2	5
Sodium	--	94	88	76	--	114	89	78
Carbonates	--	0	0	0	--	0	0	0
Bicarbonates	176	121	120	140	210	158	160	118
Phosphate	--	35	--	--	--	22	--	--
Chloride	32	34	36	31	30	46	30	55
Fluoride	1.6	1.6	.8	.7	1.6	2.6	1.5	1.2
Nitrate	40	30	66	26	35	43	31	57
Dissolved Solids	350 [a]	400 [a]	420	403	370 [a]	400 [a]	374	408
Hardness	--	49	74	66	--	37	41	55
Conductance[b]	540	620	500	475	570	620	500	450
pH[c]	--	7.0	72	7.2	--	7.1	7.2	7.[illegible]

[a] Estimated, Ref. 12 p 270

[b] Micromhos at 25° C

[c] No units

The chemical ions and physical characteristics are greater than found in natural occurring water. Metal ion analyses of effluent from the Pueblo and Bayo Plants were made in 1971 and 1972. The results indicated some trace amounts of metal ions in the effluents.

The chemical ions and physical characteristics are greater than found in natural occurring water. Metal ion analyses of effluent from the Pueblo and Bayo Plants were made in 1971 and 1972. The results indicated some trace amounts of metal ions in the effluents.

Metal Ion Analyses
(Average of three analyses in parts per billion)

	Pueblo	Bayo
In Solution		
Cadmium	1.3	.91
Beryllium	.29	1.4
Lead	<1.0	3.8
Mercury	0.5	< .02
Particulates		
Cadmium	.48	.30
Beryllium	< .25	< .25
Lead	6.5	4.7
Mercury	.34	.05

The chemical quality of the effluents released into the canyon reflects the quality of influents to the plant and chemicals used to neutralize undesirable constituents and remove radionuclides. The effluents are highly mineralized when compared to naturally occurring waters. The high pH is the result of treatment of the effluents with lime as part of the process to remove radionuclides. In general, the chemical ion concentrations vary with the ever changing quality of the influents.

Chemical Analyses of Industrial Effluents[a]
(Analyses in mg/l, except as noted)

Year	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Calcium	14	74	116	96	55	15	10	80	82	28	76	27	4
Magnesium	3	49	60	--	0	38	16	5	5	1	2	1	1
Sodium	46	162	35	87	105	57	680	78	118	87	102	99	69
Carbonates	38	3	68	289	--	138	336	162	467	100	154	82	60
Bicarbonates	132	46	140	314	284	280	599	193	530	140	201	151	130
Chloride	54	290	57	18	9	9	229	1	83	48	61	24	10
Fluoride	5	2	10	4	4	14	80	3	10	7	2	2	2
Nitrate (N)[b]	24	130	178	10	24	2	200	12	3	7	4	1	1
Hardness	46	390	537	240	88	195	90	219	225	70	200	68	10
Conductance[c]	--	--	--	--	1200	1380	600	630	795	650	1110	640	450
pH	--	--	9.1	11.5	11.4	11.2	11.0	11.8	11.6	11.0	10.9	10.8	10.5

[a] Weekly composite sample (one analysis from each years record)
[b] N x 4.4 = NO_3
[c] Micromhos at 25° C

2. Radiochemical Quality of Sewage and Industrial Effluents

Radiochemical analyses of sewage effluent from the Pueblo and Bayo Plants have been made on samples collected in 1971 and 1972. The results show only traces of radionuclides which are background.

Radiochemical Analyses of Sewage Effluents
(Average 7 samples collected in 1971 and 1972
in pCi/l except as noted)

Determination	Pueblo	Bayo
Gross alpha	1	2
Gross beta	9	30
Plutonium-238	0.05	0.05
Plutonium-239	0.05	0.05
Cesium-137	350	350
Tritium	1,000	1,000
Total Uranium[a]	1.6	1.8

[a] µg/l

The volume of effluent and concentrations of gross alpha, gross beta, total plutonium and tritium released as effluent after treatment at the plant for the period 1951 through 1964 were compiled from plant records by Group H-7 (H7-LAE-434).

Average Annual Radiochemical Quality of Effluents released from TA-45 (1951-1964)

		Picocuries per liter			
Year	Amount (M^3)	Gross alpha	Gross beta	Total Pu	^3H [a] ($x\ 10^3$)
1951	22080	111	--	59.3	140
1952	28540	144	--	38.5	110
1953	27610	139	--	41.7	110
1954	38910	112	--	56.2	77
1955	39910	102	--	54.8	75
1956	39720	150	--	26.4	76
1957	43310	200	--	20.7	69
1958	40580	94.6	--	22.4	74
1959	46110	38	--	26.5	65
1960	40870	86.5	31000	64.1	73
1961	52850	176	9600	100	57
1962	64110	115	19000	61	47
1963	30880	232	26000	97.4	97
1964	891	94	150	45	1300

[a] Estimated

Major treatment during operation of the plant was to reduce the amount of plutonium received in the liquid waste. During the period 1943 through 1964, about 170 millicuries of plutonium were released into the canyon.

Annual Amount of Radionuclides Released
with Effluents from TA-45

Year	Millicuries			
	Gross alpha	Gross beta	Total Pu	^{3}H[a]
1943-50[a]	--	--	143[b]	--
1951	2.4	--	1.3	3090
1952	4.1	--	1.1	3140
1953	3.8	--	1.2	3040
1954	4.4	--	2.2	2990
1955	4.1	--	2.2	2990
1956	6.0	--	1.0	3020
1957	8.7	--	.9	2990
1958	3.8	--	.9	3000
1959	1.8	--	1.2	2990
1960	3.5	1270	2.6	2980
1961	9.3	507	5.2	3010
1962	7.4	1220	3.9	3010
1963	3.0	803	3.0	3000
1964	.04	.1	.04	1160
Total (1943-1964)	--	--	170.	--

[a] Estimated
[b] LA-5282-MS[13]

B. Surface Water

Stream flow in Pueblo during the period 1951 through 1964 consisted of effluents from the two sewage treatment plants (Pueblo and Central) and from the industrial waste treatment plant (TA-45) near Acid Canyon, a tributary canyon to Pueblo. Precipitation and snowmelt occasionally added to the volume of flow.

The average discharge from 1957 to 1964 in Pueblo Canyon, just

below the junction with Acid Canyon, was about 56 l/sec, from September through April and about 14 l/sec from May through August. Near test Well 2 (added flow from the central plant) the average discharge was about 45 l/sec from September through April and 14 l/sec from May through August (Fig. 8). The decrease in stream flow May through August reflected decreased release from the sewage-treatment plants because most of the effluent was used for irrigation and cooling water at the power plant. Stream flow during summer usually ended near observation well PO-4A but during the summer extended to near Pueblo 3 or beyond (Fig. 8).

The same characteristics of discharge occurred in upper Pueblo Canyon from the sewage treatment plant during the period 1964 through 1971; however, stream flow generally ended near or east of test Well 2 during the summer and extended to near Hamilton Bend Springs in the winter. The new sewage-treatment plant at Bayo began operations in 1964 and by 1966 the the Central treatment plant was closed. This caused a shift in release of effluent in the lower part of the canyon.

The stream flow decreased down the canyon as water moved into the alluvium. The alluvium is thin in the upper reaches of the canyon and thinkens to about 18 m to the east. Slight or little losses of surface water were noted where the alluvium overlies the Tschicoma Formation (Fig. 8). The alluvium in the stream channel overlying the Tschicoma Formation is thin. The rocks of the formation are quite hard and resist down cutting of the stream channel. To the east where the channel is underlain by the Bandelier Tuff, the alluvium thickens as the tuff erodes and weathers quite easy. As the alluvium thickens in this section of the stream, storage

capacities of the alluvium increase which is accompanied by an increased loss of surface flow as it infiltrates into the alluvium. Surface water losses also occur to evaporation and transpiration by plants and trees.

The surface water loss in the canyon is estimated at about 5 l/sec per km when discharge at the confluence of Acid and Pueblo Canyons is about 60 l/sec. As discharge increases, these losses increase due to water taken into bank storage which is later partly released as the discharge declines. Loss from bank storage occurs from evapotranspiration and some water is held as soil moisture.

Surface water stations for monitoring the chemical and radiochemical quality of the surface water were established at Acid Weir, Pueblo 1, Pueblo 2, and Pueblo 3 in 1954.

1. Chemical quality of surface water

The chemical quality of water from Acid Weir from 1954 to 1964 reflect the chemical quality of the effluent released from the treatment plant.

Chemical Quality of Surface Water at Acid Weir
(Average of a number of analyses)

Chemical Constituents	Period 1953-1964	Period 1965-1972
Chemical (mg/l)		
Chloride	33	77
Fluoride	3.9	1.4
Nitrate	83	4.4
Total Dissolved solids	735	320
Conductance (μmhos)	670	240
pH	8.4	7.5

The water was basic and fluoride and nitrate concentrations were high as were total dissolved solids. The high chlorides in the period 1965-1972 are probably from leaching from salt-sand mixtures stored at the head of the canyon by the county. Runoff in Acid Canyon during the period 1964-1972 consisted mainly of storm run-off, release of water from the pool at the High School, and runoff from lawn watering in the residential area. The yearly average shows general decline in concentrations of fluoride and nitrate and in total dissolved solids, conductance, and pH. The chloride concentrations have increased 1970 through 1972.

Chemical Quality of Surface Water from Acid Weir
(Average yearly analyses in mg/l except as noted)

Year	No. of samples	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1953	9	--	29	4.1	157	435[c]	670	--
1954	10	--	37	5.2	242	545[c]	840	--
1955	6	--	36	5.2	304	640[c]	980	--
1956	10	--	32	5.7	50	583	---	8.6
1957	3	72	23	3.8	36	345[c]	530	7.9
1958	6	66	25	5.1	23	350[c]	540	8.1
1959	3	87	45	4.0	26	400[c]	610	8.3
1960	1	85	44	3.9	16	335[c]	515	8.6
1961	1	78	29	2.0	29	420	480	8.5
1962	2	94	39	2.2	26	400	380	9.4
1963	2	72	24	2.0	13	356	400	8.3
1965	1	38	14	1.7	4	246	240	7.6
1970	2	98	165	1.7	4	437	520	7.7
1971	1	41	52	.9	4	276	220	7.1
1972	2	86	73	1.9	4	305	395	7.4

[a] Micromhos at 25° C
[b] No units
[c] Estimated

Surface water stations were established at Pueblo 1, Pueblo 2, and Pueblo 3 in Pueblo Canyon (Fig. 8). The chemical quality of the water at the three stations reflect the chemical quality of the sewage effluent from the Pueblo, Central (abandoned) and Bayo Plants.

Chemical Quality of Surface Water at Pueblo 1, 2, and 3
(Average of a number of analyses) 1953 through 1972

Chemical (mg/l)	Pueblo 1	Pueblo 2	Pueblo 3
Chemical (mg/l)			
Chloride	30	30	28
Fluoride	2.0	1.6	1.7
Nitrate	52	34	13
Total Dissolved Solids	365	342	409
Conductance (μmhos)	450	410	400
pH	7.3	7.5	7.4

The chemical quality of water at Pueblo 1 shows little or no effect of the release of effluent from the industrial waste treatment plant at TA-45 which ceased operations in 1964.

Quality of Surface Water at Pueblo 1
(Average of Yearly Analyses in mg/l except as noted)

Year	No. of samples	Na	Cl	F	NO_3	TDS	Conductance [a]	pH [b]
1953	9	--	31	2.2	61	350 [c]	535	--
1954	11	--	30	2.4	77	350 [c]	541	--
1955	6	--	32	3.3	153	470 [c]	725	--
1956	8	--	35	2.5	14	445	--	8.0
1957	6	65	24	2.3	38	275 [c]	426	7.5
1958	12	56	24	1.6	30	280 [c]	435	7.5
1959	5	62	26	1.4	35	320 [c]	496	7.4
1961	1	45	16	1.0	22	340	360	7.7
1962	2	70	28	1.6	53	403	480	6.9
1963	2	60	33	2.0	35	348	360	7.2
1970	2	81	40	1.4	44	374	400	7.0
1971	1	82	28	1.0	57	376	400	7.0
1972	2	75	41	3.3	53	416	430	7.1

[a] Micromhos at 25° C
[b] No units
[c] Estimated

The chemical quality of water at Pueblo 1 reflects the chemical quality of the effluent from the Pueblo Sewage Treatment Plant.

The chemical quality of water at Pueblo 2 reflects the combined release of sewage effluent from 1953 to 1964 from the Pueblo and Central Plant, and after 1964 only the release from the Pueblo Plant.

Quality of Surface Water at Pueblo 2
(Average Yearly Analyses in mg/l except as noted)

Year	No. of samples	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1953	8	--	32	1.2	42	305[c]	470	--
1954	9	--	32	1.2	60	310[c]	475	--
1955	2	--	34	2.5	64	360[c]	557	--
1956	9	--	34	2.4	26	444	--	8.2
1957	4	63	27	2.3	25	280[c]	437	7.6
1958	12	64	27	1.7	24	265[c]	409	7.8
1959	5	72	31	1.5	35	325[c]	497	7.3
1961	1	38	12	1.0	13	294	285	7.8
1962	1	61	25	1.2	30	325	320	7.2
1963	3	71	30	1.5	40	398	302	7.5
1964	2	84	31	2.0	40	390	420	7.5
1970	2	81	44	1.3	22	402	410	7.5
1971	1	72	28	.6	26	330	360	7.3
1972	2	73	39	3.3	31	363	395	7.7

[a] Micromhos at 25° C
[b] No Units
[c] Estimated

The quality of water at Pueblo 3 from 1957 through 1964 reflects return flow from Hamilton Bend Springs and flow through the alluvium. The quality of water at Pueblo 3 in 1970 through 1972 reflects mainly the quality of sewage effluent released from the Bayo Plant.

Quality of Surface Water at Pueblo 3
(Average Yearly Analyses in mg/l except as noted)

Year	No. of samples	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1957	1	48	18	2.0	20	210	320	7.9
1958	7	51	22	1.4	22	215	331	7.6
1959	5	71	32	1.6	20	310	478	7.4
1961	2	59	17	.7	18	465	440	7.7
1963	1	65	28	2.0	9	362	420	7.5
1964	2	115	47	2.0	22	455	435	7.8
1970	2	84	22	1.0	61	376	344	7.0
1971	1	74	26	1.2	66	416	380	6.9
1972	2	76	39	3.3	44	385	450	7.3

[a] Micromhos at 25° C
[b] No Units
[c] Estimated

Metal ion analyses were made of surface water from Acid Weir, Pueblo 1, Pueblo 2, and Pueblo 3 in 1971 and 1972. The analyses show some traces of metal ions.

Metal Ion Analyses
(Average of two analyses in μg/l)

Metal Ion	Acid Weir	Pueblo 1	Pueblo 2	Pueblo 3
In Solution				
Cadmium	3.3	3.7	3.9	3.2
Beryllium	.25	.25	.25	.25
Lead	3.0	2.0	3.0	5.2
Mercury	0.02	.05	.02	.14
Particulate				
Cadmium	.35	7.0	.25	.75
Beryllium	.25	.25	.25	.25
Lead	.16	7.1	2.8	11.1
Mercury	.11	.34	.06	.14

2. Radiochemical Quality of Surface Water

The treated effluents were released directly into Acid Canyon, thus the direct release of effluents into the canyon and lack of

dilution of radioactivity in the surface flow in Acid Canyon was greater than in Pueblo Canyon. The plutonium and gross beta activity generally decreased downgradient from Acid Weir in Acid Canyon to Pueblo 3 in Pueblo Canyon. Due to the "slug" type of release, the radiochemical quality varied according to the time the sample was collected.

The highest concentration of plutonium reported in Acid Canyon was 17.1 pCi/l at Acid Weir in May 1959, with Pueblo 1, 2 and 3 having plutonium concentrations of less than the limits of detection (<0.5 pCi/l). Another high period of plutonium occurred in surface water during April 1963 when the plutonium was 13.6 pCi/l at Acid Weir, <0.5 pCi/l at Pueblo 1 and <0.5 pCi/l at Pueblo 2.

Plutonium in Surface Water
(Average of a number of analyses in pCi/l)

Year	Acid Weir	Pueblo 1	Pueblo 2	Pueblo 3
1958	4.2	0.6	<.5	.7
1959	4.5	<.5	<.5	<.5
1960	0.6	--	--	<.5
1961	1.3	<.5	<.5	<.5
1962	2.0	<.5	2.7	--
1963	7.6	<.5	1.0	<.5
1964	--	--	<.5	<.5
1965	<.5	--	--	--

The highest concentrations of gross beta activity occurred in July 1959. The activity decreased from 586 pCi/l at Acid Weir to 2,610 pCi/l at Pueblo 1. The samples were collected during the decline of a release of industrial effluents.

Gross Beta in Surface Water
(Average of a number of analyses, pCi/l)

Year	Acid Weir	Pueblo 1	Pueblo 2	Pueblo 3
1958	694	75	55	326
1959	285	447	<14	<14
1960	245	--	--	27
1961	225	<14	<14	52
1962	110	<14	18	--
1963	78	<14	22	17
1964	--	--	20	22
1965	<14	--	--	--

The above concentrations of plutonium and gross beta activity reflect the changing conditions in the canyon while the industrial effluents were being released.

The radiochemical results of surface water analyses in 1970 through 1972 show the condition in the canyon when the source of the plutonium and other radionuclides in the water is due to resuspension from those nuclides previously adsorped or exchanged with ions of the alluvial materials in the channel sediments. Plutonium and gross beta activity are higher in Acid Canyon (Acid Weir) than in Pueblo Canyon. In general, the concentrations decrease downgradient in the canyon. The residual of industrial effluents is still within the Acid-Pueblo Canyon system.

Radiochemical Analyses of Surface Water 1970 through 1972
(Average of 5 analyses in pCi/l, except where noted)

	Acid Weir	Pueblo 1	Pueblo 2	Pueblo 3
Gross alpha	<3	<1	<1	<1
Gross beta	153	36	15	14
Plutonium-238	.08	.08	.05	.05
Plutonium-239	1.87	.07	.27	.06
Cesium-137	<350	<350	<350	<350
Tritium	1970	<1000	<1000	<1000
Natural Uranium[a]	1.3	1.0	1.0	1.0

[a] Micrograms per liter

C. Water in Alluvium

Stream flow infiltrates into the alluvium to maintain small bodies of water perched on the underlying tuff and Puye Formation. The water in the alluvium moves downgradient and water is lost into the tuff and fanglomerate.

The laboratory analyses indicate that the coefficient of permeability of the tuff ranges from 3×10^{-5} m/day for a welded tuff to 9×10^{-1} m/day for a nonwelded tuff. Water moving through the tuff does not completely saturate the matrix because of noncommunicating pore space which are mostly of capillary size. Infiltration of water into the tuff is considered small due to the hydrologic characteristics of the tuff. Also infiltration of water into the Tschicoma Formation is considered small due to the characteristics of the rocks (generally seen in outcrops and dense with no open fractures) and that there is very little surface water loss in the reach of the channel underlain by the Tschicoma.

The stream channel is cut down to the tuff-fanglomerate contact between observation Well PO-4A and Hamilton Bend Spring (Fig. 8). The top of the Puye Formation in this area is characterized by a water laid lens of tuffaceous sediment.

As the alluvium thins due to the resistance to erosion of the sediment, water in the alluvium is returned to the surface in the seep area at Hamilton Bend Spring. A similar resistant layer of sediments occurs at Otowi Seep.

The sediment lenses are thin and underlain by fanglomerate debris which is quite permeable. The area underlain by the Puye Formation is the major recharge area for the perched aquifer that discharges in part in Los Alamos Canyon at Basalt and Los Alamos

Springs (Fig. 6).

A series of shallow observation holes were constructed in Acid and Pueblo Canyons (Fig. 5). Drive points and corrugated metal pipe were driven or dug 4 to 6 feet into the alluvium to obtain samples of water moving through the alluvium. The observation holes in Acid Canyon were designated "AC" (AC-3, AC-4, AC-5) while the observation holes in Pueblo Canyon were designated as "PC" (PC-1, PC-2, PC-3, PC-4, PC-5, PC-6, PC-7, PC-8, PC-9, PC-10, PC-11). Collection of water samples (pumped) from these holes was dependent on stream flow for recharge, therefore at times when the stream was not flowing, the hole would be dry. Storm runoff occasionally destroyed a hole so that by 1964, most of this sampling network was gone.

In 1957, sixteen test holes were drilled up to depths of 23 m in the area of Hamilton Bend Springs for additional geologic and hydrologic information. Three were incorporated into the monitoring net PO-1A (destroyed 1967), PO-4A and PO-4B. PO-1A, PO-4A, and PO-4B were completed into the alluvium. A fourth test hole in this series, PO-3B, was completed at a depth of about 17 m in the Puye Formation, and is also used as a part of the monitoring net. Recharge is from water in the alluvium. Water in the alluvium is also discharged at Hamilton Bend Springs and Otowi Seep which are a part of the monitoring net.

1. Chemical Quality of Water in the Alluvium

Chemical quality of water in the alluvium in Acid Canyon (AC-series holes) in the period 1954 through 1964 reflects chemical quality of industrial effluents while water in the alluvium in Pueblo Canyon (PC and PO series holes) reflect the quality of

sewage effluents predominating. Surface water in the canyon recharges water in the alluvium.

The chemical quality of water in the alluvium in Acid Canyon varied markedly between sampling periods, but the water was highly mineralized. In Pueblo Canyon the chemical quality of water in the alluvium was somewhat better, having a lower fluoride ion and nitrate concentration and a slight decrease in mineral concentration as shown by a decrease in conductance.

The trends or significant changes in the chemical quality of water as it moves downgradient through the alluvium in Acid and Pueblo Canyons is partly obscured by the dilution effect of snowmelt and storm runoff, changes in volume of effluent released from the sewage treatment plants, slug-type release of water from the industrial waste treatment plant, and changing of effluents released from both sewage and industrial plants. The chemical quality of water in Acid Canyon was unstable due to the high pH. In Pueblo Canyon the pH of the water in the alluvium decreased abruptly to an average pH of 7.5 or less. A general trend, however, during the period of operation of the industrial plant indicates that the chemical quality of water generally improves downgradient in the canyon. The quality of water was best during the winter and early spring when stream flow is at a maximum due to increased release of sewage effluents and snowmelt, and poorest during the late spring and early summer when sewage effluent release and storm runoff is at a minimum.

Chemical Quality of Water in Alluvium in Acid and Pueblo Canyons 1954 through 1965
(Average of a number of analyses in mg/l except as noted)

Observation Hole	No of analyses	CL	F	NO_3	TDS	Conductance[a]	pH[b]
AC-3	25	30	3.4	38	481	590	10.4
4	29	38	4.4	35	765	665	10.0
5	8	26	3.0	65	553	610	9.6
PC-1	24	27	1.8	22	300[c]	460	7.5
2	31	28	2.2	28	542	505	7.4
3	29	27	2.3	33	430	495	7.5
4	23	30	1.9	40	432	485	7.3
5	9	32	1.8	42	315[c]	485	7.3
6	37	25	1.3	12	373	380	7.4
7	21	30	1.6	28	338	470	7.4
8	16	29	1.1	36	275[c]	425	7.4
9	25	29	1.2	16	430	370	7.4
10	30	27	1.4	19	379	350	7.3
11	13	29	1.5	28	361	390	7.2
PO-1A	9	27	1.2	7	327	380	7.4
PO-4A	15	25	1.7	23	318	400	7.1
PO-4B	10	28	.9	10	330	370	7.2
Hamilton Bend Springs	31	30	.8	18	336	405	7.5
Otowi Seep	4	33	1.6	2	275[c]	422	7.5
PO-3B[d]	7	13	0.4	6	190	200	7.2

[a] Micromhos at 25° C
[b] No Units
[c] Estimated
[d] Completed in Puye Formation

Monitoring of water in the alluvium during the period 1970 through 1972 was performed at Observation Holes PO-4A and PO-4B and at Hamilton Bend Springs. The chemical quality of the surface water in the canyon which recharges the water in the alluvium.

Quality of Water in the Alluvium 1970 through 1972
(Average of several analyses)

Station	PO-4A	PO-4B	Hamilton Bend Spr.	PO-3B[a]
No. of Samples	3	1	4	5
Chemical (mg/l)				
Calcium	21	12	17	27
Magnesium	5	10	7	10
Sodium	63	66	72	28
Carbonate	0	0	0	0
Bicarbonate	85	116	118	76
Chloride	35	30	38	32
Fluoride	2.5	1.0	2.5	4.0
Nitrate	34	6	16	2.1
Dissolved Solids	344	299	423	281
Total Hardness	73	70	68	107
Conductance[b]	347	360	367	270
pH[c]	7.2	7.0	7.6	7.0

[a] Completed in Puye Formation

[b] Micromhos at 25° C

[c] No Units

Metal ion analyses were made of water from PO-4A and Hamilton Bend Springs. Traces of metal ions in the water are a bit lower than found in surface water in the canyon.

Metal Ion Analyses
(Average of a number of analyses in μg/l)

	PO-4A	Hamilton Bend Spr.	PO-3B
No of Analyses	1	1	2
In Solution			
Cadmium	1.1	.18	15
Beryllium	<.25	<.25	<.25
Lead	3.5	4.5	3.0
Mercury	.13	<.02	.25
Particulate			
Cadmium	.68	.72	5.8
Beryllium	<.25	<.25	<.25
Lead	4.5	4.8	18
Mercury	.27	<.02	.8

2. Radiochemical Quality of Water in the Alluvium

Water in the alluvium is recharged directly from stream flow; thus as with the surface water, concentrations of plutonium and gross beta activity were highest in Acid Canyon due to the direct release of effluents and lack of dilution by sewage effluents which occurs in Pueblo Canyon. In general, as with the surface water, the concentrations of radionuclides decrease downgradient in the canyons.

Plutonium in Water in the Alluvium, 1958 through 1964
(Average of a number of analyses in pCi/l)

Years	1958	1959	1960	1961	1962	1963	1964	1965
Station								
AC-3	5.3	2.9	<.5	--	14.6	18.2	--	--
AC-4	1.9	41.9	4.0	1.3	--	--	--	--
AC-5	4.9	--	<.5	--	--	--	--	--
PC-1	<.5	<.5	--	--	--	--	--	--
PC-2	<.5	10.9	--	--	--	--	--	--
PC-3	1.3	<.5	<.5	<.5	--	--	--	--
PC-4	.5	<.5	--	--	<.5	<.5	--	--
PC-5	.5	.5	--	--	--	--	--	--
PC-6	1.8	<.5	<.5	<.5	<.5	.9	.8	
PC-7	<.5	<.5	--	--	--	--	--	--
PC-8	<.5	<.5	--	--	--	--	--	--
PC-9	.7	<.5	--	--	<.5	<.5	<.5	--
PC-10	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
PC-11	--	<.5	<.5	2.7	<.5	<.5	.9	<.5
PO-1A	1.9	<.5	<.5	--	--	--	<.5	--
PO-4A	<.5	<.5	<.5	--	--	--	<.5	<.5
PO-4B	<.5	<.5	<.5	--	--	--	--	<.5
Hamilton Bend Springs	<.5	<.5	<.5	<.5	<.5	1.0	.9	--
Otowi Seep	<.5	<.5	<.5	--	3.8	<.5	.8	<.5
PO-3B	<.5	<.5	<.5	—	<.5	<.5	<.5	—

Gross Beta in Water in the Alluvium 1958 through 1965
(Average of a number of analyses, analyses in picocuries per liter)

Year	1958	1959	1960	1961	1962	1963	1964	1965
Station								
AC-3	788	347	1260	---	108	260	---	---
AC-4	810	621	165	198	---	---	---	---
AC-5	1080	---	---	---	---	---	---	---
PC-1	<14	<14	<14	---	---	---	---	---
PC-2	26	<14	---	---	---	---	---	---
PC-3	28	22	15	135	---	---	---	---
PC-4	337	<14	---	---	900	22	---	---
PC-5	<14	<14	---	---	---	---	---	---
PC-6	32	<14	16	90	<14	31	<14	---
PC-7	260	<14	---	---	---	---	---	---
PC-8	98	<14	---	---	---	---	---	---
PC-9	53	<14	---	---	<14	48	<14	---
PC-10	<14	<14	<14	48	17	31	<14	<14
PC-11	---	144	<14	<14	<14	16	57	<14
PO-1A	268	<14	<14	---	---	---	18	
PO-4A	69	<14	<14	---	---	---	<14	<14
PO-4B	27	<14	<14	---	---	---	---	<14
Hamilton Bend Springs	<14	<14	<14	<14	<14	<14	<14	<14
Otowi Seep	38	<14	<14	---	<14	87	<14	---
PO-3B		<14	<14	<14	---	<14	<14	---

[a] Six analyses, Gross beta reported 3/58, 1270 pCi/l; 5/58, 189 pCi/l, 6/58 14 pCi/l.

The maximum concentration of plutonium in water in the alluvium was 180 pCi/l from hole AC-4 in May of 1959. Gross beta

Radiochemical Analyses of Water in the Alluvium
1970 through 1972
(Average of a number of analyses in pCi/l)

Station	PO-4A	PO-4B	Hamilton Bend spr.	PO-3B
No. of Analyses	3	1	4	5
Gross alpha	1	4	2	1
Gross beta	6	10	6	6
Plutonium 238	.05	.05	.05	.08
Plutonium-239	.06	.05	.06	.06
Cesium-137	350	350	350	350
Tritium	1,100	1,100	1,200	15,000
Total Uranium[a]	1.2	0.5	1.1	0.7

[a] Micrograms per liter.

Effluent from the Bayo Plant covered the return flow from Otowi Seep. Radiochemical analyses from the three stations were background with the exception of trace amounts of plutonium-239 and tritium reported in one sample from PO-4A and Hamilton Bend Spring.

D. Radiochemical analyses of Sediments

Samples of sediments have been collected in Acid and Pueblo Canyons from 1954 to the present to determine the amount of adsorption of radionuclides with the sediment materials.

Particle size distribution of the sediments at stations are shown on the following table.

Particle Size Distribution of Sediments

Grade	Distribution (Percent by weight)						
Granules	AC-4	Acid Weir	PC-1	PC-5	PC-7	PC-9	Rd. 4
Sand	4.5	6.5	3.0	10.5	5.0	2.0	1.0
Very Coarse	47.0	42.5	36.5	34.5	28.0	10.0	17.0
Coarse	44.0	39.5	50.5	37.0	31.0	40.0	50.5
Medium	2.0	6.0	7.0	11.0	19.0	21.0	19.0
Fine	1.0	1.5	1.0	3.0	11.5	9.5	7.0
Very Fine	1.0	1.0	.5	1.5	2.5	6.5	2.0
Silt and Clay	.5	3.0	1.5	3.0	3.0	11.0	3.5

Sediments from the channel at AC-4 and Acid Weir were derived from the Bandelier Tuff. In Acid Canyon sediments from PC-1, PC-5, PC-7, PC-9 and at State Road 4 were derived from the Tschicoma Formation and Bandelier Tuff. Sediments from PC-9 and at State Road 4 may contain some reworked material from the Puye Formation.

Samples of sediments collected from the stream channel in the period 1954 through 1961 when the industrial plant was in operation were analyzed for gross alpha and gross beta activity. The gross alpha and gross beta activity increased in October 1958 due to a release of untreated effluents. The gross alpha and beta activity was considerably lower in Pueblo Canyon than in Acid Canyon. In general the activity decreased with increased distance from the effluent outfall above AC-3. There is no apparent build up of radionuclides in the sediments in Acid Canyon due to the sediment transport by storm runoff which moves the radionuclide attache to the sediments downstream dispersing them over a larger area.

Gross Alpha Activity of Sediments from Acid and Pueblo Canyon
1954 through 1961 (Analyses in picocuries per dry gram)

Location	1954	1955	1956	1957	1958	1959	1960	1961
AC-3	1600	2600	34	390	2900	360	120	130
AC-4	320	500	140	170	1600	220	67	40
AC-5	190	---	120	64	52	100	57	37
Acid Weir	---	---	---	---	34	50	48	220
Pueblo 1	35	---	2	---	11	5	3	57
PC-2	16	---	3	---	6	9	3	20
PC-4	52	---	---	---	3	---	41	10
PC-5	9	---	---	---	----	4	11	11
PC-6	4	---	---	---	---	4	9	10
PC-7	54	---	---	---	---	2	5	120
PO-4A	---	---	---	---	---	4	2	33

Gross Beta Activity of Sediments from Acid and Pueblo Canyon
1954 through 1961
(Analyses in counts per minute per dry gram)

Location	1956	1957	1958	1959	1960	1961
AC-3	360	370	11,320	990	1500	70
AC-4	142	70	10,440	290	730	60
AC-5	11	90	440	155	480	120
Acid Weir	---	---	830	107	340	3650
Pueblo 1	<1	---	120	50	<1	120
PC-2	17	---	120	7	40	20
PC-4	---	---	370	---	90	<1
PC-5	---	---	---	---	<1	<1
PC-6	---	---	----	60	20	10
PC-7	---	---	---	10	40	190
PO-4A	---	---	---	20	70	<1

The radionuclides adsorbed on the sediments are also dispersed throughout the canyons by the intermittent release of industrial effluents and sewage effluents released into the canyon.

On November 24 and 25, 1965 a series of sediment samples from Acid and Pueblo Canyons were analyzed for gross alpha, beta, and gamma activity.

Radiochemical Analyses of Sediments, November 1965
(Analyses in counts per minute per dry gram)

Location	Gross Alpha	Gross Beta	Gross Gamma
AC-3	27	5	<1
Acid Weir	22	20	6
PC-1	1	19	16
PC-5	1	6	<1
PC-7	3	<1	30
PC-9	3	32	6
Road 4	4	9	14

The gross alpha activity decreases downgradient while there appears to be no pattern for the distribution of gross beta and gamma activity.

On April 16, 1970 another set of samples were collected of sediment in Acid and Pueblo canyons. Analyses indicated residual gross alpha, beta, and plutonium-239 in Acid Canyon. In general concentrations decreased downgradient from the effluent discharge points.

Radiochemical Analyses of Sediments, April 1970
(Analyses in picocuries per dry gram)

Location	Gross Alpha	Gross Beta	Gross Gamma	Pu238	Pu 239
AC-4	41	11	7	0.19	29.0
Acid Weir	36	14	7	.21	25.0
PC-1	2	2	<1	<.001	.04
PC-2	8	2	2	.08	4.9
PC-5	8	12	<1	.011	4.6
PC-7	4	2	<1	<.001	1.2
PC-9	1	<1	<1	<.001	.40
Road 4	3	4	<1	.006	1.1

Additional samples were collected and analyzed from two stations in 1971 and 1972. One of the stations is in the middle reach of the canyon (PC-6), and the other is at the above boundary discharge point at State Road 4. All theree analyses at the two stations show residual gross alpha, beta, and plutonium-239 which was released into the canyon from the treatment plant prior to 1965. The plutonium is bound to sediments in the stream channel and is subject to transport as suspended or bed load material during periods of storm runoff.

Radiochemical Analyses of Sediments 1971 and 1972
(Analyses in picocuries per dry gram, except as noted)

	PC-6			State Road 4		
	5-7-71	10-14-71	10-11-72	5-7-71	10-14-71	10-11-72
Gross Alpha	7	10	<1	2	4	<1
Gross Beta	2	2	4	2	2	4
Plutonium-238	.016	.007	.012	.006	.001	<.002
Plutonium-239	2.93	2.20	2.55	.761	.391	.370
Cesium-137	--	<1.5	3.4	--	<1.5	3.9
Natural Uranium[a]	0.19	.22	.42	.12	.10	.32

[a] micrograms per gram

E. Inventory of Plutonium in Channel Sediments

The four sections of the channel in the canyon considered in the inventory are the section in Acid Canyon from the old outfall at TA-45 to the confluence with Pueblo Canyon, (0-480 m) and three sections in Pueblo Canyon from that point to the confluence with Los Alamos Canyon (480 to 10,280 m) as shown on Fig. 8. The physical characteristics of the four sections of channel are shown as follows:

Physical Characteristics of Channel
Acid-Pueblo Canyon

1. 0 to 480 m (Acid Canyon)
   Width 1.5 m Depth 0.15 m
   Sp. g. 1.57 Weight 170 x 10^6 g

2. 480 m to 2,600 m
   Width 2.5 m Depth 0.15 m
   Sp. g. 1.57 Weight 1,790 x 10^6 g

3. 2,600 m to 6,800 m
   Width 2.5 m Depth 0.15 m
   Sp. g. 1.57 Weight 2,967 x 10^6 g

4. 6,800 m to 10,280 m (Confluence)
   Width 4 m Depth 0.15 m
   Sp. g. 1.57 Weight 3,278 x 10^6 g

The computation showed the concentrations and amounts of plutonium at each section of the canyon for February 1970 and October 1972, and are presented in the following table.

A. Acid-Pueblo Canyon (February, 1970)

Section	Station	Concentration µCi/g	Concentration Ave	Total Pu mCi	% of Total Pu
0- 480	AC4	29.1			
	Acid Weir	24.8	27.0	4.6	25
480- 2,600	PC-2	4.98			
	PC-5	4.71	4.84	8.7	48
2,600- 6,800	PC-7	1.15			
	PC-9	.398	.775	2.3	13
6,800-10,280	PC-9	.398			
	SR-4	1.14	.770	2.5	14
Total		--	--	18.1	100

B. Acid-Pueblo Canyon (October, 1972)

Section	Station	Concentration µCi/g	Concentration Ave	Total Pu mCi	% of Total Pu
0- 480	AP-1	2.5			
	AP-2	2.3			
	AP-3	6.9			
	AP-4	50			
	AP-5	13			
	AP-6	12			
	AP-7	11	14.0	2.4	21
480- 2,600	AP-8	2.1			
	PC-5	2.6	2.4	4.3	37
2,600- 6,800	AP-9	.36			
	AP-10	1.2	.78	2.3	20
6,800-10,280	AP-10	1.2			
	SR-4	.37	.78	2.6	22
Total		--	--	11.6	100

The recap of the plutonium inventories in the canyon is presented as follows, for comparison.

Section (m)	Total Plutonium (mCi) Feb. 1970	Total Plutonium (mCi) Oct. 1972
0- 480	4.6	2.4
480- 2,600	8.7	4.3
2,600- 6,800	2.3	2.3
6,000-10,280	2.5	2.6
Total	18.1	11.6

The inventory in Acid-Pueblo Canyon indicates that form the outfall to the confluence with Los Alamos Canyon, in February, 1970 only 18.1 or 11% of the 170 mCi of plutonium released into the canyon remains in the sediments. In October, 1972, only 11.6 mCi or 7% remained of the 170 mCi. The largest changes occur in the upper sections of the canyon (0-2600 m) which contain the greatest amounts of plutonium. The amounts in the lower section (2600 to 10,280 m) appear to be somewhat in equilibrium, with the input transport equal to output. for the two years of data the transport is about 3.25 mCi per year.

F. Flood Frequency and Maximum Discharge

Acid Canyon heads on the Pajarito Plateau at an altitude of about 2,220 m and has a drainage area of about 0.8 km^2. It is tributary to Pueblo Canyon on the western part of the Pajarito Plateau. Pueblo Canyon heads on the flanks of the Sierra de los Valles at an altitude of about 2,7400 m and has cut a deep canyon into the Pajarito Plateau.

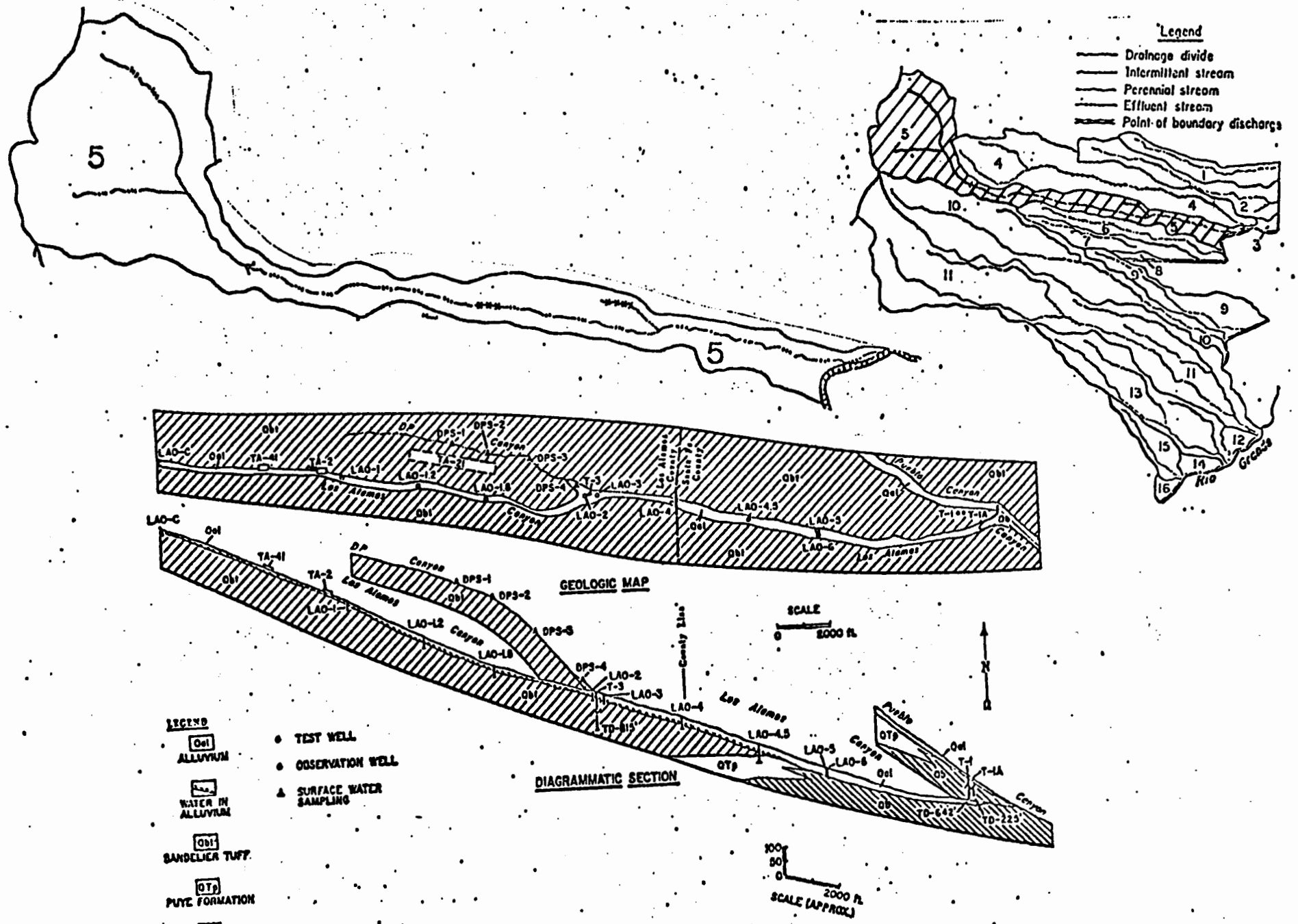
The flood-frequency and maximum discharge at the boundary are based on the following data:

Drainage Area	22.3 km^2
Main Channel Slope	-0.33

Frequency	Maximum-Discharge (m^3/sec)
2-year	3.1
5-year	7.1
10-year	10
25-year	17
50-year	21

VI DRAINAGE AREA V (LOS ALAMOS-DP CANYONS)

Los Alamos Canyon drainage area extends to the drainage divide on the flanks of the Sierra de los Valles and enters the Rio Grande to the east near Otowi (Fig. 9). Major tributaries are Pueblo Canyon just east of the AEC boundary and DP Canyon near the center of the plateau. DP Canyon is of prime importance, as an industrial treatment plant releases low level radioactive effluents into the canyon. The alluvium in the canyon is thin in the upper reaches and thickens eastward to about 20 feet near the eastern edge of the plateau. The alluvium is underlain by tuff in the western and central part of the canyon and conglomerate and basalt in the eastern part.



LOS ALAMOS AND DP CANYONS

Area 5 (DP-Los Alamos Canyons) showing geology and

In the upper reach on the flanks of the mountains, perennial surface flow occurs. A part is impounded at Los Alamos Reservoir and is used for lawn irrigation at parts of the Laboratory in a system that is independent of the municipal water supply.

Surface flow in the canyon across the plateau is intermittent. There is some release of water from the TA-41 cooling tower and sewage effluent from TA-2 and TA-41. Storm runoff in the canyon during the summer may reach the Rio Grande. The sewage effluent, water from the cooling tower, and storm runoff maintain, along with inflow of water in the alluvium from DP Canyon, recharge the water in the alluvium that is perched on the tuff (Fig. 9). As the water in the alluvium moves downgradient some is lost to evapotranspiration while the rest moves into the underlying tuff, conglomerate, and basalt. The major area of loss of water in the alluvium occurs in the lower reach of the canyon on the plateau where the alluvium is underlain by conglomerate and basalt. Infiltration of water from the alluvium into the conglomerate and basalt replenishes the body perched in the basalt in Pueblo Canyon. The water from the perched zone discharges from the base of the basalts (Basalt Spring) in Los Alamos Canyon to the east (Fig. 9).

DP Canyon heads on the plateau and has a small drainage area. The canyon is tributary to Los Alamos Canyon near the center of the plateau. The alluvium in the upper reach of the canyon is thin or non-existent; however, in the lower reach of the canyon the alluvium thickens rapidly to about 6 m at the junction with

Los Alamos Canyon. The canyon is cut into and underlain by tuff.

Initial disposal of liquid waste at TA-21 was into seepage pits dug into the tuff near the head of the canyon. In 1952, a treatment plant was constructed and put into operation. The plant processed 7.5 x 10^3 m^3 of liquid waste are released into DP Canyon along with the sewage effluent.

Treated sewage effluent is released into the canyon from the plant at the eastern edge of TA-21. The stream flow in the canyon is intermittent. Intermittent flow consists of industrial and sewage effluents and storm runoff. The industrial and sewage effluent maintains an intermittent stream which infiltrates into the alluvium in the lower reach of the canyon. Only during storm runoff in the canyon does surface flow reach Los Alamos Canyon.

A. Sewage and Industrial Treatment Plants

Sewage from Technical Area 21 is treated prior to release into DP Canyon at a plant near the eastern edge of the area. The oldest waste treatment or retention facilities for industrial effluents have been located at TA-21. Wastes have been handled by three different methods in the period 1943 through 1972.

1. Sewage Treatment Plant

The sewage treatment plant treats and releases about 30 x 10^3 m^3 of effluent per year. The plant services the facilities at TA-21 and enters the canyon between sampling stations DPS-3 and DPS-4 (Fig. 9).

2. Seepage Pits for Industrial Effluent

The seepage pits near Building 35 are the oldest used for the disposal of liquid wastes at Los Alamos. Wastes from the processing

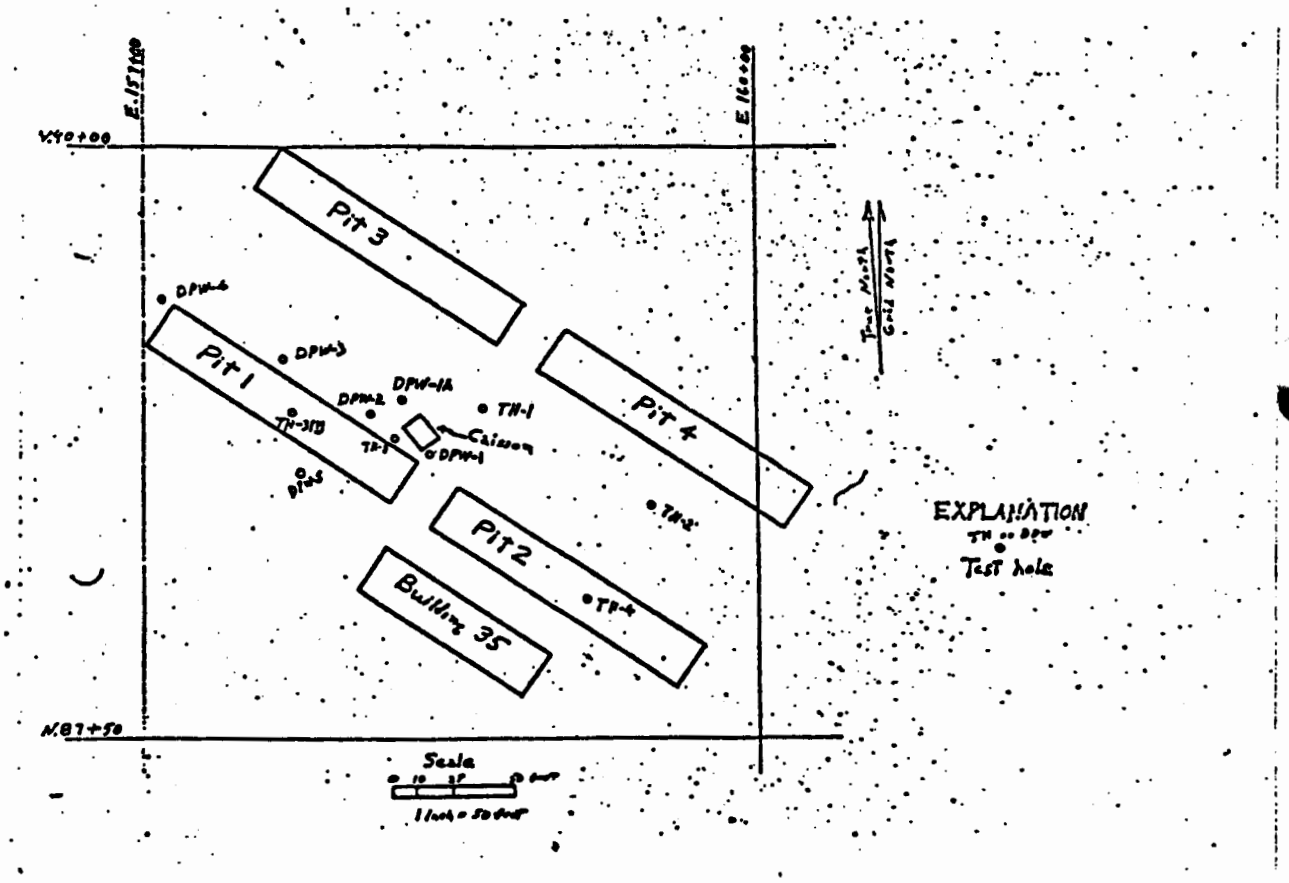


Fig. 10. Seepage pits for industrial effluents.

of plutonium at TA-21 were released into pits during the period 1943 to 1952. The use of the pits was discontinued in 1952 when a treatment plant (Building 35) was installed to remove plutonium and other radionuclides. The effluents from the plant are released into DP Canyon, a southeast trending canyon north of the pit area.

The disposal area consists of 4 pits that are about 365 m long, 60 m wide and about 2 m deep (Fig. 10). The pits are filled with about 1.2 m of sand, gravel and boulders with berms extended around the individual pits. Effluents were released through a distribution system into pits 1 and 2 and through overflow pipes into pits 3 and 4 respectively. In January 1967 the outline of the gravel portion of the pits was obscured by the growth of grasses and weeds and erosion of the berms. A new road has covered part of Pit 1 and construction has destroyed some of the berm around Pit 3.

The pits are probably excavated into Unit 3 of the Tshirege Member of the Bandelier Tuff. The lower part of this unit is nonwelded tuff grading up into a moderately welded tuff which underlies the pits. Joints are more numerous in the upper part of the unit due to the denser welding. Most of the joints are oriented vertical or near vertical. The total thickness of the unit is about 34 m. It is underlain by a moderately to densely welded tuff.

The total thickness of the Bandelier Tuff underlying the mesa at Building 35 exceeds 240 m. The tuff is in the zone of areation; the top of the main zone of saturation is about 350 m below the surface of the mesa.

The amount of effluents released into the pits during the period 1943 to 1952 has been estimated to range from 7.5×10^3 to 11×10^3 m^3 a year. The concentration of plutonium in the effluents during this period has been estimated at 60 c/m/ml (counts per minute per milliliter) with an average fluoride concentration (associated with the wastes) of 160 ppm (parts per million). In addition, 39.5 m^3 of effluent highly concentrated with ammonium citrate was released into the pits from June 1951 to July 1952. The plutonium concentration of this waste averaged about 7,000 c/m/ml and the fluoride concentrations were about 200 ppm.

The pits were not used from 1952 to January 1965. Since January 1965, pits 1 and 2 have received an average of 280 m^3 gallons a month or a total of 6.8×10^3 m^3 of low level radioactive effluent from DP-East.

A study was made in 1953 to determine the retention characteristics of the tuff with regard to plutonium while another study was made in 1961 to determine the movement of plutonium in the tuff.[14] The results of these studies are summarized in the following sections.

a. Retention of Plutonium in the Tuff

Five test holes were drilled in and around the pits in 1953. Material from the test holes was analyzed to determine the relative amounts of plutonium and the ion exchange capacities of tuff adjacent to and underlying the pits. Location of test holes are shown in Fig. 10. The exact location of the TH-3 in pit 1 is unknown. Plutonium and ion exchange capacities of the tuff are shown in the following tables:

Plutonium in Tuff from Test Holes, 1953

TH-1 Depth (m)	TH-1 Plutonium (d/m/g)[a]	TH-2 Depth (m)	TH-2 Plutonium (d/m/g)[a]	TH-3 Depth (m)	TH-3 Plutonium (d/m/g)[a]
Surface	70	Surface	9	Surface	8
0.6	4	0.6	3	0.3	400
1.2	4	1.2	2	0.6	36,100
1.8	4	1.8	2	0.9	45,600
1.8 to 3.0	2	2.4	1	3.6	1,400
3.0 to 4.3	2	3.0	4	4.6	5,000
4.6	4	3.6	3	4.9	5,100
		4.3	3	5.2	720
		4.9	4	5.5	24
		5.5	2	5.8	12
		6.1	3	6.1	12

TH-1 Depth (m)	TH-1 Plutonium (d/m/g)[a]	TH-5 Depth (m)	TH-5 Plutonium (d/m/g)[a]
Surface	410	Surface	32
0.3	600	0.6	9
0.6	10	1.2	8
0.9	80	1.8	4
1.2	3,400	2.4	3
1.5	530	3.0	2
1.8	80	3.3	2
2.1	1,800	3.6	450
2.4	40	3.8	1,510
2.7	380	4.0	1,330
3.0	2,400		

[a] Disintegrations per minute per gram.

[b] Angle hole, point of intersection with pit.

Note: TH-1 and TH-2 are vertical holes in earth filled berm.
TH-3 and TH-4 are vertical holes in pits.
TH-5 is angle hole of 45 degrees extending under pit.

Ion Exchange Capacity

TH-3 at 5.5 m 0.7 milliequivalent per 100 grams
TH-4 at 1.5 m 3.2 milliequivalent per 100 grams
TH-5 at 3.7 m 1.7 milliequivalent per grams

It was concluded from the study that plutonium is readily retained by the various earth media (clay, sand, and gravel) and that

Vertical or near vertical holes around pit

Hole No.	No. of Samples	Depth (m)	Gross alpha[a] (Avg.)	(Max.)	(Min.)
1	10	23	2	3	1
1-A	10	25	24	24	9
2	11	28	698	3,722	142
3	11	30	3	7	2
4	13	30	1.5	2	1
5	7	28	3	6	1

a/ Counts per minute per gram.
Note: Hole DPW-1A angled at 11 1/2 degrees toward pit 1
Hole DPW-2 angled at 19 degrees toward pit 1.

C. Observations January 1967

Effluents from DP-East have at times partially filled the shaft near Pit 1, thus creating a more localized point for infiltration of liquids (Fig. 10). Test holes DPW-1A and DPW-3 contained some effluent at the time of observation. It is supposed that the water in DPW-3 moved down the outside of the casing from water ponded in the pit. Radiochemical analyses of water from these holes contained only background amounts of gross alpha and gross beta gamma radioactivity and no plutonium or uranium. Results of analyses of water for tritium shown below are approximations and are subject to revision.

DPW-1A -- 462 dpm
DPW-3
Effluent running into shaft - 2,000 dpm

A sample of weathered tuff collected beneath the gravel fill of pit 1 near the shaft contained 978 c/m/g (counts per minute per gram) of gross alpha radioactivity.

The January 1967 measurements of hole DPW-1 show the effect of the 1.9 million gallons of effluent from DP-East in which the maximum concentrations of water have moved from a depth of 3.7 m (40 percent, August 1961) to 12 m (41 percent, January 1967). The hole is next to the shaft. The moisture measurements in DPW-2 and DPW-5 show a general decrease in the moisture content of the tuff from August 1961 to January 1967. The indication is that most of the effluents released into pit 1 have moved down in the area of the shaft, a focal point for collection and infiltration of effluents into the tuff.

The studies have shown that the movement of the effluents in the tuff underlying the seepage pits is mostly downward beneath the pits. The plutonium moves with the effluents and the data indicate that most of the plutonium is retained by absorption in the upper 6.1 m of the tuff. Some, however, may move to greater depths through open joints.

The construction of a solid waste disposal pit in the area may necessitate the drilling of several holes to determine the amount of contamination present as well as the structure and lithology of the underlying rock. The number and depth of the holes would depend on the size, depth, and location of the proposed pit.

3. Industrial Treatment Plant Bldg. 35.

The industrial waste treatment plant at Bldg. 35 operated from 1952 to late 1967. The treatment plant was similar to that operated at TA-45. The treatment was virtually the same, with plutonium and americium the major contaminates. Many wastes from this area contained high concentrations of inert salts that would

interfere with the usual treatment of plutonium and americium wastes. These wastes were treated separately. Chemical wastes, such as hydrofluoric acid used in processing plutonium, were neutralized and discharged with other effluents from the plant into DP Canyon.

The sludge at Bldg. 35 was also packaged and buried in the solid disposal pits on the mesa. The plant has a somewhat smaller capacity than that at TA-45 with an annual discharge into DP Canyon of 7.5×10^3 m^3 to 15×10^3 m^3. After 1967, operations were transferred to a new plant at Building 257.

4. Industrial Treatment Plant Bldg. 257

The new plant at Bldg. 257 began operation in late 1967 and had a slightly greater capacity for treatment of effluents that the old plant at Bldg. 35. The treatment of the liquid wastes was essentially the same with some modification of newer equipment such as pressure type filters rather than gravity flow and some changes in filter media.

A new process introduced at the plant was the treatment and disposal of sludges resulting from chemical and physical treatment.

The sludge from the plant is fed through a pug mill that mixes the sludge with cement with the resulting slurry pumped into shafts adjacent to the plant. Other wastes containing high concentrations of chemicals or radionuclides may be processed along with the sludges for disposal. The cement sets up, fixing the contaminants in the cement.

The shafts 2.4 m in diameter range in depth from 5.5 to 19.5 m. They are located in berm areas adjacent to old seepage pits (Fig. 11). The shafts are completed into the ashflow units

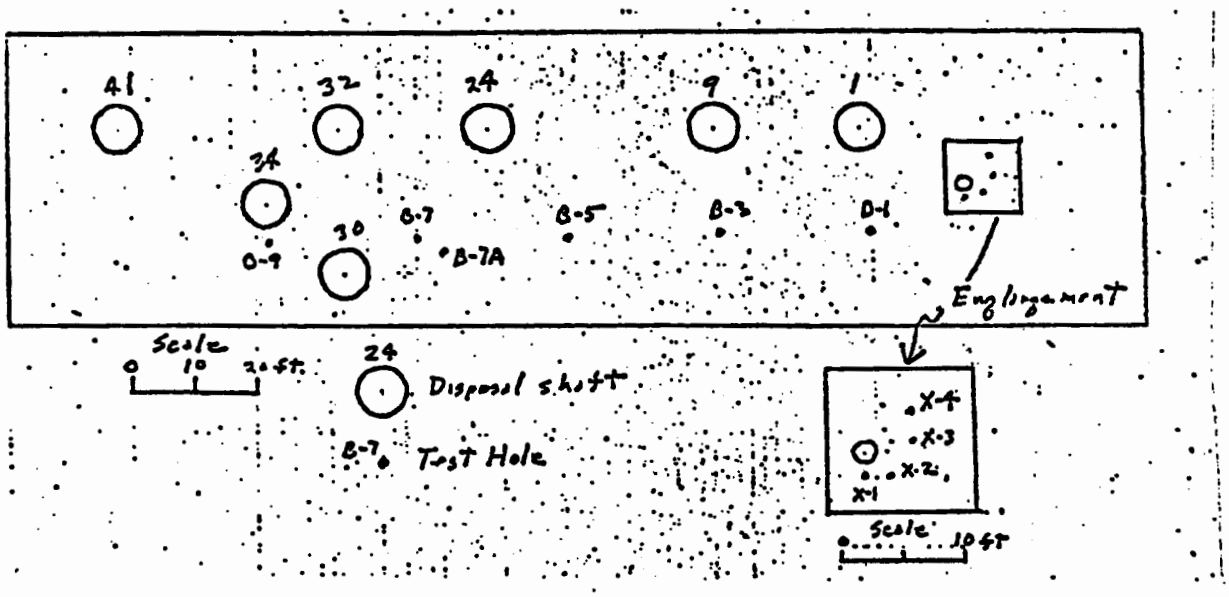


Fig. 11. Shaft disposal area for sludges fixed in cement.

of the Tshirege Member of the Bandelier Tuff.

a. Radiochemical Analyses of Tuff from Test Holes and Shafts

Samples of tuff were collected from the wall of shafts as they were being dug and analyses were made of moisture for tritium.

Tritium Analyses of Moisture from Samples of Tuff from Test Holes and Shafts

Source	Number of Samples	Average of a number of analyses Picocuries per milliliter Tritium
Test Hole B-1	11	88
Test Hole B-3	11	317
Test Hole B-5	11	183
Test Hole B-7	11	4336
Test Hole B-9	10	501
Shaft 1	10	5420
Shaft 9	6	1480
Shaft 24	4	4887
Shaft 30	3	5397
Shaft 32	2	1306
Shaft 34	8	2192
Shaft 41	7	495

The tritium has moved with the moisture from the old seepage pits into the tuff. The tuff is not saturated. There is no free water, as the tuff has a larger porosity made up mostly of capillary size pores. Where there is a moisture gradient, the moisture will tend to move to the lower moisture concentration by diffusion and capillary action.

5. Chemical Quality of Sewage and Industrial Effluents

- Samples of effluent from the sewage treatment plant were collected immediately below the effluent outfall for chemical analyses. The individual analyses varied slightly but were in the same general range in the few analyses shown. The effluents contained chemical concentrations as one would expect from sewage treatment plants. The effluents are similar to the Pueblo and Bayo Plants.

Chemical Analyses of Sewage Effluent

(Analyses in mg/l except where noted)

Determinations	12-5-67	5-5-69	8-5-69
Calcium	20	16	16
Magnesium	12	4	7
Sodium	160	230	175
Carbonate	0	0	0
Bicarbonate	280	394	190
Chloride	35	50	35
Fluoride	3	2	4
Nitrate	.9	1.3	13
Dissolved Solids	383	458	442
Total Hardness	100	55	70
Specific Conductance[a]	580	800	520
pH[b]	7.5	7.4	8.2

[a] Microhms

[b] No units

The chemical quality of effluent released from the industrial plant varied due to the changing quality of water received. In general, the effluents released into the canyon were highly

mineralized as compared to natural occurring water in the area. The table shows one weekly composite collected during the first week of July for each year, 1960 through 1972.

Chemical Quality of Industrial Effluents[a]

(Analyses in mg/l except where noted)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	197
Calcium	4	1	2	4	4	44	64	56	22	8	26	8	1
Magnesium	2	1	<1	1	1	1	2	10	<1	<1	29	2	
Sodium	532	485	423	272	413	195	270	690	280	340	270	490	68
Carbonate	314	560	428	118	690	315	1740	130	37	300	300	260	11
Bicarbonate	478	626	558	296	920	430	2036	210	212	505	420	910	79
Chloride	370	405	234	290	665	45	178	598	72	40	113	55	9
Fluoride	60	140	20	30	140	0.9	15	15	11	44	7	20	
Nitrate (N)[b]	67	25	5	10	26	13	104	23	45	34	11	48	1
Total Hardness	16	7	6	12	15	115	170	180	54	20	185	30	
Conductance[c]	1600	4000	1860	2000	5600	1880	4400	3200	900	2140	2260	2240	27
pH[d]	11.3	11.8	11.4	10.9	12.1	11.7	12.0	11.4	9.8	11.5	11.5	10.3	8

[a] Weekly Composite 1st week of July of year noted

[b] Micromhos

[c] No Units

[d] n x 4.4 = NO_3

6. Radiochemical Quality of Sewage and Industrial Effluent

Radiochemical analyses was made of effluent from the sewage treatment plant. The samples were collected below the effluent outfall. Traces of americium were found in the samples collected on 8-5-69 and 7-16-70. The presence of trace amounts of americium and plutonium may be due to some contamination getting into the sewage collection system from laboratories at TA-21 processing or working with these isotopes.

Radiochemical Analyses of Sewage Effluent

(Analyses in picocuries per liter)

Determination	12-5-69	5-5-69	8-5-69	2-16-70
Gross Alpha	3	3	< 2	3
Gross Beta	14	20	13	14
Plutonium 238	<.05	<.05	<.05	.16
Plutonium 239	<.05	<.05	<.05	.14
Americium 241	--	--	.07	.08
Radium 226	<.15	--	--	
Tritium	<50,000	<50,000	<50,000	8,000

The volume of effluent from the waste treatment plant at TA-21 has ranged from 6228 to 16,220 m^3 annually. The major waste treated contained plutonium and americium with some mixed fission products.

Average Annual Concentrations Gross Alpha, Gross Beta, and Total Plutonium in Effluents Released

Year	Volume (m^3)	Picocuries per liter Gross Alpha	Gross Beta	Total Pu
1952	16220	--	--	20
1953	14400	76	--	76
1954	11520	88	--	88
1955	9436	120	--	100
1956	11690	68	--	65
1957	16170	66	--	64
1958	9987	58	--	56
1959	9138	107	--	92
1960	8408	227	--	206
1961	9251	626	--	582
1962	11660	309	--	251
1963	12150	2800	--	174
1964	6228	26	--	181
1965	9594	140	--	103
1966	10920	93	--	81
1967	7832	290	--	290

Average Annual Concentrations Gross Alpha, Gross Beta, and Total Plutonium in Effluents Released (Continued)

Year	Volume (m^3)	Picocuries per liter Gross Alpha	Gross Beta	Total Pu
1967[a]	3509	--	--	22
1968	11360	450	2700	140
1969	13290	220	4700	120
1970	10850	--	4700	140
1971	9839	--	3100	72
1972	8780	--	1800	148

[a]1952-1967 Bldg. 35
1967-1972 Bldg. 257

The average annual concentrations of gross alpha of the effluents released ranged from 26 to 626 pCi/l during the period of record. For four years of record (1968-1972), the gross beta activity rang from 18 to 4700 pCi/l while total plutonium for 21 years of record ranged from 20 to 583 pCi/l.

Average annual concentrations of tritium, cesium-137, strontium-89, and 90 of effluents released from the waste treatment plants were available for select years.

Average Annual Concentrations of
Tritium, Cesium-137, and Strontium 89, and 90

	Picocuries per liter			
Year	Tritium	Cs 137	Sr 89	Sr 90
1952	120,000	--	--	--
1953	140,000	--	--	--
1954	170,000	--	--	--
1955	210,000	--	--	--
1956	170,000	--	--	--
1957	120,000	--	--	--
1958	200,000	--	--	--
1959	220,000	--	--	--
1960	240,000	--	--	--
1961	220,000	--	--	--
1962	170,000	--	--	--
1963	160,000	--	--	--
1964	320,000	--	--	--
1965	210,000	--	--	--
1966	180,000	--	--	--
1967	260,000	--	--	--
1968	--	1,100	--	--
1969	--	--	--	--
1970	--	--	160	240
1971	--	--	43	61
1972	420,000	--	74	120

The annual amounts of gross alpha and plutonium were computed from average annual concentrations and volumes of effluents.

Annual Amounts of Radionuclides Released with
Effluents DP-West (DP-35 and 257)

	Millicuries		
Year	Gross Alpha	Gross Beta	Total Pu
1952	--	--	.3
1953	1.1	--	1.1
1954	1.0	--	1.0
1955	1.1	--	.9
1956	.8	--	.8
1957	1.1	--	1.0
1958	.6	--	.6
1959	1.0	--	.8
1960	1.9	--	1.7
1961	5.8	--	5.4
1962	3.6	--	2.9
1963	34	--	2.2
1964	.2	--	1.1
1965	1.3	--	1.0

Annual Amounts of Radionuclides Released with Effluents DP-West (DP-35 and 257) (Continued)

Year	Millicuries Gross Alpha	Gross Beta	Total Pu
1966	1.0	--	.9
1967	2.3	--	2.4
1968	5.1	31	1.6
1969	2.9	65	1.6
1970	--	51	1.5
1971	--	30	.7
1972	--	16	1.3
Total	--	--	30.8

B. Surface Water, DP Canyon

Stream flow in DP Canyon is intermittent and is from the release of sewage and industrial effluents. The effluents do maintain some perennial flow in various sections of the canyon, however, all effluents move into the alluvium in the lower reach of the canyon. The effluents, except for periods of extreme precipitation, do not reach Los Alamos Canyon as surface flow, but move into the canyon as groundwater in the alluvium.

There are four surface water stations in the canyon (Fig. 9). Due to the thin alluvium in the upper and middle reach of the canyon, and the limited access in the lower canyon, there are no observation holes in the alluvium. A surface water gauging station was established at the mouth of DP-Canyon as a part of a study to determine transport of radionuclides in storm runoff.

1. Chemical Quality of Surface Water

The chemical quality of the surface water in the canyon reflects the quality of industrial and sewage effluents released from the treatment plants. In general, the quality of water improves as it moves down gradient in the canyon. The following

table presents the average chemical quality for each station by years. There has been a general improvement in the quality of effluents released into the canyon as seen by a general decline of chemical constituents in surface water at DPS-1. The quality of the water improves down gradient in the canyon from DPS-1 to DPS-4. A general summary is shown below, while the following table summarizes annual concentrations.

Chemical Quality of Surface Water
(average of a number of analyses in mg/l
except as noted, 1967 through 1972)

Station	DPS-1	DPS-2	DPS-3	DPS-4[a/]
No of Analyses	19	8	7	26
Sodium	357	225	277	140
Chloride	161	74	85	79
Fluoride	10.9	10.1	12.1	7.4
Nitrate	134	66	92	62
Total Dissolved Solids	1175	708	657	695
Conductance[b/]	1560	860	1040	740
pH[c]	9.5	9.1	9.1	7.9

a/ Analyses 1962 through 1972

b/ Micromhos

c/ No Units

Quality of Surface Water at DPS-1, DPS-2, DPS-3, and DPS-4

(Average of a number of analyses in mg/l)

Source	Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance [a]	pH [b]
DPS-1	1967	2	630	410	9.5	104	1740	2440	9.7
DPS-1	1968	3	670	215	23	381	1950	2730	10.1
DPS-1	1969	2	375	92	32	53	1100	1700	10.7
DPS-1	1970	5	241	140	6.0	118	878	1080	9.6
DPS-1	1971	4	233	76	4.7	62	893	1110	9.3
DPS-1	1972	3	206	137	2.5	88	932	1130	7.9
DPS-2	1967	1	290	75	8.0	140	669	900	8.5
DPS-2	1968	2	250	65	9.4	101	746	980	9.4
DPS-2	1969	2	282	103	12.0	26	716	920	9.8
DPS-2	1970	2	188	85	13.0	48	714	920	9.1
DPS-2	1971	1	68	15	3.7	35	642	330	8.[illegible]
DPS-3	1967	1	310	85	10	28	799	960	8.8
DPS-3	1968	2	325	88	16	150	676	1220	9.1
DPS-3	1969	2	293	75	12	31	409	930	9.0
DPS-3	1970	2	200	93	10	84	814	1000	9.3
DPS-4	1962	2	143	134	15	40	771	745	7.4
DPS-4	1963	2	132	113	13	41	742	740	7.5
DPS-4	1964	3	109	106	5.6	57	734	983	7.8
DPS-4	1965	2	110	109	15	40	656	910	7.8
DPS-4	1967	2	253	103	7.7	145	757	990	7.9
DPS-4	1968	2	200	85	6.2	370	607	850	8.1
DPS-4	1969	2	198	60	5.0	35	390	660	8.0
DPS-4	1970	4	103	45	11	18	464	550	8.5
DPS-4	1971	4	113	47	5.0	36	531	530	7.8
DPS-4	1972	3	214	58	4.1	30	493	600	8.0

a/ Micromhos

b/ No Units

Select trace metal ion analyses were made of water from two stations, DPS-1 and DPS-4 in 1971 and 1972. They indicate some trace metals in the surface water.

Metal Ion Analyses

(range and average of 5 analyses in μg/l)

Station	DPS-1			DPS-4		
	Min	Max	Av	Min	Max	Av
In solution						
Cadmium	0.8	13.2	6.9	0.4	7.2	3.6
Beryllium	<0.25	0.48	0.30	< .25	—	< .25
Lead	<1.0	5.0	1.8	<1.0	5.0	1.8
Mercury	<0.02	0.22	0.09	< .02	—	< .02
Particulates						
Cadmium	< .25	.89	0.43	< .25	.50	30
Beryllium	< .25	—	<.25	< .25	—	< .25
Lead	<1.0	5.2	2.8	<1.0	4.3	1.8
Mercury	<0.02	0.11	0.04	< .02	—	< .02

2. Radiochemical Quality of Surface Water

Radiochemical analyses of surface water from 1961 through 1965 indicated some Gross beta and plutonium in at DPS-4 from the treatment plant at Building 35. Analyses from 1967 through 1972 show a general decrease in the concentration of radionuclides down gradient in the canyon.

Gross Beta and Plutonium in Surface Water at DPS-4
(average of a number of analyses in picocuries per liter, 1961-1965)

Year	No. of Analyses	Gross Beta	Plutonium
1961	2	91	<0.5
1962	3	139	<0.5
1963	2	197	0.7
1964	3	71	0.9
1965	3	50	0.7

DP CANYON

SURFACE FLOW SAMPLING SITES

RADIOCHEMICAL QUALITY OF WATER

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	238 Pu	239 Pu	241 Am	226 Ra	234 U	137 Cs	90 Sr	3 H	238 U
DPS-1	1967	1	53	51700	3.87	76.10	1.29	-.15	32.10	34000	28600	542000	.021
DPS-1	1968	3	34	14307	4.25	28.82	4.52	.17	56.30	13400	11360	2002	.021
DPS-1	1969	3	14	2060	5.55	9.10	3.58	.24	32.63	3490	800	430	.021
DPS-1	1970	5	7	1202	.81	2.20	1.19	-.15	12.33	692	568	402	.021
DPS-1	1971	4	22	1392	1.16	2.07	.60	-.15	12.31	1203	716	356	.738
DPS-1	1972	3	13	2469	.32	5.68	.33	-.00	-.00	-355	-	396100	7.100
DPS-2	1967	1	4	6690	.38	2.70	.63	-.15	4.40	2740	5810	660	.021
DPS-2	1968	2	7	4695	.30	2.10	.82	-.15	11.70	3165	2620	413	.021
DPS-2	1969	2	22	1055	2.29	3.64	1.70	-.15	57.30	2260	350	670	.021
DPS-2	1970	2	8	990	1.14	1.33	.58	-.15	26.45	480	534	381	.021
DPS-2	1971	1	5	640	5.64	.72	.25	-.00	2.11	523	376	195	.021
DPS-2	1972	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-.000
DPS-3	1967	1	5	290	.21	.77	-.05	-.15	9.30	310	2260	927	.021
DPS-3	1968	2	6	1525	.43	2.63	1.42	.18	16.20	1445	3180	549	.02
DPS-3	1969	2	19	940	3.05	4.23	1.00	-.15	54.10	530	500	14[illegible]	[illegible]
DPS-3	1970	2	24	945	1.40	1.09	.62	-.15	88.60	395	453	45[illegible]	[illegible]
DPS-3	1971	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	[illegible]
DPS-3	1972	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-.00
DPS-4	1967	1	-2	1800	.13	.14	-.05	.35	2.05	-240	632	410000	-.00
DPS-4	1968	2	6	625	.09	.08	.08	.17	3.35	-240	435	476000	-.00
DPS-4	1969	4	2	418	.44	.52	.35	-.15	2.71	-243	380	346250	-.00
DPS-4	1970	4	1	457	.13	.21	.20	-.00	1.53	-234	233	162250	-.00
DPS-4	1971	4	3	370	.11	.13	.08	-.00	1.72	-306	315	103250	.60
DPS-4	1972	3	2	609	.11	.27	.25	-.00	-.00	-354	-	172500	3.30
DPS-E	1967	1	3	14	-.05	-.05	-.00	-.15	-.00	-	-	-50000	-.00
DPS-E	1968	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-.00
DPS-E	1969	2	2	17	-.05	-.05	.07	-.00	-.00	-	-	-50000	-.00
DPS-E	1970	1	3	14	.16	.14	.08	-.00	-.00	-	-	8000	-.00
DPS-E	1971	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-.00
DPS-E	1972	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-.00

C. Surface Water, Los Alamos Canyon

Los Alamos Canyon heads on the flanks of the mountains and has a small perennial stream and a spring that feeds into the reservoir. Surface flow below the reservoir is intermittent due to overflow from the reservoir and storm runoff. Small amounts of waste water are released from TA-2 and some treated sewage effluent from a treatment plant near TA-41. Due to only intermittent flow below the reservoir, samples are collected when flow occurs in this reach of the canyon.

1. Chemical Quality of Surface Water

Water samples have been collected and analyzed from above and at the reservoir. The following table presents results of some of the earlier analyses.

Quality of Surface Water at and above
Los Alamos Reservoir

	Milligrams per liter				µmhos	
Date	Sodium	Chloride	Fluoride	Nitrate	Conductance	pH
6/7/61 1/	3	1.0	0.1	.2	65	7.4
6/12/58 2/	3	1.2	.4	.3	80	7.1
10/1/52 3/	3	5	2.0	<.1	—	8.0

1/ 1.1 Mile above Reservoir

2/ 0.2 Mile above Reservoir

3/ Reservoir

Later analyses from 1967 through 1972 are shown below.

Quality of Water in Los Alamos Reservoir

(Analyses 1967-1972 in mg/l except as noted)

Date	Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	Conductance [a]	pH [b]
12/67	8	3	.2	.4	80	120	7.3
4/69	6	2	<.1	.4	85	110	7.3
5/71	7	<1	<.1	.4	110	140	7.1
5/72	7	2	<.1	.4	98	140	7.0

[a] Micromhos at 25° C

[b] No units

The stream flow in the canyon below the reservoir is intermittent. The following table lists miscellaneous analyses taken in this reach of canyon.

Intermittent Stream Flow
(Analyses in mg/l except as noted)

Date	Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	Conductance [a]	pH [b]
5/67 1/	38	28	<.1	.9	180	210	7.5
8/69 1/	79	26	.5	2.2	250	280	7.7
12/67 1/	70	35	.3	13	260	290	7.6
8/57 3/	12	4	1.2	2.3	—	240	7.6
4/58 4/	9	5	.6	2.2	—	130	7.5
6/58 4/	19	11	.4	5.2	—	210	7.7

1/ Near obs. Well LAO-1

2/ Near Obs. Well LAO-4.5

3/ Flood Flow at Highway 4

4/ Snow melt at Highway 4

[a] Micromhos at 25° C

[b] No Units

2. Radiochemical Analyses of Surface Water

Radiochemical analyses of surface water from sources other than storm runoff are shown on the following table. The analyses only reflect background radioactivity except the tritium concentration at LAO-4.5. The surface flow at LAO-4.5 is return flow from the alluvium and the tritium is from the effluents in DP-Canyon.

Radiochemical Analyses of Surface Water in Los Alamos Canyon

(Average of a number of analyses in picocuries per liter except as noted)

Source	No of Analyses	Date	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{3}H	Total Uranium 1/
Reservoir	1	1971	2	2	<.05	<.05	—	<.4
At LAO-1	3	1969	<1	17	<.05	<.06	$<1x10^3$	.7
At LAO-1.8	1	1964	<1	4	<.05	<.05	—	1.5
At LAO-4.5	1	1967	<1	18	<.05	<.05	$160x10^3$	1.1

1/ μg/l

D. Water in Alluvium, Los Alamos Canyon

The alluvium in the canyon ranges from about 6 ft thick at LAO-C to about 20 ft at LAO-5. The alluvial aquifer is recharged from the release of sewage effluent from TA-41, cooling water, and intermittent storm runoff. Recharge also moves into the aquifer from the alluvium at the mouth of DP Canyon. There are 9 shallow observation wells in the Canyon (Fig).

1. Chemical Quality of Water in Alluvium

The chemical quality of water from wells in the alluvium from test holes LAO-C, LAO-1, and LAO-1.8 show concentrations of chemical constituents above what would be expected in natural water. These concentrations are due to runoff from storm drains and probably outfalls from Technical Areas, HRL, TA-41, and TA-2.

Quality of Water in Alluvium

(Average of a number of analyses in mg/l except as noted)

Source	No. of Analyses	Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	Conductance[a]	pH
LAO-C	7	39	47	0.5	2.6	223	265	7.5
LAO-1	22	80	38	0.8	4.4	356	415	7.4
LAO-1.8	2	47	30	< .1	.4	203	245	7.4
LAO-2	18	96	49	7.1	17	461	535	7.6
LAO-3	20	126	52	6.6	18	370	515	7.6
LAO-4	10	68	38	1.4	9.2	280	340	7.4
LAO-4.5	14	47	30	0.3	1.7	261	270	7.3
LAO-5	6	36	36	0.4	1.3	215	240	7.3
LAO-6	2	50	30	0.3	.4	211	270	7.4

[a] µmhos

The following table presents an annual recap of certain chemical constituents from 1967 through 1972 for each test hole. In general there were slight chemical changes at each station during the years 1967 through 1972. The quality of the water at LAO-2 reflects the inflow from DP-Canyon which receives industrial effluents. The quality of the water improves down gradient in the canyon from LAO-2 to LAO-6.

Quality of Water in Alluvium

(Average of a number of analyses)

Source	Year	No. of Analyses	Milligrams per Liter Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	µmhos Conductance	pH
LAO-C	1970	1	28	21	1.0	4.4	166	160	7.5
LAO-C	1971	2	37	46	.2	.4	249	190	7.5
LAO-C	1972	4	53	74	.4	2.4	253	345	7.5
LAO-1	1967	2	132	32	.6	2.1	406	505	7.2
LAO-1	1968	3	82	33	1.7	1.8	246	335	7.4
LAO-1	1969	2	83	47	.3	1.8	295	370	7.3
LAO-1	1970	4	54	26	.9	3.5	434	335	7.8
LAO-1	1971	4	74	27	.6	6.6	414	470	7.3
LAO-1	1972	4	75	50	.7	5.7	397	475	7.4
LAO-1.8	1969	2	47	30	< .1	.4	203	245	7.4
LAO-2	1967	1	180	73	7.0	7.5	594	760	7.3
LAO-2	1968	3	94	39	8.1	9.6	334	440	7.6
LAO-2	1969	2	37	37	5.0	7.9	369	410	7.6
LAO-2	1970	3	96	44	6.3	20	479	510	7.7
LAO-2	1971	2	91	33	5.6	18	431	490	7.5
LAO-2	1972	3	97	55	4.4	24	472	573	7.5
LAO-3	1967	2	139	57	7.5	25	451	550	7.4
LAO-3	1968	2	84	30	8.5	4.4	362	405	7.6
LAO-3	1969	2	115	54	5.0	15	394	500	7.6
LAO-3	1970	4	85	43	7.0	13	445	490	7.7
LAO-3	1971	3	82	40	5.2	17	439	500	7.4
LAO-3	1972	4	109	69	4.9	27	484	615	7.5
LAO-4	1967	2	100	36	.6	7.0	294	360	7.3
LAO-4	1968	3	66	31	1.5	1.8	285	315	7.5
LAO-4	1969	2	65	35	2.3	.9	217	280	7.5
LAO-4	1970	1	57	40	2.0	18	284	370	7.1
LAO-4.5	1969	2	58	32	< .1	.9	277	270	7.6
LAO-4.5	1970	5	38	32	.5	1.3	265	275	7.2
LAO-4.5	1971	3	36	30	< .1	3.9	280	255	7.3
LAO-4.5	1972	4	55	27	.4	.9	222	270	7.5
LAO-5	1967	1	42	28	.4	2.6	208	240	7.2

Source	Year	No. of Analyses	Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	Conductance	pH
LAO-5	1968	2	17	25	.8	.4	224	250	7.2
LAO-5	1969	2	52	33	< .1	.9	210	240	7.4
LAO-6	1968	1	49	26	.5	< .4	227	295	7.4
LAO-6	1969	1	51	33	.1	.4	195	250	7.3

Water from 5 observation wells were analyzed for metal ions in 1971 and 1972. The average is presented in the following table. In general, the metal ion concentration increases below the confluence with DP Canyon due to the recharge consisting partly of effluents from the Industrial Treatment Plant at TA-21.

Metal Ion Analyses of Water in Alluvium

(Average of a number of analyses in µg/l)

Source	LAO-C	LAO-1	LAO-2	LAO-3	LAO-4.5
No of Analyses	4	5	4	5	4
In Solution					
Cadmium	2.1	4.5	3.7	2.6	2.8
Beryllium	< .25	< .25	< .25	.27	< .25
Lead	4.8	1.3	4.8	1.9	<1.0
Mercury	< .02	.07	< .02	.38	< .02
Particulate					
Cadmium	2.1	.65	1.35	1.30	.55
Beryllium	1.7	< .25	.78	.77	.42
Lead	22.6	10.7	10.2	12.3	13.2
Mercury	.11	.07	.5	.04	< .02

2. Radiochemical Analyses of Water in Alluvium

The earlier analyses , 1966 and 1968, are shown on the following table. Traces of radionuclides were reported in the canyon.

Radiochemical Analyses of Water in Alluvium 1966-1967

(Average of a number of analyses)

Source	Year	No. of Analyses	Picocuries per liter Gross Beta	Plutonium	µg/l Total Uranium
LAO-1	1966	3	17	<.5	< .5
LAO-1	1967	1	113	<.5	< .5
LAO-2	1966	2	32	.6	< .5
LAO-3	1966	3	32	<.5	2.6
LAO-4	1966	2	<14	<.5	< .5
LAO-4	1967	1	15	<.5	< .5
LAO-5	1966	1	<14	<.5	< .5

The recap of radiochemical analyses from 1967 through 1972 are presented on the following table. The increase in radionuclides is noted at LAO-2 where the industrial effluents from DP Canyon recharge the water in the alluvium. As in DP Canyon, the concentration of radionuclides decrease downgradient due to ion exchange and adsorption with alluvial materials and dilution with water moving through the alluvium.

LOS ALAMOS CANYON

ALLUVIAL AQUIFER OBSERVATION WELLS

RADIOCHEMICAL QUALITY OF WATER

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LAO-C	1970	1	-1	4	-.05	-.05	-.00	-.00	-.00	-	-	-1000	1.200
LAO-C	1971	2	-1	3	-.05	-.05	-.00	-.00	-.00	-345	-	-1000	-.400
LAO-C	1972	4	-1	5	.06	.07	.13	-.00	-.00	-353	-	-1225	1.100
LAO-1	1967	1	-1	50	-.05	-.05	-.00	.19	-.00	-	-	-	1.300
LAO-1	1968	3	3	37	-.05	.08	-.05	.16	.32	-240	-	-	-.000
LAO-1	1969	3	-1	36	-.05	.06	-.00	-.00	-.00	-	-	-	.800
LAO-1	1970	4	-1	76	.05	-.00	-.00	-.00	-.00	-	-	-	.500
LAO-1	1971	4	1	94	.05	.27	-.00	-.00	-.00	-345	-	20750	.800
LAO-1	1972	4	1	127	.17	.18	-.05	-.00	-.00	-354	-	19575	.700
LAO-1.2	1969	2	1	5	-.05	-.05	-.00	-.00	-.00	-	-	-	.600
LAO-1.2	1970	1	-1	3	-.05	-.05	-.00	-.00	-.00	-	-	-	-.400
LAO-1.8	1969	2	1	5	-.05	-.05	-.00	-.00	-.00	-	-	-	1.000
LAO-2	1967	1	-1	91	-.05	-.05	-.00	.30	-.00	-	-	-	2.000
LAO-2	1968	3	3	59	-.05	.06	-.05	-.15	-.00	-250	-	-	1.600
LAO-2	1969	2	1	77	.10	.60	-.00	-.00	-.00	-	-	-	1.600
LAO-2	1970	3	-1	80	-.05	.14	-.00	-.00	-.00	-250	-	-	.600
LAO-2	1971	2	1	101	.15	.33	-.00	-.00	-.00	-340	-	52000	.900
LAO-2	1972	3	2	188	.09	.19	.12	-.00	-.00	-354	-	153300	2.700
LAO-3	1967	1	-1	45	-.05	.05	-.00	.19	-.00	-	-	214000	4.900
LAO-3	1968	3	2	61	.07	.08	-.05	.24	-.00	-240	-	125667	.800
LAO-3	1969	2	2	49	-.05	.06	-.00	-.00	-.00	-	-	350000	1.400
LAO-3	1970	4	2	56	-.05	.08	-.00	-.00	-.00	-230	-	73000	.930
LAO-3	1971	3	3	95	.07	.08	-.00	-.00	-.00	333	-	37667	1.200
LAO-3	1972	4	3	92	.10	.15	-.05	-.00	-.00	-355	-	186850	3.000
LAO-4	1967	1	-1	9	-.05	.06	-.00	-.00	-.00	-	-	222000	.800
LAO-4	1968	3	3	16	.05	.05	-.05	-.15	-.00	-240	-	61000	1.200
LAO-4	1969	2	-1	9	-.05	-.05	-.00	-.00	-.00	-	-	55500	.600
LAO-4	1970	1	-1	10	-.05	-.05	-.00	-.00	-.00	-	-	66000	[illegible]
LAO-4.5	1969	3	-1	5	-.05	-.05	-.00	-.00	-.00	-	-	43000	.700
LAO-4.5	1970	5	1	26	.06	.07	-.00	-.00	-.00	-	-	77750	.400
LAO-4.5	1971	3	1	5	.07	.08	-.00	-.00	-.00	-	-	24000	.700
LAO-4.5	1972	4	2	10	.09	.06	.05	-.00	-.00	-353	-	28175	1.300
LAO-5	1967	1	-1	4	-.05	-.05	-.00	-.00	-.00	-	-	126000	-.400
LAO-5	1968	2	1	8	-.05	.09	-.05	-.15	-.00	-240	-	70000	1.200
LAO-5	1969	2	-1	5	-.05	-.05	-.00	-.00	-.00	-	-	55500	.800
LAO-6	1968	1	2	18	.17	.25	-.00	-.15	-.00	-240	-	75000	.400
LAO-6	1969	1	-1	7	-.05	-.05	-.00	-.00	-.00	-240	-	51000	-.400

E. Storm Runoff DP - Los Alamos Canyon

A gaging station was constructed at the mouth of DP Canyon in the Spring of 1967. A second gaging station was established on Los Alamos Canyon above the junction with DP Canyon in the Spring of 1968. The following table presents a recap of flow events from 1970 through 1972 at each station.

Storm Runoff at DP-Canyon Gaging Station

Year	Month	No. of Events	Total Discharge m^3
1970	April	7 1/	5300
	May	1	615
	June	5	2220
	July	5	3945
	Aug	9	11590
	Sept	4	2465
1971	April	1	125
	July	9	22200
	Aug	3	11590
	Sept	4	6660
	Oct	4	10230
	Dec	1	6040
1972	July	3	740
	Aug	4	1480
	Sept	4	46000
	Oct	2	50500

1/ Snowmelt (7 day)

Storm Runoff at Los Alamos Gaging Station

Year	Month	No. of Events	Total Discharge m^3
1970	April	17 a/	44000
	June	3	2465
	July	4	6290
	Aug	9	51800
	Sept	8	9600
1971	July	5	13600
	Aug	1	615
	Oct	2	1970
1972	Sept	4	37000

a/ 17 days of snowmelt runoff

2. Transport of radionuclides in storm runoff

A study to determine transport of radionuclides in storm runoff was made at DPS-4 at the mouth of DP Canyon (Fig. 9).

Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County, New Mexico.[15]

ABSTRACT

Effluents from the waste treatment plant at Los Alamos Scientific Laboratory's Technical Area 21 are released into DP Canyon. The radionuclides remaining in the effluents are bound to stream-channel sediments which are later carried out of the canyon by storm runoff.

A study was made to determine the runoff volume, the suspended-sediment load, and the amount of radio-activity carried out of DP Canyon by storm runoff. During the summer of 1967, precipitation resulted in 23 runoff events that carried ≈88 000 kg of suspended sediments out of the canyon in ≈36 800 m^3 of water. Less than 74 μCi of gross alpha emitter and ≈40 100 μCi of gross beta were carried out of the canyon in solution. The suspended sediments carried out ≈70 μCi of gross alpha emitters and ≈11 300 μCi of gross beta emitters. About 31 000 μCi of ^{90}Sr left the canyon in solution, as did traces of ^{238}Pu, ^{239}Pu, and ^{241}Am.

Cumulative samplers to collect samples of storm runoff (water and suspended sediments) were installed in the wall of the gauging station at DPS-4 in 1967. Samples were collected of the runoff events during the summer of 1967 and 1968. The chemical quality of the water is shown on the following table.

Chemical Quality of Storm Runoff
(Average of a number of analyses, 1967 and 1968)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance	pH
1967	14	103	47	4.5	13	354	490	8.6
1968	10	125	38	4.1	6	343	550	11.6

Radiochemical analyses of surface runoff for the similar period are presented on the following table. The analyses indicate that some radionuclides are

being transported out of the canyon.

DP CANYON

SURFACE FLOW SAMPLING SITES

RADIOCHEMICAL QUALITY OF WATER

(FLOOD FLOW CONDITIONS)

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
DPS-4	1967	10	-2	1089	.16	.19	.27	-.15	1.09	-240	851	-	-.000
DPS-4	1968	15	4	770	.35	1.11	.91	-.15	3.44	328	444	-	-.000

Trace concentrations of radionuclides were detected in solution of the runoff at DPS-4, thus indicating the transport of radioactivity out of the effluent release area.

In 1968, cumulative samplers were installed in the stream channel in Los Alamos Canyon, one above the junction with DP Canyon and three below the junction. The runoff was collected from four events; however, plugging of the intake on some of the samplers during an event caused loss of sample for that station. The samples were collected to see if a measurable amount of radioactivity carried out of DP Canyon diluted with runoff in Los Alamos Canyon could be detected.

The average of a number of water samples from cumulative samplers at the four stations in Los Alamos are shown on the following table for the year 1968. The locations are shown on Fig. 12.

		Average of a number analyses - (picocuries per liter)			
Source	Number of Analyses	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
LAS-1	4	<2	12	.08	.10
LAS-2	1	<2	220	<.05	.19
LAS-3	4	<2	288	<.05	.12
LAS-4	1	<2	830	.12	.17

Suspended sediments from the runoff were also analyzed and are shown on the following table for the year 1968.

Source	Number of Samples	Average of a number of analyses Picocuries per dry gram	
		Gross Alpha	Gross Beta
LAS-1	4	5	5
LAS-2	1	6	52
LAS-3	4	9	38
LAS-4	1	13	92

The results indicate that measurable amounts of radionuclides are found in solution and in the suspended sediments in Los Alamos Canyon, having been carried out of DP Canyon.

A series of samples were collected of storm runoff with a DH-48 sediment sampler at the gauging station in Los Alamos and DP Canyon in the summer of 1968. The samples were collected at intervals through an event. The discharge and sediment concentrations were determined. The fluids were separated from the suspended sediments and were analysed for gross alpha and gross beta activity. The investigation was made to determine if sediment and radioactivity changed with time through a runoff event. The following tables recaps the data.

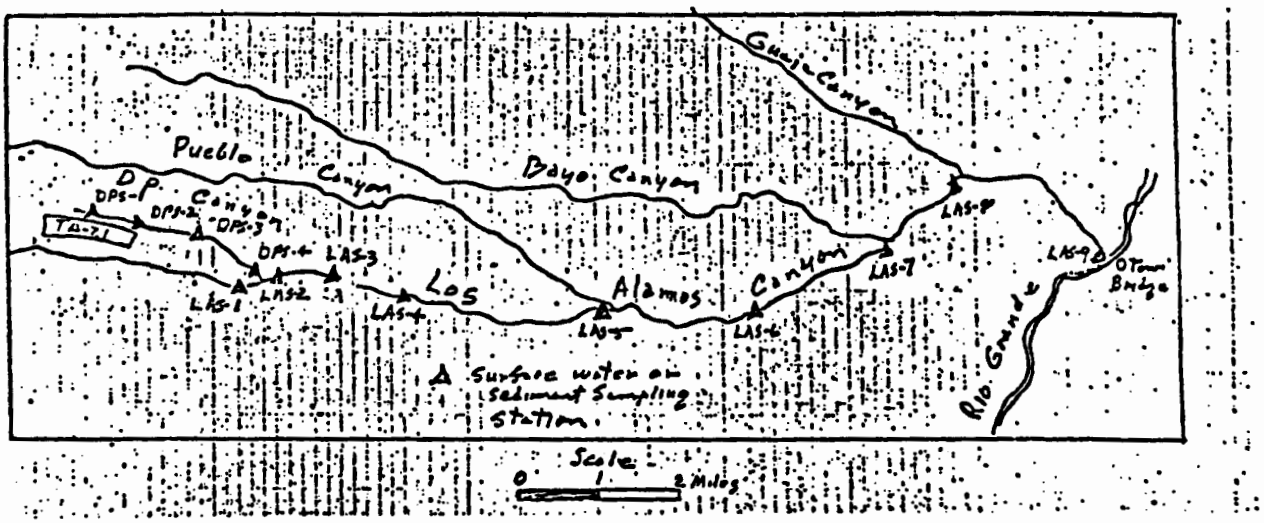


Fig. 12. Channel bed sediment sampling stations in DP-Los Alamos Canyons.

DP Canyon, July 30, 1968

Hour	Discharge (l/sec)	Suspended Sediment Concentration (mg/l)	In Solution (pCi/l) Gross Alpha	In Solution (pCi/l) Gross Beta	Suspended Sediment (pCi/g) Gross Alpha	Suspended Sediment (pCi/g) Gross Beta
14:50	1540	19,500	<1	1800	39	1120
15:00	1540	11,200	<1	1700	43	1050
15:30	1410	20,400	<1	1080	17	520
16:15	525	9,920	3	1360	15	670
17:00	270	4,010	0	1150	48	1170
18:20	165	1,340	14	1190	47	1680

A second set of samples were collected on July 31, 1968. Discharge, sediment concentrations and gross alpha and gross beta activity were determined from the sample in solution and in the suspended sediment. The results are presented as follows:

DP Canyon, July 31, 1968

Hour	Discharge (l/sec)	Suspended Sediment Concentration (mg/l)	In Solution (pCi/l) Gross Alpha	In Solution (pCi/l) Gross Beta	Suspended Sediment (pCi/g) Gross Alpha	Suspended Sediment (pCi/g) Gross Beta
13:50	56	1,080	<1	920	64	890
14:20	1730	43,000	<1	1080	9	260
14:30	1640	26,000	<1	820	14	300
14:45	2040	13,000	<1	770	10	350
14:50	1700	11,000	<1	860	52	390
15:00	1410	37,000	<1	1180	6	210
15:05	1260	37,000	3	1190	9	210
15:10	1220	48,000	8	1190	6	180
15:20	1190	27,000	<1	1090	7	220
15:30	1020	56,000	14	1220	4	140
15:40	570	4,900	8	1000	21	650

DP Canyon, July 31, 1968
(Continued)

Hour	Discharge (l/sec)	Suspended Sediments Concentration (mg/l)	In Solution (pCi/l) Gross Alpha	In Solution (pCi/l) Gross Beta	Suspended Sediments (pCi/g) Gross Alpha	Suspended Sediments (pCi/g) Gross Beta
15:50	480	4800	6	1100	79	610
16:00	490	4400	8	1070	16	650
16:10	480	4600	19	1120	20	520
16:20	440	2500	41	1060	15	790

A series of samples were collected from DP Canyon and Los Alamos Canyon above the confluence with DP for comparison on August 6, 1968.

DP and Los Alamos Canyon, August 6, 1968

Hour	Discharge (l/sec)	Suspended Sediments Concentration (mg/l)	In Solution (pCi/l) Gross Alpha	In Solution (pCi/l) Gross Beta	Suspended Sediments (pCi/g) Gross Alpha	Suspended Sediments (pCi/g) Gross Beta
DP Canyon						
15:35	690	24,000	19	1180	3	227
15:55	525	18,000	<1	920	3	191
16:15	450	7,700	3	710	4	300
16:30	305	5,900	11	800	93	324
16:45	240	5,400	3	740	2	280
17:00	210	2,800	8	730	4	420
17:15	160	1,700	3	760	10	580
17:30	135	1,800	14	840	2	590
17:45	120	1,000	3	832	<1	620
Los Alamos Canyon						
15:40	2040	20,000	6	16	6	6
16:10	1560	10,000	<1	14	8	6
16:25	1130	9,400	<1	11	4	6
16:45	880	6,800	<1	18	2	4
16:55	760	5,800	<1	18	3	6
17:15	680	4,200	11	17	5	7
17:40	590	4,800	<1	<1	<1	<1

Only trace concentrations of gross alpha activity were found in solution in the runoff in both DP and Los Alamos Canyons. Gross beta activity in solution and gross alpha and gross beta activity indicate transport of radionuclides out

of DP Canyon which receives industrial effluent. A comparison of the activity in the runoff of DP Canyon and Los Alamos Canyon indicates magnitude of measureable concentrations being transported. In general, the sediment concentrations decrease with discharge. In DP Canyon, the activity concentrations vary throughout the event.

F. Radiochemical Analyses of Sediments

Channel sediments in DP Canyon are derived from weathering of the Bandelier Tuff. Sediments in Los Alamos Canyon are derived from weathering of the Bandelier Tuff and Tschicoma Formation.

Particle-size distribution of channel sediments at stations are shown on the following table.

Particle-Size Distribution

(Percent by Weight)

Source	DPS-1	DPS-4	LAO-C	LAO-1	LAO-3
Granules	8.0	4.0	16.5	< 0.5	0.5
Sand					
Very Coarse	48.5	42.5	38.0	23.0	13.0
Coarse	29.0	36.0	32.0	53.0	40.0
Medium	8.0	10.5	10.5	18.5	23.5
Fine	3.0	4.5	2.0	4.0	11.0
Very Fine	1.5	1.0	.5	.5	4.5
Silt and Clay	2.0	1.5	.5	.5	7.5

Channel sediments were collected in DP Canyon in 1967 and 1968 for radiochemical analyses.

Source	Number of Samples	Average of a number of analyses Picocuries per dry gram. Gross alpha	Gross beta	^{238}Pu	^{239}Pu
DPS-1	2	16	536	.62	7.68
DPS-2	1	3	140	.12	1.32
DPS-3	1	2	122	.12	.79
DPS-4	3	3	29	.07	.65

The concentration of radioactivity and radionuclides in the channel sediments is greater near the effluent outfall from the treatment plant at TA-21 in DP Canyon with the concentrations decreasing downgradient in DP Canyon and Los Alamos Canyon to the Rio Grande. The radionuclides in the effluent are being adsorbed or exchanged with clay minerals in the channel sediments. Storm runoff is moving the sediments downgradient in the canyon dispersing them over a larger area. It appears that there is a build-up in the sediments near the effluent outfall during the fall, winter, and spring when storm runoff is at a minimum. Heavy thunder showers during the summer transport the sediments downgradient in the canyon so that a large build up of radionuclides at the outfall does not occur.

Channel sediments were collected from DP and Los Alamos Canyon in November, 1965 and analyzed for gross alpha, beta, and gamma activity. The results are shown in the following table.

Radiochemical Analyses of Sediments, November 1965

(Analyses in Counts per Minute per Dry Gram)

Location	Gross Alpha	Gross Beta	Gross Gamma
DPS-1	6	566	130
DPS-4	3	25	8
LAO-C	2	7	30
LAO-1	2	8	2
LAO-3	2	4	12
Rd-4	1	<1	< 1

A similar set of samples were collected and analyzed for gross alpha, gross beta, and plutonium in the spring of 1970. The results are shown on the following table.

Radiochemical Analyses of Sediments, February and March, 1970

(Analyses in picocuries per dry gram)

Location	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
DPS-1	28	391	15.8	2.69
DPS-4	5	92	.219	1.40
LAO-C	2	1	< .001	< .001
LAO-1	1	4	.026	.101
LAO-3	2	9	.09	.189
LAO-4	2	12	.011	.153
LAO-6	2	9	.032	.364
Rd-4	2	8	.003	.845

Samples of sediments from the stream channel were collected in February 1970, from Los Alamos Canyon, one above the junction with DP Canyon and the rest downgradient to the Rio Grande (Fig. 12). The averages of the samples of the channel sediments are shown on the following table.

Source	Number of Samples	Average of a number of samples Picocuries per dry gram			
		Gross alpha	Gross beta	^{238}Pu	^{239}Pu
LAS-1	3	3	45	.07 1/	.87 1/
LAS-2	2	4	16	.08 1/	2.39 1/
LAS-3	4	3	61	.08 2/	.50 2/
LAS-4	3	12	124	.04 1/	.45 1/
LAS-5	3	2	16	.05	.16
LAS-6	2	2	9	.02	.56
LAS-7	2	1	11	.03	.16
LAS-8	2	2	6	.02	12

1/ Average 2 analyses

2/ Average 3 analyses

Samples were analyzed from two stations at LAO-3 and State Road 4 in 1971 and 1972.

Radiochemical Analyses of Sediments 1971 and 1972

(Analyses in picocuries per dry gram except as noted)

	LAO-3			Rd. 4		
	5/7/71	10/14/71	10/10/72	5/7/71	10/14/71	10/10/72
Gross Alpha	3	18	<1	2	<1	<1
Gross Beta	1	73	2	4	<1	6
^{238}Pu	.007	2.45	.037	.007	.003	.004
^{239}Pu	.961	1.36	.370	.112	.054	.004
^{137}Cs	—	103	7.3	—	3.4	4.6
Total Uranium	0.81	.16	.40	.09	.02	.33

The results of the analyses of channel sediments indicate that storm runoff is transporting radionuclides out of DP Canyon and into Los Alamos Canyon and probably measurable amounts to the Rio Grande.

G. Inventory of Plutonium in Channel Sediments

The inventory of plutonium was made of channel sediment of DP and Los Alamos Canyon to the Rio Grande. The physical characteristics of the channel used in computing the inventory for July 1968, August 1968, February 1970, and October 1972, are shown below.

Physical Characteristics of Channel

DP-Los Alamos Canyon

1. 0 to 1 800 m (DP Canyon)
   Width 1.5 m Depth 0.15 m
   Sp. g. 1.57 Weight 459×10^6 g

2. 1 800 m to 6 600 m (Los Alamos Canyon)
   Width 2.5 m Depth 0.15 m
   Sp. g. 1.57 Weight $2\ 832 \times 10^6$ g

Confluence Pueblo-Los Alamos to Rio Grande

1. Confluence to 4 800 m
   Width 3 m Depth 0.15 m
   Sp. g. 1.57 Weight $3\ 408 \times 10^6$ g

Physical Characteristics of Channel
(Continued)

Confluence Pueblo-Los Alamos to Rio Grande

2. 4 800 m to 7 2 00 m (Rio Grande)
Width 4 m Depth 0.15 m
Sp. g. 1.57 Weight 2 261 x 10^6 g

The concentrations of plutonium at each station, average at each station, and total amount at each section are presented in the following table.

Concentrations and Total Plutonium in Sections of Channel

DP-Los Alamos Canyon (May, 1968)

Section	Station	Concentration µCi/g	Concentration Ave.	Total mCi	% of Total Pu
0-1 800	DPS-1	16.20			
	DPS-4	.84	8.5	3.9	78
1 800-6 600	LAS-3	.65			
	LAS-5	.15	.40	1.1	22
TOTAL		—	—	5.0	100

Los Alamos Canyon (July, 1968)

1 800-6 600	LAS-2	4.39			
	LAS-3	.72			
	LAS-4	.68			
	LAS-5	.22	1.5	0.4	—
TOTAL		—	—	0.4	

DP-Los Alamos Canyon (August, 1968)

0-1 800	DPS-1	0.41			
	DPS-2	1.44			
	DPS-3	.91			
	DPS-4	.88	0.91	.4	27
1 800-6 600	LAS-2	.60			
	LAS-3	.37			
	LAS-4	.30			
	LAS-5	.23	.38	1.1	73
TOTAL		—	—	1.5	100

Concentrations and Total Plutonium in Sections of Channel
(Continued)

DP-Los Alamos Canyon (February, 1970)

Section	Station	Concentration µCi/g	Concentration Ave.	Total Pu mCi	% of Total Pu
0-1 800	DPS-1	18.4			
	DPS-4	1.62	10.1	4.6	81
1 800-6 600	LAS-2	.198			
	LAS-3	.156			
	LAS-4	.396			
	LAS-5	.848	0.4	1.1	19
TOTAL		--	--	5.7	100

DP-Los Alamos Canyon (October, 1972)[1]

0-1 800	DP-5	0.76			
	DP-6	19			
	DP-7	.93	6.9	3.2	86
1 800-6 600	DP-9	.20			
	DP-10	.30			
	SR-4	.01	.17	.5	14
TOTAL		--	--	3.7	100

1/ DP Series Ecology Section

Los Alamos Canyon [Confluence LA-Pueblo to Rio Grande] (May, 1968)

Confluence-4 800	LAS-6	.62			
	LAS-8	.34	.48	1.6	62
4 800-7 200	LAS-8	.34			
	LAS-9	.24	.29	1.0	38
TOTAL		--	--	2.6	100

Los Alamos Canyon [Confluence LA-Pueblo to Rio Grande], (August, 1968)

Confluence-4 800	LAS-6	.53			
	LAS-8	.02	.28	1.0	100
4 800-7 200	LAS-8	.02			
	LAS-9	<.01	.01	<.02	--
TOTAL		--	--	1.0	100

Los Alamos Canyon [Confluence LA-Pueblo to Rio Grande] (February, 1970)

Confluence-4 800	LAS-6	.860			
	LAS-7	.338	.60	2.0	65
4 800-7 200	LAS-8	.591			
	LAS-9	.364	.48	1.1	35
TOTAL		--	--	3.1	100

The inventories are considered in DP Canyon (0-1800 m) and Los Alamos Canyon (1800 to 6600) to the confluence with Pueblo Canyon. Recap is as follows:

	Total Plutonium (mCi)				
Section (m)	May 1968	July 1968	Aug. 1968	Feb. 1970	Oct. 1972
0-1 800	3.9	—	.4	4.6	3.2
1 800-6 600	1.1	0.4	1.1	1.1	.5
TOTAL	5.0	—	1.5	5.7	3.7

The inventory in DP-Los Alamos Canyon for 1968 reflects the transport by storm runoff. The May concentrations decrease through August as the material containing plutonium moves out into Los Alamos Canyon with summer runoff. The channel in this reach (0-1 800) has a very thin alluvium cover and a steep gradient. Runoff is above normal due to the developed area. In the lower reach (May, 1968, February, 1970 and October, 1972), the transport appears to have equalized, with input equal to output.

The inventory in the canyon in May, 1968, indicates that from the outfall to the confluence with Pueblo only 5.0 mCi or 21% of the 24.1 mCi (1952-1967) released remains in the Canyon. In August, only 1.5 mCi or 6% of the 24.1 mCi remained. Transport out of this reach of the canyon by storm runoff for the year was about 3.5 mCi. In February, 1970, about 5.7 mCi or 21% of the 27.3 mCi (1952-1969) of plutonium remained in this reach. The October 1972 sampling indicated about 3.7 mCi or 8% of 30.8 mCi (1952-1972) remained in the canyon.

The inventories are considered in Los Alamos Canyon from the junction of Pueblo Canyon to the Rio Grande (0-7 200 m). The recap of the total amount of plutonium in the two sections in this reach of channel are as follows:

Los Alamos Canyon from Junction with Pueblo to Rio Grande

Section (m)	Total Plutonium (mCi) May 1968	Aug. 1968	Feb. 1970
0-4 800	1.6	1.0	2.0
4 800-7 200	1.0	<.02	1.1
TOTAL	2.6	≈1.0	3.1

The inventory in Los Alamos Canyon from the confluence of Pueblo to the Rio Grande in May 1968, was 2.6 mCi which decreased to ≈1.0 in August with the transport of plutonium with summer runoff.

The inventory of February 1970, combining both DP-Los Alamos (5.7 mCi) and Acid-Pueblo (18.1 mCi) and below the confluence (3.1 mCi), indicates a total of 26.9 mCi of plutonium in the three separate reaches ≈14% of the amounts released into DP-Los Alamos (27.3 mCi, 1952-1969) and Acid-Pueblo (170 mCi, 1943-1964). If one considers the inventory in each of the three segments of the three canyons or combinations of segments and assumes all plutonium is tied up in the sediments, the loss of plutonium or transport to the Rio Grande is about 80 to 90% of all plutonium released from the treatment plants.

H. Flood Frequency and Maximum Discharge

Los Alamos Canyon heads on the flanks of the Sierra de los Valles at an altitude of about 3170 m. The flood frequency and maximum discharges at boundary are based on the following data.

Drainage Area - 27.5 km^2

Main Channel Slope - 0.040

Frequency Frequency	Maximum Discharge (m^3/sec)
2-year	3.0
5-year	6.8
10-year	11
25-year	16
50-year	20

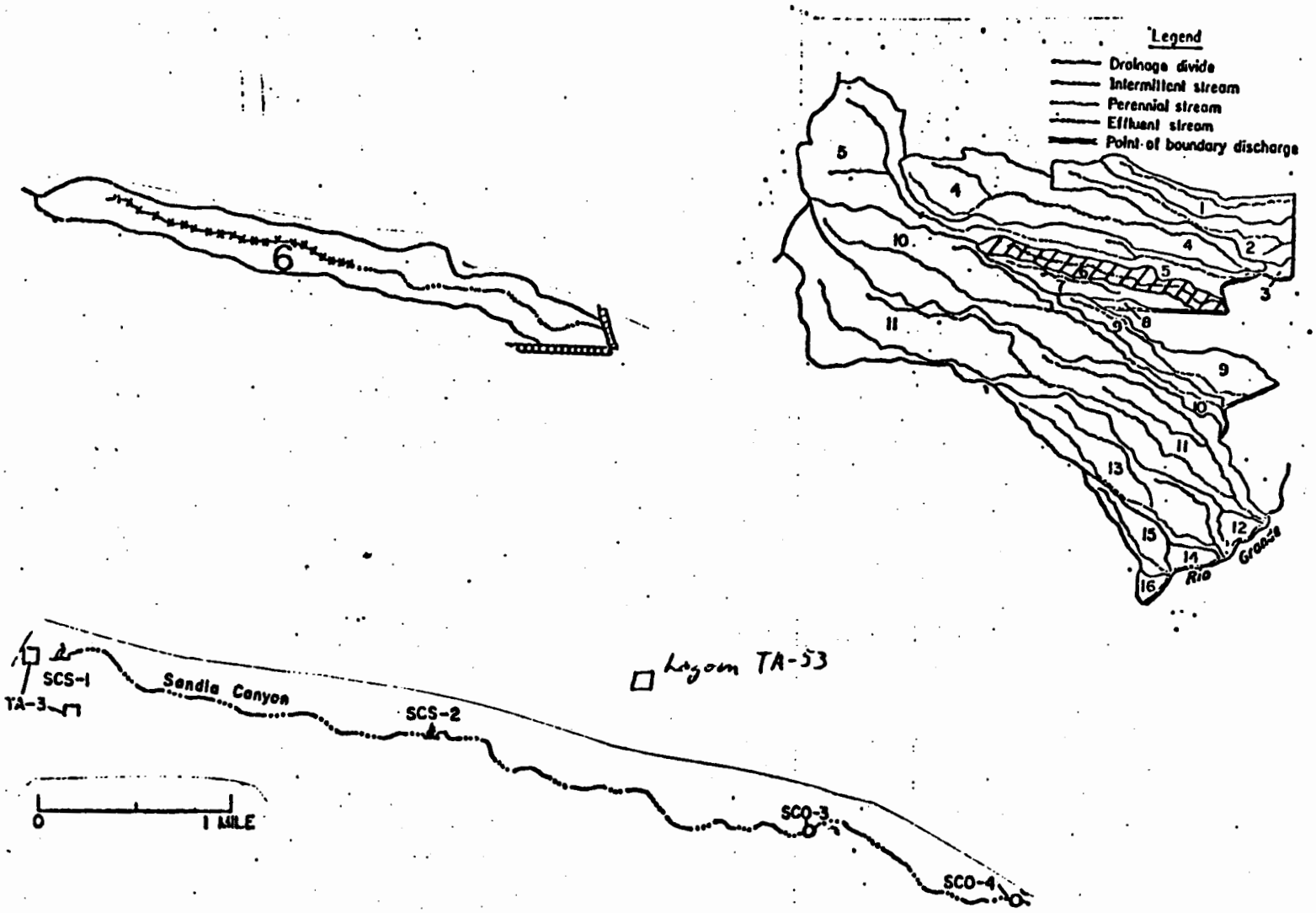


Fig. 13. Drainage Area 6 (Sandia Canyon) showing sampling stations.

VII. DRAINAGE AREA 6 (SANDIA CANYON)

Sandia Canyon heads on the Pajarito Plateau and is tributary to the Rio Grande. The alluvium in the upper reach of the canyon is thin in the western part of the plateau, but thickens to about 12 m at State Road 4. The alluvium is underlain by the Bandelier Tuff.

The stream in the upper reach of the canyon is perennial from the release of effluents from the sewage treatment plant and power plant at TA-3 (Fig. 13). The flow extends eastward to near the center of the plateau where all flow is lost to evapotranspiration or infiltration into the underlying tuff. Only during heavy thundershowers during the summer does the intermittent storm runoff extend in the canyon across the plateau to the Rio Grande.

A. Industrial Waste Treatment Plants

The sewage treatment plant serves the office-type complex of laboratories and shops that are centrally located in the TA-3 area. About 75 percent of the effluent is cycled into the power plant for cooling purposes. The combined release of effluents from the sewage treatment and power plant is about 2.3×10^5 m^3 of effluent per year into Sandia Canyon. Sewage lagoons at TA-53 are located on the mesa between Sandia and Los Alamos Canyons. Overflow from the lagoons does not reach the channel in either of the canyons.

B. Surface Water

Effluents from the treatment plants and surface water are sampled at two stations, SCS-1 and SCS-2 (Fig. 13).

1. Chemical Quality of Surface Water

The chemical quality of water at SCS-1 below the outfall from both treatment plants reflects the quality of effluent released into the canyon. As shown on the following table, the quality of the water improves downgradient in the stream.

Chemical Quality of Surface Water, 1969-1972
(Average of a number of analyses in mg/l except as noted)

Station	SCS-1	SCS-2
No. of Analyses	12	12
Sodium	200	150
Chloride	282	66
Fluoride	27.5	3.6
Nitrate	18	17
Total Dissolved Solids	1260	730
Conductance a/	1515	730
pH b	6.4	7.1

a/ Micromhos
b/ No Units

The following table presents averages of analyses by years of the two stations.

Chemical Quality of Surface Water
(Average of a number of analyses in mg/l except as noted)

Source	Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance a/	pH b/
SCS-1	1969	1	375	45	55	<.4	1738	1120	7.7
SCS-1	1970	3	104	55	.3	28	826	690	6.9
SCS-1	1971	4	206	49	2.1	22	1565	3465	5.6
SCS-1	1972	4	117	48	.52	22	913	785	5.5
SCS-2	1969	1	190	50	6.0	12	680	720	7.9
SCS-2	1970	3	153	75	1.7	25	850	840	7.3
SCS-2	1971	4	153	75	2.5	22	795	850	7.6
SCS-2	1972	4	107	64	4.2	4.2	591	510	5.6

a/ Micromhos at 25° C
b/ No Units

The chemical treatment of water for use at the power plant resulted in release of hexavalent chromate. The use of chromate in treatment of water for cooling at the power plant was discontinued in April 1972. The concentrations varied downgradient in the channel, showing no apparent trends.

Hexavalent Chromate in Surface Water

(Average of a number of analyses in mg/l)

Station	Year	No of Analyses	Hexavalent Chromate
SCS-1	1969	1	0.07
SCS-1	1970	4	8.5
SCS-1	1971	2	11.2
SCS-1	1972	4	.18
SCS-2	1969	1	2.4
SCS-2	1970	4	5.4
SCS-2	1971	2	7.3
SCS-2	1972	4	1.3

Select trace metal ion analyses were made of water from the two stations. The following table shows some metal ions in the surface water that are probably the result of treatment of the water used in the cooling process at the Power Plant.

METAL ION ANALYSES

(Range and average of a number of analyses in µg/l)

Station	SCS-1[a] Min	SCS-1[a] Max	SCS-1[a] Av	SCS-2[b] Min	SCS-2[b] Max	SCS-2[b] Av
In Solution						
Cadmium	<0.25	18.8	8.6	0.4	6.8	3.2
Beryllium	<0.25	—	<0.25	<0.25	0.28	0.27
Lead	<1.0	25.0	7.5	<1.0	2.5	1.5
Mercury	< .02	—	<	<0.02	—	<0.02
Particulates						
Cadmium	<0.25	2.8	1.4	<0.25	0.56	0.36
Beryllium	<0.25	—	<0.25	<0.25	—	<0.25
Lead	<1.0	11.9	8.1	<1.0	1.8	1.2
Mercury	<0.02	0.32	0.15	<0.02	0.43	0.18

a/ Four analyses

b/ Three analyses

2. Radiochemical Quality of Surface Water

The radiochemical analyses of surface water from stations SCS-1 and SCS-2 showed only traces of radionuclides which may have been released with sewage influent from laboratories in the TA-3 complex. The following table presents an annual average of radionuclides for the years 1969 through 1972.

SANDIA CANYON

(Average of a number of analyses in pCi/l except as noted)

SURFACE FLOW SAMPLING SITES

RADIOCHEMICAL QUALITY OF WATER

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	2
SCS-1	1969	1	-1	8	-.05	-.05	-.00	-.00	-.00	-	-	8700	3.
SCS-1	1970	5	-1	14	.06	.05	-.00	-.00	-.00	-	-	32600	-.
SCS-1	1971	4	1	16	.07	.07	-.00	-.00	-.00	-230	-	4675	2.
SCS-1	1972	4	1	17	.11	.06	-.00	-.00	-.00	-150	-	3350	1.
SCS-2	1969	1	-1	11	-.05	-.05	-.00	-.00	-.00	-	-	7100	-.
SCS-2	1970	5	-1	11	-.05	-.05	-.00	-.00	-.00	-	-	17000	-.
SCS-2	1971	4	-1	11	-.05	-.05	-.00	-.00	-.00	-240	-	7750	-.
SCS-2	1972	4	1	16	.08	06	.07	-.00	-.00	753	-	4300	1.

a/ Analyses in µg/l

C. Water in Alluvium

Two observation holes were drilled into the alluvium (SCO-3 and SCO-4) in the middle and lower reach of the canyon. They did not encounter any water. After storm runoff in the canyon in early September, 1969 water did infiltrate into the alluvium near hole SCO-4 and a sample was collected and analyzed.

1. Chemical Quality of Water in Alluvium

The chemical quality of the water in the alluvium recharged from storm runoff showed some effects from the effluent released from the power plant with the presence of chromate.

Analyses of Water in Alluvium at SCO-4

(Sept. 1969, mg/l except as noted)

Sodium	Chloride	Fluoride	Chromate	Nitrate	Dissolved Solids	Conductance
80	15	<0.1	0.18	1.3	320	350

a/ micromhos

2. Radiochemical Quality of Water in Alluvium

The radiochemical analyses indicated only background amounts of radionuclides.

Radiochemical Analyses of Water in Alluvium at SCO-4

(Sept. 1969, in pCi/l except as noted)

Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{3}H	Total Uranium a/
<1	2	<0.05	<0.05	$<4x10^{3}$	0.4

a/ Micrograms per liter

D. Radiochemical Analyses of Sediments

Sediments from the stream channel have been collected for particle size distribution analysis. The particle size distribution of sediments at stations are shown on the following table.

Grade	Stations (Distribution by weight) Near SCS-2	Near SCO-4	State Road 4
Granules	20.5	9.0	6.0
Sand			
Very Coarse	23.0	22.5	12.0
Coarse	35.0	43.5	44.0
Medium	15.0	14.0	19.0
Fine	4.5	6.5	11.0
Very Fine	1.0	2.5	4.0
Silt and Clay	1.0	2.0	4.0

Sediments from the stream channel near SCS-2, SCO-3 and at State Road 4 were collected for analyses in 1965 and 1970. The results of the analyses indicate only background amounts of radionuclides.

Radiochemical Analyses of Sediments

(Analyses in pCi/g except as noted)

Source (Near)	Year	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
Power Plant	1970	1	2	<0.001	0.004
SCS-2 a/	1965	1	2	—	—
SCS-2	1970	2	1	<0.001	<0.001
SCS-3 a/	1965	1	17	—	—
SCS-3	1970	1	< 1	<0.001	<0.001
State Rd 4 a/	1965	2	<1	—	—
State Rd 4	1970	2	2	<0.001	0.003

a/ Counts per minute per dry gram

E. Flood Frequency and Maximum Discharge

Sandia Canyon heads on the Pajarito Plateau at an altitude of about 2290 m and is tributary to the Rio Grande. The flood-frequency and maximum discharge at the boundary are based on the following data:

Drainage Area 7.0 km^2

Main Channel slope 0.028

Frequency	Maximum Discharge (cubic ft per second)
2-year	2.0
5-year	5.4
10-year	8.5
25-year	16
50-year	18

VIII. Drainage Area 7 (Mortandad Canyon

Mortandad Canyon heads on the Pajarito Plateau and is tributary to the Rio Grande (Fig. 14). The main industrial treatment plant at TA-50 releases effluent into the canyon. The plant began treating liquid waste in 1963. The plant releases 54 x 10^3 m^3 of effluent annually into the canyon. An additional 26 x 10^3 to 125 x 10^3 m^3 of waste water from TA-48, New Sigma and storm runoff enter the canyon annually. The stream in the upper reach of the canyon is perennial from the release of industrial effluents and cooling water. Storm runoff adds to the volume of flow; however, since 1960, when hydrologic observations began, all storm runoff as well as effluent has infiltrated into the alluvium west of the discharge boundary due to the small drainage area and large volume of unsaturated alluvium. The alluvium in the canyon thickens from less than 1 m

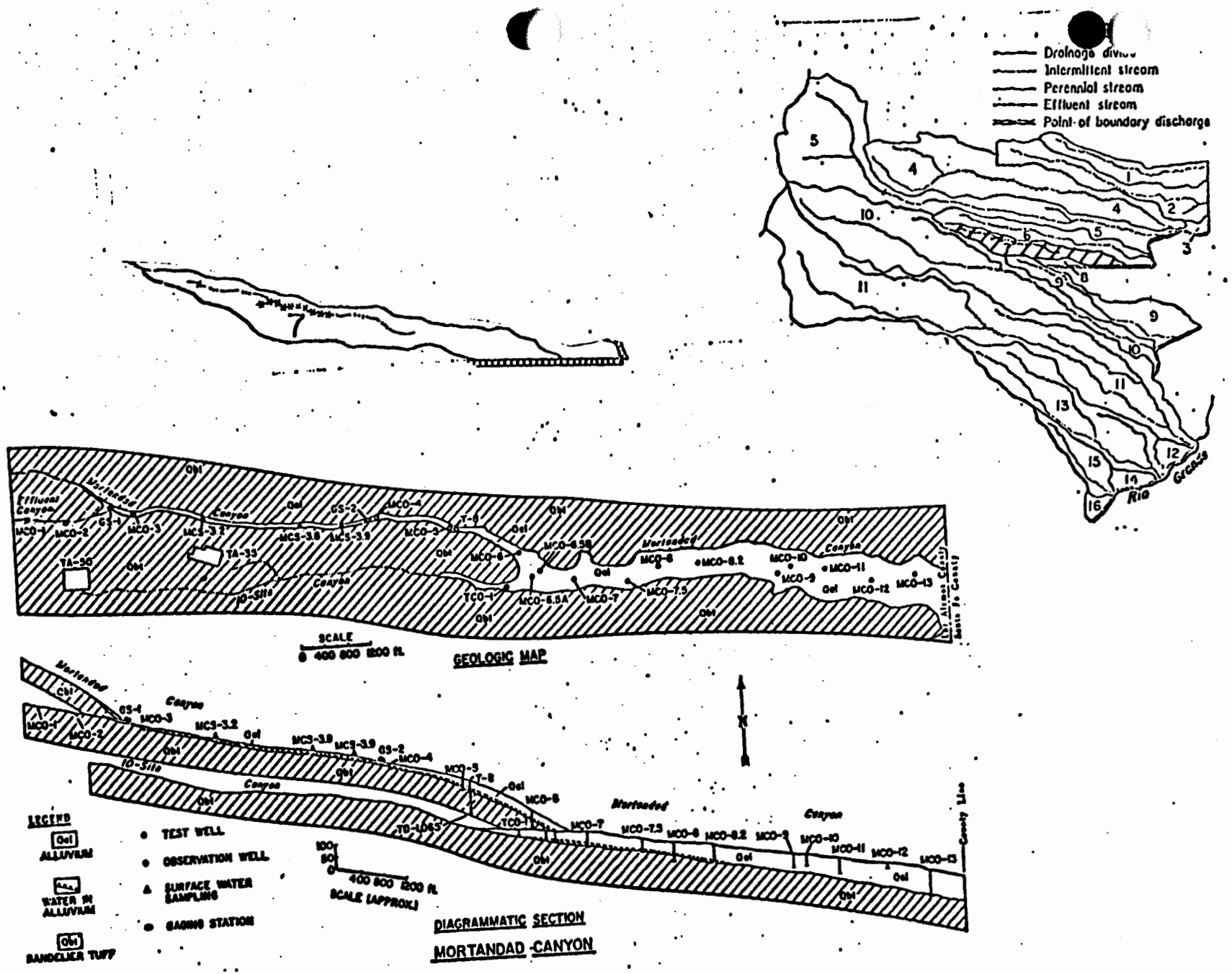


Fig. 14. Drainage Area 7 (Mortandad Canyon) showing geology and sampling stations.

in the upper reaches to more than 40 m at the boundary.

The perennial flow from the effluents and intermittent storm runoff recharges a small body of water in the alluvium that is perched on the underlying tuff. As the water in the alluvium moves eastward, steady losses to evapotranspiration with minor losses into the tuff occur so that the water in the alluvium is of limited extent and does not extend to the surface water discharge boundary at the Santa Fe-Los Alamos County line.

B. Geologic and Hydrologic Investigations

Prior to release of effluents into Mortandad Canyon, studies were made to determine the geologic and hydrologic characteristics of the canyon in regard to the disposal of low-level radioactive liquid wastes. A series of additional studies have been made in the canyon as it receives the bulk of the effluent from the treatment wastes generated by the laboratory. An abstract of the results from these reports is presented in the following section.

1. Preliminary Report of the Geology and Hydrology[16]

The preliminary report (1963) summarizes the studies October 1960 through June 1961

ABSTRACT

The U.S. Geological Survey, in cooperation with the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory, selected the upper part of Mortandad Canyon near Los Alamos, New Mexico as a site for disposal of treated, liquid, low-level radioactive waste. This report summarizes the part of a study of the geology and hydrology that was done from October 1960 through June 1961. Additional work is being continued.

Mortandad Canyon is a narrow, east-southeast-trending canyon about 9-1/2 miles long that heads on the central part of the Pajarito Plateau at an altitude of about 7,340 feet. The canyon is tributary to the Rio Grande. The drainage area of the part of Mortandad Canyon that was investigated is about 2 square miles, and the total drainage area is about 4.9 square miles.

The Pajarito Plateau is capped by the Bandelier Tuff of Pleistocene age. Mortandad Canyon is cut in the Bandelier, and alluvium covers the floor of the canyon to depths ranging from less than 1 foot to as much as 100 feet. The Bandelier is underlain by silt, sand, conglomerate, and interbedded basalt of the Santa Fe Group of Miocene, Pliocene, and Pleistocene age. Some ground water is perched in the alluvium in the canyon; however, the top of the main aquifer is in the Santa Fe Group at a depth of about 990 feet below the canyon floor.

Joints in the Bandelier Tuff probably were caused by shrinkage of the tuff during cooling. The joints range from hairline cracks to fissures several inches wide. Water can infiltrate along the open joints where the Bandelier is at the surface; however, soil, alluvial fill, and autochthonous clay inhibit infiltration on the tops of mesas, and probably in the alluvium-floored canyons, also.

Thirty-three test holes, each less than 100 feet deep, were drilled in 10 lines across Mortandad Canyon from the western margin of the study area to just west of the Los Alamos-Santa Fe county line. Ten of the holes were cased for observation wells to measure water levels and collect water samples from the alluvium. Twenty-three of the holes were cased to seal out water and were used as access tubes to accomodate a neutron-neutron probe for determining the moisture content of the alluvium and tuff.

The source of recharge for the perched ground-water body in the alluvium in Mortandad Canyon is the precipitation in the drainage area of the canyon. During the winter of 1960-61, a snowpack 1-2 feet thick accumulated in the narrow shaded upper part of the canyon. The alluvium beneath the snowpack received some recharge because of diurnal melting during the winter. In March 1961 the snow-melt water saturated most of the thin alluvium in the upper part of the canyon, and a surface stream began to flow. The maximum flow of the surface stream was about 250 gpm (gallons per minute). Water from the stream infiltrated into the alluvium at the front of the surface stream and in the reach upstream from the front. A ground-water mound was formed beneath the channel by water infiltrating from the stream. The front of the surface stream and the front of the ground-water mound advanced eastward to about the middle of the area studied. From this point eastward, the alluvium is thick enough to absorb and transmit the amount of flow in 1961. Late in April the front of the surface stream retreated, and by the first of May the surface flow stopped. During and after this period the ground-water mound decayed, and ground-water levels dropped in the upper part of the canyon as water drained into the channel and downgradient through the alluvium.

The amount of recharge was small in the wide lower part of the canyon during the period of study. The rise in ground-water levels and the increase in moisture content of the alluvium in the lower part of the canyon indicate that water moved downgradient by underflow through the alluvium from the recharge area in the upper part of the canyon. Moisture measurements indicate that only a little water moved into the underlying Bandelier Tuff from the saturated alluvium in the part of the canyon studied.

A deep test well was drilled in Mortandad Canyon near the middle of the area studied. The top of the main aquifer in the well was between the depths of 985 and 990 feet below the bottom of the canyon. The water rose almost 30 feet in the well, indicating that confining beds exist in the lower part of the Puye Conglomerate. The piezometric surface of the main aquifer slopes eastward,

indicating that the main aquifer is recharged mainly west of the Pajarito Plateau, and that it discharges the water near the Rio Grande. Samples of water from the main aquifer and the alluvium had no radioactivity above that of a standard sample of water.

The infiltration and movement of waste liquid will follow the same general pattern as that of the perched ground water in the alluvium. The liquid will infiltrate in the upper and middle reaches of the part of the canyon studied and move eastward through the alluvium. The data indicate that the alluvium in the lower reach will absorb and transmit the predicted discharge of 500,000 gallons of waste per week. Little of the liquid will move downward into the Bandelier Tuff in the area studied, and probably none will reach the main aquifer in the Santa Fe Group. The movement of ground-water in the part of the canyon east of the Los Alamos-Santa Fe County line was not determined.

The clay in the alluvium probably will remove most of the radioactive waste material by sorption and base exchange. This might eventually build up relatively high concentrations of radioactive material which would move slowly downgradient through the alluvium. Further work will be necessary, before and after waste is discharged from the plant, to obtain quantitative hydrologic data and to determine the movements of the water in the alluvium below the area studied.

A progress report was issued in 1964 covering the period 1961 to June 1963. Data included are surface water records, quality of water prior to the release of effluents as well as radiochemical analyses of sediments from the stream channel and observation holes.[17]

2. Distribution of Radioactivity in Alluvium[18]

A short paper was prepared in 1966 which describes radioactivity in the alluvium of Mortandad Canyon.

ABSTRACT

Fine particles in alluvial material in a disposal area for liquid radioactive wastes at Los Alamos have greater affinity for radionuclides than coarse particles; however, most of the radioactivity is in the coarse material, which is more abundant. The radioactivity in the alluvium is dispersed by waste water and storm runoff and decreases with distance from the point of effluent outfall. Most of the radionuclides are retained in the upper 3 feet of the deposits, resulting in very little change in the quality of the ground water perched in the alluvium.

3. Disposal of Industrial Effluents in Mortandad Canyon[19]

A report was submitted in 1967 describing a study to determine the movement of effluents in Mortandad Canyon and evaluate the possibility of contamination of surface and ground water outside the canyon disposal area.

ABSTRACT

Mortandad Canyon is cut into the Bandelier Tuff, which forms the Pajarito Plateau. The drainage area above and within the disposal area is small. The alluvium is thin in the upper canyon but thickens eastward into the middle and lower canyon.

The canyon has no natural perennial streamflow. Surface water entering the disposal area is storm runoff, waste water from cooling process at New Sigma and TA-48, and industrial effluents from the waste treatment plant at TA-50. The storm runoff, waste water and effluents infiltrate into the alluvium to recharge a body of water perched in the alluvium overlying the tuff. As the water moves through the alluvium some is lost to evapotranspiration while the remainder infiltrates into the tuff.

An inventory of surface water and water in the alluvium from July 1963 to June 1965 indicated that a greater amount of water was lost into the tuff in the upper canyon than in the middle and lower canyon of the disposal area becuase the alluvium overlying the tuff in the upper canyon is more permeable (silty sand) than the alluvium overlying the tuff in the middle and lower canyon (sandy silt). The movement of water in the tuff is downward beneath the disposal area into the unsaturated volcanic rocks and sediments of the Puye Conglomerate.

The upper part of the main aquifer in the Los Alamos area is in the Puye Conglomerate, about 1,000 feet beneath the canyon floor. The water in the main aquifer is moving at about 70 feet per year toward the Rio Grande. The Rio Grande, about 6 miles east of the disposal area, is the natural discharge for the main aquifer.

The chemical and radiochemical quality of water in the alluvium improves downgradient in the disposal area due to dilution of the effluent by storm runoff and waste water, and by adsorption of certain ions and radionuclides by clay minerals. Water in the main aquifer showed no sign of chemical or radiochemical contamination.

The geology and hydrology of Mortandad Canyon is ideal for the disposal of low-level radioactive effluents. The small drainage area and the volume of alluvium (to absorb the storm runoff) reduces chances for storms to flush contaminates to the Rio Grande. Chemical and radiochemical contamination is confined to the disposal area. The disposal area has an environment that reduces the contamination in the effluents, and the slow movement of water in the main aquifer beneath the disposal area would allow ion-exchange and half life decay of any radionuclides

that should reach the aquifer, so that no contamination would remain in the water when it reached its natural discharge area.

4. Occurance of Tritium in the Shallow Alluvial Aquifer, 1966-1969 [20]

The occurance and dispersion of tritium in water in the alluvium was described in a section of a 1973 report.

ABSTRACT

Tritium was detected in the stream-connected aquifer in the alluvium of the canyon. Concentrations were greater in the lower part of the canyon. The tritium was probably residual from liquid waste released in early operations of the treatment plant at TA-50 (1963 through 1966) or from TA-35 in the late 1950's or early 1960's.

It was estimated in February 1967 that storage of water in the alluvium in the lower canyon was about 19.0 million liters. The average tritium concentration (MCO-6, MCO-7, MCO-7.5, and MCO-8) for February was 490 pCi/ml; thus, it was estimated that the water in storage contained about 9.3 Ci of tritium. In May 1969 the storage was estimated at 14.4 million liters with an average tritium concentration of 80 pCi/ml or about 1.2 Ci of tritium in the total water in storage.

The tritium concentrations decrease with time due to the dilution of the water with the inflow of waste effluents and storm runoff into the alluvium and tritium losses to evapotranspiration.

5. Dispersion and Movement of Tritium in the Shallow Aquifer [21]

A report in 1974 describes the movement and dispersion of tritium in ground water in the alluvium.

ABSTRACT

Twenty (20) Ci of tritium discharged into Mortandad Canyon in November 1969 were used to determine the dispersion and movement of the tritium in a shallow aquifer in the alluvium. It took 388 days for the peak concentration to move 3,027 m from the effluent outfall to the eastern end of the aquifer. The concentration decreased from 77,700 pCi/ml to 310 pCi/ml in that distance. Ground water in transit storage contained about 0.9 Ci of tritium prior to the release of the 20 Ci. About 3.9 Ci of tritium remained in transit storage at the end of 1970. The remaining 17.0 Ci were lost with evapotranspiration, infiltration with ground water into the underlying tuff, or suspended with soil moisture above the aquifer.

The rate of movement of water in the alluvium and field coefficient of permeability were described for the three sections of the canyon using tritium and chloride ion as tracers.

Canyon Location	Type of Unit	Velocity of Tracers (m/day)	Coefficient of Permeability (m/day)
Upper	Coarse Sand	18	141
Middle	Silty-Sand-Clay	5	50
Lower	Silty-Sand-Clay	2	7.6

B. Industrial Waste Treatment

Liquid wastes, products of research by the Los Alamos Scientific Laboratory, are treated at the waste treatment plant at TA-50. The liquid wastes contain a varying amount of chemical and radiochemical constituents. However, the treatment of the influents to reduce harmful contamination is about the same regardless of the chemical and radiochemical quality of the liquid wastes. The chemical composition of the influent is changed by the addition of certain chemicals during treatment.

The chemicals are added at several stages during treatment. Sodium hydroxide is added to the liquid wastes as it arrives at the plant to neutralize the acid and to raise the pH. Ferric sulfate and calcium hydroxide are added as the influent enters flocculator clarifiers; this precipitates out the radioactivity that was carried in suspension or was otherwise insoluble. The precipitate is collected as a sludge in settling basins, dried, mixed with vermiculite, placed in barrels, and buried in disposal pits on the plateau. Flocculation removes most of the plutonium and fission products. If, however, the liquid waste still contains excessive radioactivity it is acidized with nitric acid and passed through ion exchange columns where artificial resins remove most of the remaining radionuclides, generally strontium 90, cesium 137, and other fission products. The waste is again treated with sodium hydroxide to raise the pH to about 11 before transfer to holding tanks prior to disposal.

Concentrations of sodium, calcium, carbonate, bicarbonate, nitrate, and chlorides, as well as total dissolved solids, are higher than found in native waters. If the wastes are acidized for the ion-exchange columns, high nitrate and conductivity are characteristic of the effluent.

Careful control is maintained throughout the entire treatment operation by frequent collection and analysis of the influent at the different stages of treatment. The resulting effluent is discharged into the disposal area when the radioactivity is less than 10 percent of the MPC (maximum permissible concentration) as recommended by the International Committee on Radiation Protection.

1. Chemical Quality of Effluent

The liquid wastes vary in chemical and radiochemical constituents when they arrive at the plant; however, the resulting effluents reflect the chemical treatment of a weekly composite, as shown on the following table.

Chemical Quality of Effluents [a]

(Analyses in mg/l except where noted)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Calcium	40	37	20	56	129	167	25	32	48	12
Magnesium	3	< 1	4	< 1	< 1	< 1	1	5	2	2
Sodium	96	280	205	135	100	135	2250	500	740	215
Carbonate	139	280	290	130	230	340	2350	158	120	20
Bicarbonate	199	370	415	160	320	448	2610	282	720	290
Chloride	10	37	25	19	10	24	52	35	140	10

Chemical Quality of Effluents[a]
(Analyses in mg/l except where noted)
(Continued)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Fluoride	2	2	3	1	3	2.6	.2	.9	3.2	< .1
Nitrate (n)[b]	3	29	6.0	7	7.9	6.0	74	223	280	52.8
Cyanide	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Total Dissolved Solids							4258	2132	2118	768
Conductance[c]	760	1980	1760	1280	1380	2090	4500	2400	2520	1140
pH[b]	11.3	11.6	11.5	11.5	11.4	11.7	12.1	10.9	9.7	8.9

a/ Weekly Composite, 1st week of July, filter Sample; if ion-exchange column used, nitrate and calcium higher.

b/ N x 4.4 = NO_3

c/ Micromhos

d/ No Units

The average annual chemical quality of the effluents is presented in the following table.

The Average Annual Chemical Quality of Industrial Effluent from TA-50.

Effluent TA-50	Chemical Constituents											
	Milligrams per liter											
Year	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (μmhos at 25°C)	pH
1963[a]	52	1.4	188	302	376	28	1.7	63	830	135	1730	11.6
1964	36	0.9	219	280	386	41	2.5	97	960	94	1950	11.6
1965	40	0.8	196	278	367	30	2.2	131	860	109	2070	10.9
1966	52	3.2	151	213	292	17	1.4	50	660	145	1280	11.4
1967	110	3.1	120	226	306	21	2.3	55	570	289	1520	11.2
1968	100	2.7	153	265	353	28	3.2	63	618	259	1630	11.2
1969	91	2.3	286	300	428	34	2.7	131	940	235	1990	11.2
1970	56	4.8	406	354	472	38	2.1	551	1500	155	2340	11.2
1971	42	3.9	433	218	641	169	2.7	372	1590	120	2450	9.2
1972	30	3.6	571	91	506	108	1.2	766	1670	91	2570	8.8

A measure of the effect of the effluents on plant growth is the sodium-adsorption ratio (SAR) and conductance. The SAR approximates the base exchange of sodium in the effluent and is a measure of the alkali hazard that could occur and in turn would effect plant growth in the canyon. It is expressed in equivalents per million as:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Wg}{z}}}$$

The sodium (alkali) hazard is based on SAR of 0 - 10, low, 11 - 18, medium, 19 - 26, high; and above 26 very high.

The salinity hazard is based on the conductance or mineral concentration in solution of the effluent that is available for precipitation into the soil that in turn can effect plant growth. The classification is based on 100 to 250 µmhos, low; 250 to 750 µhmos, medium; 750 to 2250 µmhos, high; and above 2250 µmhos very high. The following table shows the sodium (alkali) and salinity hazard of the effluent based on average annual concentration.

	Effluent - TA-50			
Year	SAR	Sodium (Alkali) Hazard	Conductance (µmhos/cm)	Salinity Hazard
1962	--	--	--	--
1963	7.0	Low	1730	High
1964	6.9	Low	1950	High
1965	8.4	Low	2070	High
1966	5.5	Low	1280	High
1967	3.1	Low	1520	High
1968	4.1	Low	1630	High
1969	8.1	Low	1990	High
1970	14	Medium	2340	very high
1971	17	Medium	2450	very high
1972	26	High	2570	very high

Waste water is discharged into the disposal area from New Sigma and TA-48 from cooling processes in the laboratories. The water is originally from the municipal supply from Los Alamos. No chemicals are added; however, the chemical quality may have been changed slightly by use, due to evaporation losses as shown on the following table:

Chemical Quality of Waste Water TA-48 and New Sigma

(Analyses in mg/l except as noted)

Source	Year	Sodium	Chloride	Fluoride	Nitrate	Dissolved Solids	Conductance a/	pH
TA-48	1962	36	6	0.8	1.3	192	218	7.7
TA-48	1965	44	2	0.8	.4	210	240	8.0
New Sigma	1962	34	4	1.6	1.8	162	180	8.3
New Sigma	1965	32	2	0.4	2.2	599	640	8

a/ Micromhos

B. Radiochemical Quality of Effluent

After treatment and release, the effluents contain some radionuclides. The following table presents the average annual concentrations in the effluent.

Average Annual Radiochemical Quality of Effluents, TA-50

Year	Amount (M^3)	pCi/l Gross Alpha	Gross Beta	Total Pu	^{89}Sr	^{90}Sr
1963	27390	194	12700	58.4	5430	1450
1964	51400	70	52000	37.7	1200	1700
1965	49000	109	16600	71.2	860	1260
1966	52810	70	7500	31.0	460	670
1967	59680	128	6300	70.7	890	220
1968	60290	86	5400	43.0	540	130
1969	54480	24	6600	120	1000	240
1970	53180	160	11000	94	250	370
1971	45680	230	24000	150	270	690
1972	57080	240	6700	148 a/	62	96

a/ ^{238}Pu 130; ^{239}Pu 18

The annual and total amount of radionuclides released in effluents from TA-50 is presented in the following table.

Annual Amount of Radionuclides Released with Effluents, TA-50

Year	mCi Gross Alpha	Gross Beta	Total Pu	^{89}Sr	^{90}Sr
1963	5.3	348	1.6	148.7	39.7
1964	3.6	2670	1.9	64.9	87.4
1965	5.3	813	3.5	42.1	61.7
1966	3.7	396	1.6	24.3	35.4
1967	7.6	376	4.2	53.1	13.1
1968	5.2	326	2.6	32.6	7.8
1969	1.3	360	6.5	54.5	13.1
1970	8.5	585	5.0	13.3	19.7
1971	10.5	1096	6.8	12.3	31.5
1972	13.7	382	8.4 a/	3.5	5.5
	64.7	7352	42.1	449.3	314.9

a/ ^{238}Pu, 7.4; ^{239}Pu, 1.0.

In addition to the effluents released from the treatment plant at TA-50, a smaller plant was operated at TA-35 from 1956 through 1963. The effluents were released into 10-Site Canyon. The volume of effluent was not sufficient to move as surface flow into Mortandad Canyon. Storm runoff entered Mortandad Canyon between MCO-6 and MCO-7. The effluents contained mainly strontium and cesium. The annual average concentrations of radionuclides are shown on the following table.

Average Annual Radiochemical Quality of Effluents, TA-35

		pCi/l		
Year	Amount (M^3)	Gross Beta	^{89}Sr	^{90}Sr
1956	682.5	—	1 370 000	241 000
1957	1630	1 430 000	130 000	22 600
1958	1391	119 000	73 000	7 700
1959	667.5	6 600 000[a/]	38 900	5 990
1960	1248	76 000	27 200	4 800
1961	1541	64 000[a/]	5 840	650
1962	1241	82 000[a/]	7 410	820
1963	399.5	310 000	250[a/]	250[a/]

a/ Estimated

The annual and total amounts of ^{89}Sr and ^{90}Sr released from TA-35 into 10-Site Canyon are presented in the following table.

Annual Amounts of ^{89}Sr and ^{90}Sr Released with Effluents, TA-35

Year	mCi	
	^{89}Sr	^{90}Sr
1956	935	164
1957	212	36.8
1958	101	10.7
1959	25.9	4.0
1960	33.9	5.9
1961	9.0	1.0
1962	8.9	.9
1963	0.1	0.1 a/
TOTAL	1 325.8	223.4

a/ Estimated

C. Surface Water

Surface water entering the canyon consists of effluent from TA-50, storm runoff and waste water. The effluent from TA-50 for the period 1964 (first full year of discharge) to 1972 has ranged from 46 x 10^3 to 60 x 10^3 m^3 or an annual average of about 54 x 10^3 m^3. Waste water from TA-48 has ranged from 1.6 x 10^3 to 2.0 x 10^3 m^3 annually. Six (6) release of waste water from New Sigma have occurred ranging from 2 to 6 weeks in time. The releases were 1962 (18 x 10^3 m^3), 1963 (37 x 10^3 m^3), 1964 (19 x 10^3 m^3), 1965 (18 x 10^3 m^3), and 1969 (48 x 10^3 m^3). The average annual runoff and waste water entering the canyon from 1962 through 1972 has ranged from 26 x 10^3 to 125 x 10^3 m^3 or an annual average of about 63 x 10^3 m^3. Thus, over a period of time the dilution of effluent to runoff and waste water has been about one to one. The volume of water entering the canyon is measured at Gauging Station 1 (Fig. 14). The following table shows annual volume of effluent, storm runoff, and waste water passing through Gauging Station 1.

Volume of Effluent Storm Runoff and Waste Water
at Gauging Station 1

	Effluent TA-50 (x 10^3 m^3)	Storm-runoff and Waste Water (x 10^3 m^3)	Total (x 10^3 m^3)
1961	--	--	--
1962	--	70	70
1963	27[a]	125	152
1964	51	59	110
1965	49	75	124
1966	53	35	88
1967	60	79	139
1968	60	52	112
1969	54	93	147
1970	53	50	103
1971	46	29	75
1972	57	26	83

[a] Operations July-December

A second gauging station GS-2 was operated about 1370 m downgradient from GS-1 from March 1962 through December 1965. The annual surface water loss between the two stations ranged from 51 x 10^3 m^3 to 115 x 10^3 m^3. The loss was to evapotranspiration and infiltration into the alluvium and underlying tuff. Water infiltrating into the alluvium recharges the water in the alluvium that is preched on the underlying tuff. The water in the alluvium moved downgradient into the lower section of the canyon east of GS-1. During the period of record, about 74% of the surface water passing through GS-1 was lost before reaching GS-2. The following table presents the annual records of surface water passing by Gauging Stations 1 and 2 and losses between the two stations.

Surface Discharge at Gauging Stations 1 and 2 and Loss between Stations 1962-1964 (In Cubic Meters)

Year	Gauging Station 1	Gauging Station 2	Surface Water loss between Stations
1962[a]	70	19	51
1963	152	37	115
1964	110	28	82

a/ March through December

Surface water sampling stations are at GS-1, MCS-3.8, MCS-3.9, and GS-2. The surface flow at stations MCS-3.8 and MCS-3.9 is return flow from the alluvium. The increased gradient in the channel causes thinning of the alluvium causing water in the alluvium moving downgradient to flow on the surface for 30 to 60 m.

1. Chemical Quality of Surface Water

The chemical quality of the surface flow after June 1963 reflects the release of treated industrial effluents from TA-50. The following table presents average chemical quality of surface water at the four stations from 1962 through 1972.

Chemical Quality of Surface Water, 1962-1972
(Average of a number of analyses in mg/l except as noted)

Station	GS-1	MCS-3.8	MCS-3.9	GS-2[a]
No. of Analyses	37	16	19	3
Sodium	183	134	148	122
Chloride	15	20	31	14
Fluoride	1.2	2.0	1.3	1.3
Nitrate	24	33	11	29
Total Dissolved Solids	494	555	636	443
Conductance[b]	570	600	720	500
pH[c]	9.6	8.4	8.3	--

[a] Samples collected during release of effluents from New Sigma.

[b] Micromhos

[c] No Units

The return flow at MCS-3.8 and 3.9 indicates dissolution of chemical ions in the alluvium as seen by the increase in total dissolved solids concentration. Analyses of water at GS-2 were taken during the release of waste water from New Sigma Bldg. The following table presents average annual quality of water at GS-1 from 1962 to 1972.

Quality of Surface Water at Gauging Station 1
(Average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1962	2	40	6	0.8	1.3	212	240	7.6
1963	2	70	10	1.2	1.3	324	440	8.7
1964	6	146	19	1.3	63	566	670	9.8
1965	5	245	16	1.4	36	921	1150	10.2
1966	3	109	20	1.8	35	412	500	10.4
1967	2	86	5	1.2	1.3	255	415	10.2
1968	2	56	13	0.8	.9	194	260	9.4
1969	1	22	5	<.1	2.2	244	220	9.0
1970	6	881	16	1.7	40	1309	1190	11.1
1971	4	139	38	1.9	36	517	620	11.0
1972	4	221	15	1.0	44	479	520	7.7

[a] Microhmos
[b] No Units

The chemical quality varies due to the change in quality of the effluent from TA-50. The nitrate concentrations have increased in the latter part of the period due to a greater use of the ion-exchange columns which use nitric acid as part of the treatment process.

The following table presents the average annual chemical quality of water at MCS-3.8 for the years 1963 through 1971.

Quality of Surface Water at MCS-3.8
(Average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1963	2	78	7	0.8	4.8	328	405	8.6
1964	5	186	36	4.6	119	742	440	8.0
1965	4	128	11	1.8	19	583	520	8.4
1966	2	100	35	1.5	15	385	540	9.5
1967	1	149	24	1.4	16	346	460	8.0
1968	1	115	5	1.0	9.7	318	440	8.2
1971	1	185	30	3.0	490	1186	1400	8.3

[a] Microhmos at 25° C
[b] No Units

The next table presents the quality of water at MCS-3.9 for the years 1963 through 1972.

Quality of Surface Water at MCS-3.9
(Average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1963	1	43	6	.4	<.4	221	290	7.7
1964	3	152	29	.9	114	748	920	8.0
1965	2	114	12	1.6	37	552	600	9.6
1966	2	102	32	1.5	15	437	500	8.6
1967	2	132	20	1.2	15	356	400	7.9
1968	1	110	15	2.2	11	260	370	8.3
1970	1	260	20	1.0	246	662	820	8.5
1971	3	280	104	1.5	303	1390	1300	8.2
1972	4	139	39	1.5	299	1098	1235	7.8

[a] Micromhos at 25° C
[b] [illegible]

Analyses from Stations MCS-3.8 and MCS-3.9 are of return flow from the alluvium, in which the nitrate increase in the latter part of the period, is quite prominent. Total dissolved solids also shows a large increase in concentration.

The following table shows analyses of water at Gauging Station GS-2 which is mainly waste water from New Sigma Bldg.

Quality of Surface Water at Gauging Station 2
(Average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1962	1	48	6	.8	.2	232	250	7.7
1964	2	151	17	1.8	10.0	544	600	9.5
1965	1	167	20	1.3	10.0	552	640	10.2

[a] Micromhos at 25° C
[b] No Units

Selected metal ions were analyzed from samples of water collected at Gauging Station 1 in 1971 and 1972 and from MCS-3.9 in 1971.

Metal Ion Analysis
(Average of a number of analyses in μg/l)

Source	Gauging Station 1	MCS-3.9
No. of Analyses	3	2
In Solution		
Cadmium	2.6	5.4
Beryllium	.26	<.25
Lead	<1.0	9.2
Mercury	.26	<.02
Particulates		
Cadmium	0.30	0.38
Beryllium	<.25	<.25
Lead	1.2	<1.0
Mercury	.41	< .02

2. Radiochemical Quality of Surface Water

The surface water in Mortandad Canyon at GS-1 and GS-2, prior to the release of effluents from TA-50, contained less than 0.5 pCi/l of plutonium and gross beta was near or below 14 pCi/l. The following table presents radiochemical quality of water from 1962 through 1965.

Radiochemical Quality 1967-1965

Station	Year	No. of Analyses	pCi/l Gross Beta	pCi/l Total Pu	µg/l Total Uranium
GS-1	1964	6	570	6.0	1.1
GS-1	1965	5	1200	2.5	.8
MCS-3.8	1963	2	18	<.5	.7
MCS-3.8	1964	5	180	4.5	<.5
MCS-3.8	1965	4	140	1.2	.8
MCS-3.9	1963	1	<14	<.5	<.5
MCS-3.9	1964	3	100	2.9	<.5
MCS-3.9	1965	2	80	<.5	<.5
GS-2	1962	1	<14	<.5	<.5
GS-2	1964	2	490	2.7	.8
GS-2	1965	4	140	1.2	<.5

There was no analyses of surface water in 1966. The following table presents the radiochemical quality of water from 1967 through 1972.

MORTANDAD CANYON

SURFACE FLOW SAMPLING SITES

RADIOCHEMICAL QUALITY OF WATER

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	^{238}Pu	$^{239+}$Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
GS-1	1967	1	-1	343	-.05	-.05	-.00	.38	.40	-240	-	-50	.021
GS-1	1968	2	-1	292	.46	.42	-.05	-.15	.88	235	-	-50	.271
GS-1	1969	2	10	1174	6.46	6.64	-.00	-.15	1.18	3020	169	241	.621
GS-1	1970	8	19	3338	19.80	5.60	3.06	-.15	2.01	6336	385	87	.021
GS-1	1971	5	31	1604	25.35	5.06	4.51	-.15	4.16	3556	233	31	.021
GS-1	1972	4	12	520	8.68	.97	.77	-.00	-.00	718	-	23475	3.250
MCS-3.9	1967	1	-1	97	-.05	-.05	-.00	-.15	-.00	-	-	82	.821
MCS-3.9	1968	2	1	193	.12	.22	-.05	-.15	-.00	-240	-	-	3.121
MCS-3.9	1969	1	-1	142	.22	.17	-.00	-.00	-.00	-	-	6	1.221
MCS-3.9	1970	2	2	309	.35	.28	-.00	-.00	-.00	-	87	391	1.471
MCS-3.9	1971	4	10	817	3.14	.34	-.00	-.15	-.00	323	167	45	5.571
MCS-3.9	1972	4	12	523	5.97	.90	.86	-.00	-.00	-350	-	46933	[illegible].30
GS-2	1971	1	95	312	1.05	5.00	3.02	-.15	2.03	390	89	28	[illegible]21

In general the surface water near the effluent outfall contains the largest concentrations of radioactivity which decrease with increase distance from the outfall.

D. Water in Alluvium

Water in the alluvium is recharged from industrial effluents, storm run-off and waste water. As the water in the alluvium moves downgradient in the canyon, loss to evapotranspiration and into the underlying tuff is of limited extent.

The volume of water in the alluvium was calculated from the known volume of saturation in the alluvium as determined by test drilling, and subsequent water level in test holes as the volume of water fluctuates, dependent on amount of recharge. The following table presents the volume of water in storage in the aquifer as of December 31 for the years 1961 through 1972 and the annual volume of surface and ground water loss in the canyon. The calculations are based on volume of inflow at Gauging Station 1 for the year and changes in storage.

Storage in Aquifer and Surface and Ground Water Loss

Year	Storage in aquifer[a] ($\times 10^3$ m^3)	Annual surface and ground water loss in canyon ($\times 10^3$ m^3)
1961	20	--
1962	20	70
1963	22	150
1964	24	108
1965	25	123
1966	20	93
1967	30	129
1968	24	118
1969	25	146
1970	20	108
1971	29	66
1972	23	89

[a] Storage as of December 31

Storage in the aquifer has ranged from 20 x 10^3 m^3 to 30 x 10^3 m^3 from the years 1961 through 1972. The volume of loss has ranged from 70 x 10^3 m^3 to 146 x 10^3 m^3. The volume of water in storage has remained fairly constant for the period of record. The loss from storage has been essentially equal to the volume of surface water inflow for the year, thus, the aquifer has remained of limited extent, within the project boundaries.

The canyon has been subdivided into three sections to facilitate computation of storage. This division is sometimes used to compute the mass of radionuclides or chemicals in storage. The following table presents the volume of water in storage in the alluvium in the three sections of the canyon from 1961 through 1972 as of December 31.

Volume in Storage in Three Sections of Aquifer, 1961-1972

	Volume in x 10^3 m^3 a/			
Year	Upper	Middle	Lower	Total
1961	3.2	3.3	13.3	19.8
1962	2.4	5.7	11.8	19.9
1963	2.1	3.5	16.5	22.1
1964	5.9	4.7	13.2	23.8
1965	3.9	6.3	14.9	25.1
1966	2.8	3.1	14.2	20.1
1967	6.7	5.1	18.3	30.1
1968	5.2	4.7	14.3	24.2
1969	2.9	5.6	16.6	25.1
1970	2.5	2.9	14.4	19.8
1971	4.8	7.1	16.9	28.8
1972	4.4	5.0	13.5	22.9

[a] As of December 31

Water samples were collected from ten (10) observation holes (Fig. 10). The depth to water ranges from about 1.2 m at Observation Hole MCO-3 to 24 m at Observation Hole MCO-8. The water levels will vary dependent on the volume of water entering the canyon as surface flow.

1. Chemical Quality of Water in Alluvium

Samples were collected and analyzed prior to the release of effluents from TA-50 to provide a base line of the chemical quality changes that would occur in water in the alluvium.

The following table presents a summary of the chemical quality of water prior to the release of effluents from TA-50.

Chemical Quality of Water in Alluvium, 1961-1962

(average of a number of analyses in mg/l except as noted)

Obs. Hole	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
MCO-1	1	95	10	1.0	0.5	175[c]	270	7.1
MCO-2	1	115	12	1.0	1.5	188[c]	290	7.0
MCO-3	3	52	7	0.7	0.9	398	420	7.1
MCO-4	3	48	7	0.7	0.8	370	440	7.2
MCO-5	3	28	7	0.7	0.8	203	270	6.7
MCO-6	3	16	8	0.7	1.1	325	350	6.6
MCO-7	3	15	7	0.7	1.1	283	240	6.7
MCO-7.5	2	18	8	0.4	1.4	230[c]	350	6.8
MCO-8	3	16	7	0.7	0.9	175	230	6.8

[a] Micromhos at 25° C

[b] No Units

[c] Estimated

Observation Holes MCO-1 and MCO-2 were drilled in or near the stream channel to depths of less than 2 m. The chemical quality is essentially the same as the stream or cooling water discharged from TA-48. No samples were collected after 1962.

Observation Hole MCO-3 is located 122 m west of the effluent outfall. The hole was drilled to a depth of 3.6 m. The depth to water is about 1 m. The average chemical quality of water from 1961 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-3
(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	59	8	1.0	0.9	250[c]	380	7.0
1962	2	48	7	0.4	0.8	398	460	7.2
1963	9	109	15	0.9	45	458	540	7.6
1964	10	165	28	2.2	73	673	740	8.1
1965	5	100	13	1.6	22	428	460	8.6
1966	3	89	16	1.2	13	359	400	8.6
1967	2	100	14	1.2	8.8	253	290	8.5
1968	2	84	12	1.4	5.3	229	310	9.0
1969	2	237	5	3.0	7.0	567	660	8.8
1970	4	210	20	1.0	761	738	790	8.6
1971	4	256	69	2.6	260	964	1215	9.1
1972	4	234	28	1.6	285	977	1075	8.2

[a] Micromhos at 25° C
[b] No Units
[c] Estimated

Observation Hole MCO-4 is located 1460 m east of the effluent outfall. The hole was drilled to a depth of 5.8 m. The water level is about 3.7 m. The average chemical quality of water from 1961 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-4
(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	52	8	1.0	1.0	210[c]	320	6.8
1962	2	44	6	0.4	0.5	371	440	7.2
1963	9	72	11	0.5	37	387	415	7.4
1964	10	140	26	0.7	96	605	750	7.6
1965	5	144	15	1.2	57	455	640	7.9
1966	3	113	26	0.9	26	433	500	7.9
1967	2	140	22	1.6	18	341	435	7.6
1968	2	128	10	1.6	8.8	296	395	8.0
1969	2	118	10	<0.1	22	293	390	8.2
1970	5	158	18	0.7	202	624	740	7.8
1971	4	262	77	1.0	392	1108	1300	7.6
1972	4	262	42	1.4	299	1018	1175	7.6

[a] Micromhos at 25° C

[b] No Units

[c] Estimated

Observation Hole MCO-5 is located 1841 m east of the effluent outfall. The hole was drilled to a depth of about 11.5 m. The water level is about 6.4 m. The average chemical quality of water from 1961 through 1962 is presented on the following table.

Chemical Quality of Water, MCO-5
(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	29	6	1.0	1.0	186	220	6.5
1962	2	28	8	0.4	0.6	220	320	6.9
1963	8	36	7	0.4	3.5	222	241	7.1
1964	10	102	22	0.4	89	494	601	7.4
1965	5	101	13	0.3	44	396	496	7.6
1966	4	133	27	0.2	40	411	608	7.7
1967	1	164	13	1.0	0.8	315	350	7.5
1968	2	128	15	0.4	8.8	307	360	7.5
1969	2	118	12	<0.1	28	281	375	8.3
1970	1	131	10	<0.1	20	546	660	7.5
1971	4	209	46	0.4	367	926	1100	7.3
1972	4	199	57	0.5	216	808	955	7.5

[a] Microhmos at 25° C
[b] No Units

Observation Hole MCO-6 is located 2234 m east of the effluent outfall. The hole was drilled to a depth of 21.6 m. The water level is about 11 m. The average chemical quality of water from 1961 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-6

(average of a number of analyses in mg/l except as noted)

Year	No. of analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	15	7	1.0	1.4	140[c]	210	6.5
1962	1	28	9	0.4	0.8	325	350	6.7
1963	9	36	7	0.4	6.2	218	240	7.1
1964	10	96	21	0.4	95	475	590	7.5
1965	5	104	12	0.4	43	412	470	7.5
1966	3	112	30	0.2	31	462	480	7.7
1967	2	183	14	0.4	16	404	460	7.6
1968	2	120	10	0.9	9.7	312	335	8.1
1969	2	121	10	<0.1	24	312	370	8.2
1970	5	102	18	0.7	114	483	550	7.4
1971	4	226	45	0.8	409	1000	1195	7.5
1972	4	231	73	0.8	246	920	1100	7.6

[a] Microhmos at 25° C

[b] No Units

[c] Estimated

Observation Hole MCO-7 is located 2554 m east of the effluent outfall. The hole was drilled to a depth of 20.7 m. The water level is about 12.2 m. The average chemical quality of water from 1961 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-7

(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	14	7	1.0	1.4	237	220	6.6
1962	2	16	7	0.4	0.7	330	260	6.8
1963	6	23	6	0.4	3.1	222	245	7.1
1964	10	32	12	0.4	33	235	288	7.3
1965	5	48	8	0.4	22	258	310	7.3
1966	3	71	25	0.1	28	309	452	7.5
1967	2	140	18	0.2	15	362	435	7.5
1968	2	112	15	0.2	6.6	314	360	7.6
1969	2	122	15	<0.1	15	360	375	8.2
1970	3	90	13	0.2	35	357	407	7.4
1971	4	166	28	0.6	374	872	995	7.2
1972	4	170	74	0.3	217	785	925	7.5

[a] Microhmos at 25° C

[b] No Units

Observation Hole MCO-7.5 is located 2844 m east of the effluent outfall. The hole was drilled to a depth of 18.3 m. The water level is about 13.7 m. The average chemical quality of water from 1962 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-7.5

(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1962	2	18	8	0.4	1.4	905	350	6.8
1963	5	17	6	0.4	2.2	237	336	7.2
1964	10	23	12	0.4	39	370	349	7.3
1965	5	50	13	0.5	60	340	408	7.1
1966	3	69	28	<0.1	35	391	460	7.4
1967	2	145	20	<0.1	26	426	465	7.6
1968	2	123	10	0.4	3.5	322	390	7.6
1969	2	110	8	<0.1	7.9	454	395	8.0
1970	2	86	8	0.1	35	303	400	7.4
1971	3	190	24	0.5	378	889	973	7.1
1972	4	166	77	0.2	216	792	930	7.4

[a] Microhmos at 25° C

[b] No Units

Observation Hole MCO-8 is located 3027 m east of the effluent outfall. The hole was drilled to a depth of 25.3 m. The water level is about 21.3 m. The average chemical quality of water from 1962 through 1972 is presented on the following table.

Chemical Quality of Water, MCO-8

(average of a number of analyses in mg/l except as noted)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1961	1	23	6	1.0	1.2	200	240	6.7
1962	2	9	8	0.4	0.6	151	225	6.9
1963	4	13	5	0.5	3.3	292	172	7.1
1964	10	14	8	0.4	21	203	239	7.4
1965	5	30	10	0.6	51	274	324	7.4
1966	3	38	18	0.1	31	328	363	7.3
1967	2	86	16	0.6	26	327	465	7.4
1968	2	69	22	0.3	18	311	370	7.4
1969	2	84	25	<0.1	8.8	404	365	8.0
1970	4	50	11	0.3	18	310	345	7.6
1971[c]	—	—	—	—	—	—	—	—
1972	3	107	57	0.3	216	718	820	7.

[a] Micromhos at 25° C

[b] No

[c] 1971 observation Hole dry

The release of effluents into the canyon from TA-50 has significantly changed the chemical quality of water in the alluvium. The following table shows the increase of certain chemical and physical constituents. There was no change in fluoride. Total dissolved solids increase about three fold. The major change is seen by the release of a predominately alkaline effluent with a high concentration of sodium. This has resulted in a change from a slightly acid water to a basic water in the alluvium.

Chemical Quality of Water 1962 and 1972

(average of analyses from seven observation holes)

	1962	1972
Sodium (mg/l)	28	196
Chloride (mg/l)	0.8	242
Fluoride (mg/l)	0.7	0.7
Nitrate (mg/l)	1.0	55
Total Dissolved Solids (mg/l)	292	860
Conductance (μmhos)	330	1000
pH	6.8	7.6

Select metal ions were analyzed in water from observation holes in 1971 and 1972. Traces of the few constituents found are slightly higher than what would be expected in natural waters.

Metal Ion Analyses, 1971-1972

(average of a number of analyses in μg/l)

Source	MCO-3	MCO-4	MCO-5	MCO-6	MCO-7	MCO-7.5
No. of Analyses	4	2	3	3	4	3
In Solution						
Cadmium	5.0	5.2	4.8	3.2	6.9	0.33
Beryllium	<0.25	0.26	0.35	0.40	<0.25	<0.25
Lead	26	16	9.3	1.7	2.9	1.7
Mercury	0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Particulates						
Cadmium	0.86	0.69	1.4	2.2	0.53	3.2
Beryllium	0.35	0.46	0.73	1.7	0.53	2.6
Lead	22	27	26	32	37	57
Mercury	0.12	0.10	0.08	0.11	0.10	0.19

2. Inventory of Chemical Released and in Storage

An inventory of chemicals released into the canyon was estimated using the annual average concentration and volume of effluent for the period July 1963 through December 1972. The inventory of chemicals in solution in the aquifer was made prior to release of effluents and in December 1972 by using the average annual concentrations from seven (7) Observation Holes and the volume of water in storage. The following table presents mass of chemical released with effluent, the mass in storage prior to release of effluents and the mass in storage after 10 years of effluent release.

Inventory of Chemicals in Effluents Released and in Storage in the Aquifer

	kg x 10^3		
	Effluents	In Storage	
Chemical	1963-1972	1962	1972
Calcium	32	0.2	0.9
Magnesium	1.4	.08	.3
Sodium	143	.6	4.9
Carbonate	126	0	0
Bicarbonate (as $CaCO_3$)	210	1.8	5.1
Chloride	26	.1	1.2
Fluoride	1.1	.01	.01
Nitrate	120	.06	5.7
Total Dissolved Solids	519	6.4	20.9
TOTAL	989.5	9.2	39.0

The inventory of chemicals released into the canyon are estimated at 989 x 10^3 kg. This increased the mass from 9.2 x 10^3 kg in 1962 (pre-release) to 39.0 x 10^3 kg in 1972 (after 10 years of release). The amount of chemicals unaccounted for in the inventory were taken up by plants, base exchange with alluvial material in the stream channel or carried into the underlying tuff by infiltrating water.

The sodium (alkali) and salinity hazard of water in storage in the aquifer was compiled from annual average concentration of sodium, calcium, and magnesium (SAR) and conductance.

Sodium and Salinity Hazard
in Storage in the Aquifer

Year	SAR	Sodium (Alkali Hazard)	Conductance (μmhos/cm)	Salinity Hazard
1962	2.1	low	360	medium
1963	3.2	low	360	medium
1964	1.1	low	510	medium
1965	5.5	low	440	medium
1966	5.4	low	470	medium
1967	7.2	low	400	medium
1968	5.9	low	360	medium
1969	6.7	low	410	medium
1970	5.9	low	560	medium
1971	7.9	low	1160	high
1972	9.6	low	1000	high

3. Radiochemical Quality of Water in Alluvium

Samples were collected and analyzed prior to release of effluents from TA-50 to provide a base line of the radiochemical changes that would occur in water in the alluvium.

The following table presents a summary of the radiochemical quality of water prior to the release of effluents from TA-50.

Radiochemical Quality of Water in Alluvium

(average of a number of analyses, 1961-1962)

Obs. Hole	No. of Analyses	pCi/l		µg/l
		Gross Beta	Total Pu	Total Uranium
MCO-1	3	<14	<0.5	<0.5
MCO-2	3	<14	<0.5	<0.5
MCO-3	5	<14	<0.5	<0.5
MCO-4	5	<14	<0.5	<0.5
MCO-5	5	<14	<0.5	<0.5
MCO-6	5	<14	<0.5	<0.5
MCO-7	5	<14	1.8	<0.5
MCO-7.5	1	<14	3.1	<0.5
MCO-8	5	<14	<0.5	<0.5

The following table presents radiochemical data 1963 through 1965 after effluents were released into the canyon.

Radiochemical Quality 1963-1965

(average of a number of analyses)

Obs. Hole	Year	No. of Analyses	pCi/l Gross Beta	pCi/l Total Pu	µg/l Total Uranium
MCO-3	1963	2	14	6.5	<0.5
MCO-3	1964	10	247	3.2	<0.5
MCO-3	1965	5	131	1.7	3.8
MCO-4	1963	4	54	1.8	<0.5
MCO-4	1964	10	136	4.1	<0.5
MCO-4	1965	5	130	1.6	<0.5
MCO-5	1963	1	23	<0.5	<0.5
MCO-5	1964	10	105	2.2	<0.5
MCO-5	1965	5	34	1.4	<0.5
MCO-6	1963	3	26	<0.5	1.5
MCO-6	1964	10	64	2.0	<0.5
MCO-6	1965	5	32	2.0	<0.5
MCO-7	1963	3	<14	<0.5	<0.5
MCO-7	1964	10	38	<0.5	0.6
MCO-7	1965	5	15	<0.5	<0.5
MCO-7.5	1963	2	<14	<0.5	<0.5
MCO-7.5	1964	9	30	0.5	0.5
MCO-7.5	1965	6	17	<0.5	<0.5
MCO-8	1963	3	<14	<0.5	<0.5
MCO-8	1964	10	16	0.7	1.5
MCO-8	1965	6	<14	<0.5	<0.5

The concentrations of plutonium were greater near the effluent discharge area and decreased downgradient in the canyon. Only trace concentrations of plutonium were noted at observation hole MCO-7 by 1965. Gross beta emitter in the water showed the same general pattern as the plutonium decreasing in concentration downgradient in the canyon. The gross beta activity may have extended to hole MCO-7.5. Total uranium showed no apparent increase or trend in the canyon.

There were no radiochemical analyses of water in the alluvium in 1966. The following table presents a recap of radiochemical analyses from 1967 through 1972.

MORTAR DAD CANYON

ALLUVIAL AQUIFER OBSERVATION WELLS

RADIOCHEMICAL QUALITY OF WATER

SOURCE	YEAR	MAX. # SAMPLES	GROSS ALPHA	GROSS BETA	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-3	1967	1	-1	116	-.05	.14	-.00	-.15	-.00	-	-	-	1.30
MCO-3	1968	2	1	166	.27	.22	-.05	-.15	2.77	-240	-	-	.20
MCO-3	1969	1	7	93	.27	.35	-.00	-.00	-.00	-	-	-	.90
MCO-3	1970	5	6	305	1.03	.47	.20	-.15	-.00	345	92	-	1.90
MCO-3	1971	4	21	1471	14.31	1.60	-.00	-.15	-.00	2090	314	40500	9.0
MCO-3	1972	4	11	612	3.94	.35	.50	-.00	-.00	382	-	47100	7.58
MCO-4	1967	1	-1	83	-.05	.06	-.00	-.15	-.00	-	-	-	-.40
MCO-4	1968	2	1	83	.13	.43	-.05	-.15	1.48	-240	-	-	1.20
MCO-4	1969	3	3	129	.14	.12	-.00	-.00	-.00	-	-	-	1.7
CO-4	1970	6	3	141	.11	.08	-.00	-.15	-.00	-230	-	-	1.5
CO-4	1971	4	3	418	.23	.07	-.00	-.00	-.00	-277	179	49250	3.7
MCO-4	1972	4	9	343	.93	.16	.10	-.00	-.00	-350	-	64475	6.0
MCO-5	1967	1	2	9	-.05	-.05	-.00	-.15	-.00	-	-	-	-.
MCO-5	1968	2	1	45	.11	.63	3.81	-.15	-.00	-240	-	-	.5
MCO-5	1969	2	-1	29	.05	.09	-.00	-.00	-.00	-	-	-	.7
MCO-5	1970	2	4	25	.06	-.05	-.00	-.00	-.00	-	-	-	.5
MCO-5	1971	4	1	186	.09	-.05	-.00	-.00	-.00	-263	175	64000	1.
MCO-5	1972	4	3	112	.14	.07	.19	-.00	-.00	-350	-	78250	2.
MCO-6	1967	1	2	7	-.05	.09	-.00	-.00	-.00	-	-	-	4.
MCO-6	1968	2	6	27	.07	.79	-.05	.36	-.00	-240	-	-	1.
MCO-6	1969	2	4	18	-.05	.06	-.00	-.15	-.00	-	-	-	.
MCO-6	1970	6	4	31	-.05	-.05	-.00	-.15	-.00	-230	-	-	.
MCO-6	1971	4	2	168	.05	-.05	-.00	-.00	-.00	-240	-	51500	.
MCO-6	1972	4	2	132	.08	-.05	.22	-.00	-.00	-350	-	59500	3.
MCO-7	1967	1	2	2	-.05	.05	-.00	-.00	-.00	-	-	-	1.
MCO-7	1968	2	1	10	-.05	.11	-.05	-.15	-.00	-240	-	-	.
MCO-7	1969	2	5	9	-.05	.05	-.00	.19	-.00	-	-	-	.
MCO-7	1970	4	2	17	-.05	.06	-.00	-.00	-.00	-230	-	-	-.
MCO-7	1971	4	-1	105	.09	-.05	-.00	-.00	-.00	-265	-	84000	.
MCO-7	1972	4	2	73	.12	.06	.08	-.00	-.00	-350	-	68875	1.
MCO-7.5	1967	1	3	11	-.05	.06	-.00	-.15	-.00	-	-	-	3.
MCO-7.5	1968	2	2	9	.11	.32	.10	.56	-.00	-240	-	-	.
MCO-7.5	1969	2	1	39	.10	.15	-.00	-.00	-.00	-	-	-	.
MCO-7.5	1970	3	7	32	.32	.37	-.00	-.00	-.00	-240	-	-	-.
MCO-7.5	1971	3	1	68	.12	-.05	-.00	-.00	-.00	-277	-	122000	.
MCO-7.5	1972	4	1	70	.08	.12	1.08	-.00	-.00	-350	-	49525	1.
MCO-8	1967	1	-1	10	-.05	-.05	-.00	-.15	-.00	-	-	-	-
MCO-8	1968	2	-1	8	.05	.11	-.05	-.00	-.00	-240	-	-	1
MCO-8	1969	2	1	22	-.05	-.05	-.00	-.00	-.00	-	-	-	
MCO-8	1970	4	-1	10	.06	-.05	-.00	-.00	-.00	-230	-	-	
MCO-8	1971	-	-	-	-.00	-.00	-.00	-.00	-.00	-	-	-	-
MCO-8	1972	3	1	46	.10	.52	.31	-.00	-.00	-350	-	129733	

During 1972, gross alpha activity decreased from 11 pCi/l to less than 1 pCi/l downgradient in the aquifer. Gross beta decreased from 612 to 46 pCi/l. The concentration of plutonium was greater for ^{238}Pu than ^{239}Pu as shown on the preceeding table. The influent to the plant was carrying more ^{238}Pu than ^{239}Pu for treatment. The ^{238}Pu decreased from 3.94 to 0.10 pCi/l downgradient in the canyon. The ^{239}Pu varied from <0.5 to 0.52 pCi/l showing no particular trend. The ^{241}Am in the aquifer also varied in the canyon showing no particular trend. Tritium increased from 47 x 10^3 to 129 x 10^3 pCi/l downgradient in the canyon. The increase was due to the release of 20 curies of tritium with effluent in 1969 and shows residual from movement downgradient.

E. Inventory of Plutonium in Solution in Storage

An inventory was made of the total plutonium in solution in the aquifer by using the average concentration in three sections of the aquifer and volume of water in storage as of December 1972. The following table shows data used in estimating inventory.

Inventory of Plutonium In Solution

Section	Obs Hole	Total Pu (pCi/l)	Av. Pu (pCi/l)	Volume in Aquifer x 10^3 m^3	Total Pu µCi
Upper	MCO-3	4.29	--		
	MCO-4	1.09	2.69	4.4	11.8
Middle	MCO-4	1.09	--		
	MCO-5	.21	--		
	MCO-6	.13	0.72	5.0	3.6
Lower	MCO-6	.13	--		
	MCO-7	.18	--		
	MCO-8	.6	0.28	13.6	3.8
TOTAL	--	--	--	--	19.2

The total amount of plutonium in solution in the aquifer as of December 1972, was estimated to be 19.2 µCi. The amount of plutonium released with the effluent from 1963 through 1972 was 21.9 mCi (21.9 x 10^3 µCi). Thus, only a small fraction (0.08%) of plutonium released was present in solution in the

F. Storm Runoff and Transport of Radionuclides

Three stations were established and equipped with cumulative samplers at GS-1, GS-2, and midway between GS-1 and GS-2. The stations were equipped with 5 samplers each. The water from the samplers was combined for radiochemical analyses for flow events on July 11, 1967 and September 14, 1967.

The average of the radiochemical analyses for storm runoff event July 11, 1967, are shown on the following table. Total volume of runoff was about 560 m^3 through the GS-1 gauging station.

Runoff event July 11, 1967 m pCi/l

	Source		
	Upper	Middle	Lower
Gross alpha	2	2	<1
Gross beta	94	163	205
^{238}Pu	.13	.17	.12
^{239}Pu	.13	.56	.37
^{234}U	.25	.69	1.13
^{226}Ra	<.15	<.15	<.15
^{137}Cs	<240	<240	<240

The radiochemical analyses of storm runoff that occurred on September 14, 1967 are shown on the following table. The voluem of storm runoff was about 1.1×10^3 m^3 through the GS-1 gauging station.

Storm runoff September 14, 1972
(analyses in pCi/l except as noted)

	Upper	Middle	Lower
Gross alpha	2	1	3
Gross beta	35	123	80
^{238}Pu	.18	.32	.18
^{239}Pu	.22	.09	.67
^{226}Ra	<.15	<.15	<.15
^{137}Cs	<240	<240	<240
Total Uranium	<.4	.5	16.9

Sediments from the upper station were analyzed for gross alpha and gross beta for the runoff event that occurred on July 11, 1967. The analyses were made of the five samples collected at 0.0 m, 0.3 m, 0.6 m, 0.9 m, 1.2 m above the stream channel to determine the distribution of radionuclides at various heights within a flow event.

The anlayses indicate that the concentrations of radioactivity decrease with increasing height above the channel. The sediment concentrations also decrease with increasing height above the channel, the heavier and larger sediments being transported as channel bed sediments. The larger and heavier suspended sediments decrease with the increased height above the channel with lighter and finer suspended sediments near the top of the flow.

Sediments analyzed; runoff event 9/11/67

Height above stream channel (m)	Picocuries per dry gram	
	Gross alpha	Gross beta
0.0	171	234
0.3	175	297
0.6	44	68
0.9	15	72
1.2	14	28

In general the finer sediments (clay and silts) contain the greater amount of radionuclides; however, the transport of the finer material is greater over a period of flow along the base of the channel due to a greater concentration of a mixture of sediment sizes and duration of flow (tail-off of runoff decreases with time).

G. Radiochemical Analyses of Cuttings from Test Holes

Twenty-seven (27) test holes were drilled in seven lines across the canyon

in the fall of 1960. The test holes are located above the stream channel. Samples were collected and analyzed of the upper 0.6 m of the hole for gross alpha and beta emitters. Locations are the same as observation holes. The following table presents average activity for a number of holes drilled in the line.

Radiochemical Analyses of Cuttings
(average of a number of analyses in counts per minute per dry gram)

Location	No. of Holes	Gross alpha 0.3m	Gross alpha 0.6m	Gross beta 0.3m	Gross beta 0.6m
Line 1	3	1.3	3.0	1.4	13
Line 2	2	1.6	5.2	1.8	<.5
Line 3	2	1.3	< .5	1.0	<.5
Line 4	3	1.0	2.7	1.4	<.5
Line 5	4	1.3	2.4	1.2	1.0
Line 6	6	0.8	2.3	1.0	1.8
Line 8	7	1.4	20	1.8	22

The analyses show background in most of the cuttings. The gross beta activity at Line 1 may be in part from TA-46. Line 8 shows excessive amounts of gross beta activity that may be in part from effluents released from Ten-Site. There were also some liquid effluents released from Ten-site into Ten-Site Canyon which is confluent to Mortandad upgradient from Line 8 and below Line 6.

H. Radiochemical Analyses of Sediments

Channel sediments in Mortandad and tributary canyons are derived from weathering of the Bandelier Tuff. Particle-size distribution of channel sediments at stations are shown on the following table.

Particle-Size Distribution

(Percent by Weight)

Source	Near New Sigma	GS-1	MCS-3.8	MCO-5	Near TSC-1	MCO-12
Granules	4.5	15.0	18.0	11.0	1.5	5.5
Sand						
Very Coarse	16.0	32.0	26.0	20.5	35.0	22.5
Coarse	52.5	28.5	42.5	41.0	41.0	42.5
Medium	21.5	13.0	9.5	17.5	11.5	16.5
Fine	5.0	6.0	1.5	6.5	4.5	5.5
Very Fine	.3	2.0	0.5	1.0	2.0	1.5
Silt and Clay	.2	3.5	1.0	2.5	3.0	6.0

The very fine sand and silt and clay size fractions make up less than percent by weight of the channel sediments. These sediments have the greatest capacity for adsorption and ion-exchange of radionuclides in the liquid effluents.

1. Sediment Analyses Mortandad Canyon

Radiochemical analyses of alluvium from the stream channel were made prior to the release of effluents from TA-50. The results are presented in the following table. The samples were collected at the surface of the channel and at depths of 0.3, 0.6 and 0.9 m below the channel.

Radiochemical Analyses of Sediments, May, 1963

(Counts per minute per day gram)

Type of activity	Depth below land surface (m)	Sampling Stations						
		Gaging Station No. 1	MCO-3	MCS-3.8	MCO-4	MCO-5	MCO-6	MCO-7
Gross alpha	Surface	1	<1	2	1	2	2	1
	0.3	1	1	2	1	<1	1	<1
	0.6	3	1	2	<1	2	2	1
	0.9	2	-	2	1	1	3	3
Gross beta	Surface	159	2	2	27	10	36	28
	0.3	22	13	32	2	<1	<1	<1
	0.6	11	<1	<1	4	<1	9	<1
	0.9	3	-	<1	31	15	8	21

Another set of surface sediments were collected in November, 1965 and analyzed for gross alpha, beta, and gamma activity. The results are shown on the following table.

Radiochemical Analyses of Sediments
November, 1965

(Analyses in Counts per Minute per Dry Gram)

Location	Gross Alpha	Gross Beta	Gross Gamma
Near New Sigma	1	23	32
GS-1	5	189	74
MCS-3.8	3	60	4
MCO-5	24	36	72
MCO-12	1	< 1	< 1

A similar set of samples were collected and analyzed for gross alpha, gross beta, and plutonium in the spring of 1970. The results are shown on the following table.

Radiochemical Analyses of Sediments
February and March, 1970

(Analyses in picocuries per dry Gram)

Location	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
Near New Sigma	2	2	<.002	<0.002
GS-1	76	350	42	46
MCS-3.8	8	36	1.33	2.44
MCO-5	6	30	.697	2.14
MCO-7	3	6	.188	.209
MCO-12	3	5	.003	.016

Additional samples were collected in 1971 and 1972 at MCO-5.

Radiochemical Analyses of Sediments at
MCO-5, 1971 and 1972

(Analyses in picocuries per dry gram)

	5-14-71	10-14-71	10-10-72
Gross Alpha	6	4	2
Gross Beta	31	20	24
^{238}Pu	1.61	.044	1.98
^{239}Pu	1.11	.384	.78
^{137}Cs	-	130	63
Total Uranium	.07	.19	.67

The results of the 1965 and 1970 analyses indicate no sediment transport out of the disposed area or off the AEC controlled property.

2. Sediment Analyses Ten-Site Canyon

Samples of sediments in Ten-Site Canyon were collected and analyzed for radionuclides due to the release of effluents from TA-35. The earliest analyses were made in 1956. The following table show results of analyses of surface sediments from 1956 through 1961.

The high activity in the Canyon is due to strontium. The major isotope of strontium released into the canyon is ^{89}Sr as shown by inventory of radionuclides treated at the site and released with liquid effluents.

Radiochemical Analyses of Sediments
1956-1961

	Distance from outfall in meters				
	At Outfall	60	400	670	930
Gross Beta 1/					
1956	824,000	885,000	29,600	2,000	1,200
1957	23,480	3,270	2,510	750	20
1958	87,420	1,910	2,440	130	-
1959	2,801	237	294	33	< 1
1960	830	370	1,470	260	< 1
1961	2,130	590	1,530	1,440	850
Strontium 2/					
1956	320,000	210,000	56,000	42,000	2,000
1957	3,800	1,400	87	350	14
1958	2,500	750	1,400	69	10
1959	61	39	110	34	-
1960	130	76	89	76	-
1961	30	22	20	20	-

1/ Counts per minute per dry gram
2/ Picocuries per dry gram

Results of analyses of samples collected in 1965 are shown on the following table.

Radiochemical Analyses, November 1965
(Analyses in counts per minute per dry gram)

Location	Gross Alpha	Gross Beta	Gross Gamma
At Outfall	4	10	16
Near TSCO-1	1	10	< 1

The results of analyses of samples collected in 1970 are presented on the following table.

Radiochemical Analyses, February 1970
(Analyses in picocuries per dry gram)

Location	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
At Outfall	3	7	0.063	0.113
Near TSCO-1	2	4	0.044	0.369

I Inventory of Plutonium in Channel Sediments

There has been no transport of sediments out of the disposal area to the disposal area to the boundary since hydrologic observations in the canyon began.[21] The area of the canyon considered for the inventory was determined by the results of analyses that indicated above ground concentration of plutonium in the channel.

The physical characteristics of the channel used in the inventory are presented below.

Physical Characteristics of Channel

1. 0 to 1 460 m
   Width 1 m Depth 0.15 m
   Sp. g. 1.57 Weight 344 x 10^6 g

2. 1 460 m to 3 040 m
   Width 2 m Depth 0.15 m
   Sp. g. 1.57 Weight 744 x 10^6 g

The inventories were estimated using the following concentrations for February 1970 and October 1972.

Concentrations and Total Plutonium
in Sections of Channel

February, 1970

Section	Station	Concentration µCi/g	Concentration Ave.	Total Pu mCi	% of Total Pu
0-1 460	GS-1	87.9			
	MCS-3.8	3.8	45.8	15.8	93
1 460-3 040	MCO-5	2.8			
	MCO-7	.40	1.6	1.2	7
TOTAL		--	--	17.0	100

October, 1972

Section	Station	Concentration µCi/g	Concentration Ave.	Total Pu mCi	% of Total Pu
0-1 460	M-1	223			
	M-2	117			
	M-3	91			
	M-4	48			
	M-5	124			
	M-6	24			
	M-7	21			
	M-8	9.1	82	28.2	85
1 460-3 040	MCO-5	2.8			
	M-9	11	6.9	5.1	15
TOTAL		--	--	33.3	100

The recap for 1970 and 1972 is presented below.

Mortandad Canyon

Section	Total Plutonium (mCi) Feb. 1970	Total Plutonium (mCi) Oct. 1972
0-1 460	15.8	28.2
1 460-3 040	1.5	5.1
TOTAL	17.0	33.3

The inventory in Mortandad Canyon for February 1970 shows about 17.0 mCi of Pu in the reach from 0 to 3 040 m. The total release from 1963 through 1969 was 21.9 mCi. The remaining 4.9 mCi has been carried past MCO-8 by storm runoff, but not to MCO-12 where the sediments contained only background amounts of Pu. The inventory in October, 1972 shows about 33.3 mCi of Pu in the reach from 0-3 040 m. The release during the period 1964 to 1972 was 42.1 mCi. The remaining 8.8 mCi were carried east of MCO-8 by storm runoff but not to MCO-12 (Fig. 14).

J. Flood Frequency and Maximum Discharge

There has been no runoff out of the canyon disposal area to the AEC boundary since hydrologic observation began in 1960. The canyon heads on tha Pajarito Plateau and has a small drainage area. Total drainage area west of the county line is about 4.7 km^2 with 1.2 km^2 above GS-1, and an additional 2.1 km^2 from GS-1 to Obs. Hole MCO-8. Observations indicate that most, if not all, surface runoff into the canyon occurs in the 3.3 km^2 west of Obs. Hole MCO-8. The canyons contributing runoff are Mortandad, Effluent and Ten-Site canyon. East of MCO-8, the remaining 1.4 km^2 are relatively flat with no major or minor canyons entering from adjacent mesas.

The stream channel east of MCO-6 braids out on the canyon floor as the canyon begins to widen and alluvium thickens. The small drainage area with thick sections of unsaturated alluvium allows rapid infiltration of storm runoff to date.

As the channel is not well defined in the lower section of the canyon, the method for flood-frequency and maximum discharge analyses as described by Scott is not applicable. However, as the channel is well defined west of MCO-6, the flood-frequency and maximum discharge was computed at GS-1. The drainage area is 1.2 km^2 with a mean channel slope of 0.029.

Flood-Frequency and Maximum Discharge
at Gaging Station 1

Frequency	Max. Discharge m^3/sec.
2-year	1.1
5-year	3.4
10-year	5.4
25-year	12
50-year	14

The maximum discharge during the period 1962 through 1972 was estimated to be about 2.3 in which 11 x 10^3 m^3 of water passed through the gaging station. This occurred on July 31, 1968 and caused flooding in the canyon which ended between MCO-10 and MCO-12. The runoff did not reach the AEC boundary. The events predicted by use of Scott's method for the 12 years of record appear high.

The increased construction in the area (TA-35, TA-55) will increase the storm runoff into the canyon. At a maximum discharge of 2.8 to 3.4 m^2/sec at GS-1, the flood flow will probably reach the boundary and move on to Indian land.

IX. DRAINAGE AREA 8

Drainage area 8 is a small mesa top and slope which contain no defined drainage (Fig. 15). No data has been collected in the area which is about 0.5 km^2.

X. DRAINAGE AREA 9 (Cañada del Buey)

Cañada del Buey heads on the Pajarito Plateau. It has cut a canyon in the Bandelier Tuff which is quite narrow and deep just north of TA-46. The stream flow in the canyon is intermittent. One small stretch near TA-46 contains some surface flow from waste water released from the operations of a cooling tower (Fig. 15). The alluvium in the canyon is quite thin and contains little or no known perched water in tha alluvium.

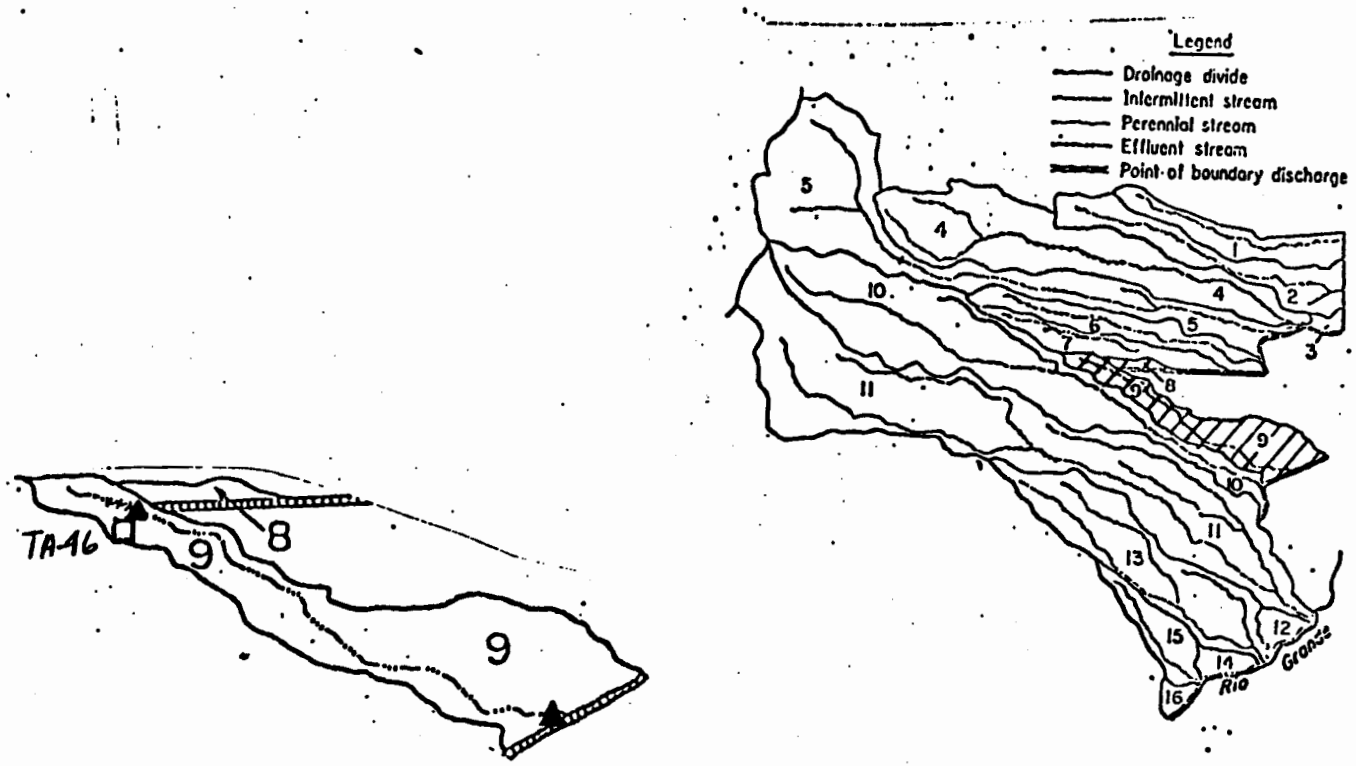


Fig. 15. Drainage Area 8 and Drainage Area 9 (Canada del Buey) showing location of sampling stations.

A. Surface Water

Intermittent flow in the canyon is from storm runoff, though a small reach of the canyon contain perennial flow from waste water released on the south wall of the canyon from TA-46. It is this waste water that is sampled for chemical and radiochemical constituents.

1. Chemical Quality of Surface Water

The chemical quality of the water in the canyon reflects the release of waste water from TA-46. The following table presents the quality of water in the canyon from 1967 through 1972.

Chemical Quality of Surface Water in Canada del Buey
Near TA-46, in mg/l except as noted

Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1967	1	41	5	2.6	9.7	183	170	8.0
1971	1	24	5	0.8	17	184	180	7.3
1972	1	17	6	1.0	4.4	162	140	7.3

[a] Microhmos at 25° C
[b] No Units

Select trace metal ion analyses were made of the water in 1971 and 1972 at the same station.

Metal Ion Analyses
µg/l

	1971	1972
In Solution		
Cadmium	0.92	0.25
Beryllium	<0.25	<0.25
Lead	<1.0	5.5
Mercury	<0.02	<0.02
Particulates		
Cadmium	0.49	<0.25
Beryllium	<0.25	<0.25
Lead	2.9	<1.0
Mercury	<0.02	--

The chemical quality of the water is good. The concentration dissolved is low, in the range of water in the municipal water supply.

2. Radiochemical Quality of Surface Water

Radiochemical quality of surface water in Cañada del Buey below TA-46 is shown below for the year 1970 through 1971.

Radiochemical Quality of Surface Water in Cañada del Buey Near TA-48
pCi/1 except as noted

	1970	1971	1972
Gross Alpha	1	2	<1
Gross Beta	5	3	2
^{238}Pu	< 0.05	< 0.05	0.20
^{239}Pu	< 0.05	< 0.05	<0.05
^{137}Cs	-	-	<350
Tritium	-	-	1,100
Total Uranium a/	0.4	0.4	1.8

a/ μg/1

B. Radiochemical Analyses of Sediments

Channel sediments in Cañada del Buey are derived from the Bandelier Tuff. The particle size distribution was made of sediments in the canyon at the AEC Boundary on State Road 4.

Particle-Size Distribution
(Percent by Weight)

Granules	2.0
Sand	
Very Coarse	31.5
Coarse	40.0
Medium	13.5
Fine	7.0
Very Fine	3.0
Silt and Clay	2.0

Radiochemical analyses at the same station for the year 1965 and 1970 are shown below.

Radiochemical Quality of Sediments in Cañada del Buey at State Road 4

	1965 1/	1970 2/
Gross Alpha	2	1
Gross Beta	<1	1
Gross Gamma	14	-
^{238}Pu	-	<0.002
^{239}Pu	-	0.009

1/ Counts per minute per dry gram

2/ Picocuries per dry gram

C. Flood - Frequency and Maximum Discharge

Cañada del Buey heads on the Pajarito Plateau at an altitude of 2 210 ft. The flood-frequency and maximum discharge are based on the following data:

Drainage Areas 3.4 sq mi Main Channel Slope 110 ft/mi

Frequency	Maximum Discharge (Cfs)
2 Year	2.6
5 Year	6.2
10 Year	9.4
25 Year	19
50 Year	21

XI. DRAINAGE AREA 10 (Pajarito Canyon)

Pajarito Canyon heads on the flanks of the Sierra de los Valles and thus drains a large area (Fig. 16). The stream channel is cut into the Bandelier Tuff across the Pajarito Plateau. The alluvium is thin in the upper reaches of the canyon and thickens eastward. Stream flow in the canyon is intermittent from storm runoff and snowmelt. The intermittent flow recharges water which moves downgradient in the alluvium overlying the tuff. Water in the alluvium is seasonal and dependent on intermittent flow for recharge.

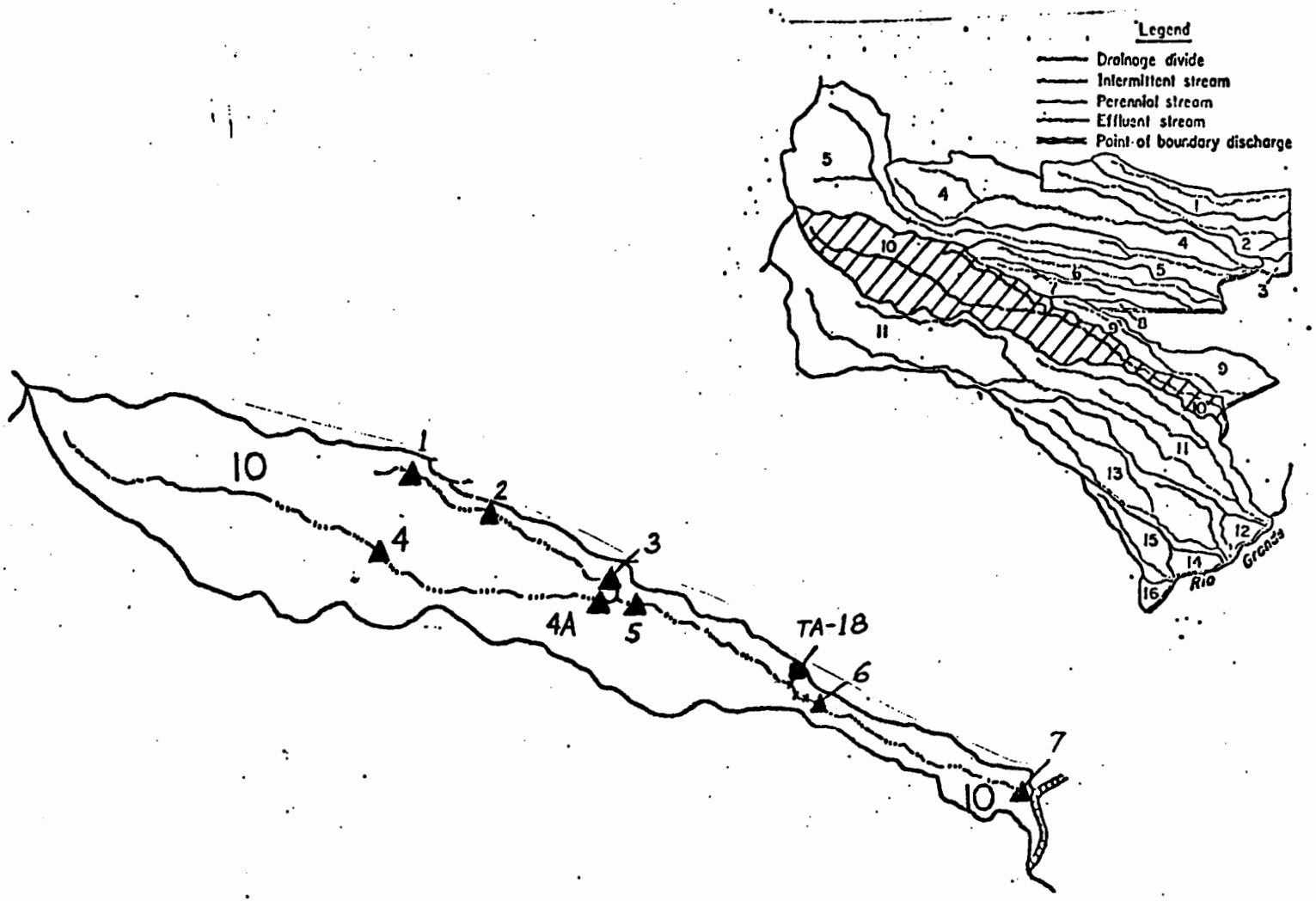


Fig. 16. Drainage Area 10 (Pajarito Canyon) showing location of sampling stations.

A. Surface Water

There is only minor release of water or treated sewage effluent into the canyon, mainly from TA-18. There is one surface water sampling station in the canyon below TA-18. The canyon bottom in this area has been excavated for gravel or base coarse. There are no observation holes in the canyon.

1. Chemical Quality of Surface Water

Water samples for chemical analyses are collected from one of the gravel pits below TA-18. The following table presents the quality of water from near TA-18.

Chemical Quality of Water in Pajarito Canyon Near TA-18

		in mg/l except as noted						
Year	No. of analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1962	1	46	11	0.4	0.9	204	210	7.0
1967	2	36	11	1.5	0.9	186	210	7.9
1971	1	24	5	0.8	1.8	184	180	[illegible]
1972	1	17	6	1.0	0.4	162	140	7.3

a Micromhos at 25° C

b No Units

Select trace metal ion analyses were made of water in 1971 and 1972 at the same station

Metal Ion Analyses
(In parts per Billion)

	1971	1972
In Solution		
Cadmium	1.6	0.38
Beryllium	<0.25	<0.25
Lead	<1.0	4.5
Mercury	<0.02	<0.02
Particulates		
Cadmium	0.64	<0.25
Beryllium	<0.25	<0.25
Lead	5.8	<1.0
Mercury	<0.02	-

The chemical quality of the water is good as shown by low total dissolved solids.

2. Radiochemical Quality of Surface Water

The radiochemical quality of water from the gravel pit near TA-18 for 1962 and 1967 is presented on the following table.

Radiochemical Quality of Surface Water 1962 and 1967
(Picocuries per liter, except as noted)

	1962	1967
No. of Analyses	1	2
Gross Beta	<14	< 1.4
Total Plutonium	< 0.4	< 0.4
Total Uranium a/	< 0.5	< 0.5

a/ μg/l

B. Radiochemical Analyses of Sediments

Main stems of Pajarito Canyon west of TA-18 consist of two canyons, Pajarito and Two-Mile Canyons, which head on the flanks of the mountains. The sediments in the canyon are derived from weathering of the Tschicoma Formation and Bandelier Tuff.

Particle size distribution from stations in the drainage area are shown on the following table while locations are shown on Figure .

Particle-Size Distribution
(Percent by Weight)

Stations	1	2	3	4	5	6	7
Granules	8.5	3.0	17.5	8.0	20.5	2.5	14.5
Sand							
Very Coarse	22.5	24.0	36.0	22.0	44.0	15.0	34.0
Coarse	41.0	46.0	34.0	31.5	26.0	52.0	33.5
Medium	17.5	19.5	8.0	22.0	6.0	26.0	8.0
Fine	5.5	5.0	2.0	11.5	2.0	3.0	2.0
Very Fine	2.0	1.0	0.5	3.5	1.0	0.5	2.0
Silt and Clay	3.0	1.5	1.5	1.5	0.5	0.5	5.0

The following table presents the radiochemical analyses of sediments collected in 1965.

Sediment Analyses, 1965
(Counts per minute per dry gram)

Station	Gross Alpha	Gross Beta	Gross Gamma
1	1	<1	20
2	1	<1	8
3	1	<1	8
4	1	<1	18
5	2	8	4
6	3	<1	48
7	3	<1	<1

A second set of samples were collected in 1970 from similar stations. The results are shown on the following table.

Sediment Analyses, 1970
(pCi/g)

Station	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
1	1	<1	.018	.003
2	2	1	.019	<.002
3	1	<1	.016	.038
4	2	<1	<.002	.004
4A	2	2	<.002	.003
5	2	2	<.002	.009
6	<1	<1	<.002	<.002
7	2	2	<.002	.008

Four (4) samples were collected from station 7 (Pajarito Canyon at State Road 4) in 1971 and 1972. The analyses are shown on the following table.

Sediment Analyses 1971 & 1972
(pCi/g except as noted)

	5-7-71	10-14-71	4-5-72	10-10-72
Gross Alpha	2	5	-	2
Gross Beta	4	18	-	12
^{238}Pu	0.002	0.001	-	0.003
^{239}Pu	0.002	0.002	-	0.026
^{137}Cs	-	4.1	1.9	9.1
Total Uranium	0.07	0.05	0.18	0.58

The radiochemical analyses of sediments in the drainage area are low, in the range of worldwide fallout.

C. Flood-Frequency and Maximum Discharge

Pajarito Canyon heads on the flanks of the mountains at an altitude of 3 170 m. The flood-frequency and maximum discharge are based on the following data.

Drainage Area 27.4 km^2; Main Channel Slope -0.039.

Frequency	Maximum Discharge (m^3/sec)
2-year	3.0
5-year	7.1
10-year	10
25-year	16
50-year	20

XII. DRAINAGE AREA II (WATER CANYON)

Water Canyon heads on the flanks of the mountains where it has cut canyons into the Tschicoma Formation and Bandelier Tuff. Across the plateau the canyons are cut into the Bandelier Tuff while along the eastern edge where the canyon joins the Rio Grande the canyon is cut into basalts of Chino Mesa and underlying Tesuque Formation. The alluvium is thin in canyons on the flanks of the mountains where the channel gradient is steep, and the alluvium thickens across the plateau. Near State Road 4 gravels have been removed for use as base coarse.

A. Surface Water

A perennial stream occurs in Upper Valles Canyon which is tributary to Water Canyon near the center of the plateau. Several springs discharge from perched layers in the tuff in Upper Water Canyon (Fig. 17). One of the larger Springs (Water Canyon-S-Site Supply) furnishes a part of the water supply for the S-Site area. Waste water from several areas in S-Site is released into Valles Canyon and Water Canyon. This water moves into the alluvium a short distance downgradient from the junction of these two canyons. The stream flow in the remainder of Water Canyon is intermittent and results from storm runoff and snow melt. There are no observation holes in the alluvium that have been used as a part of the monitoring net.

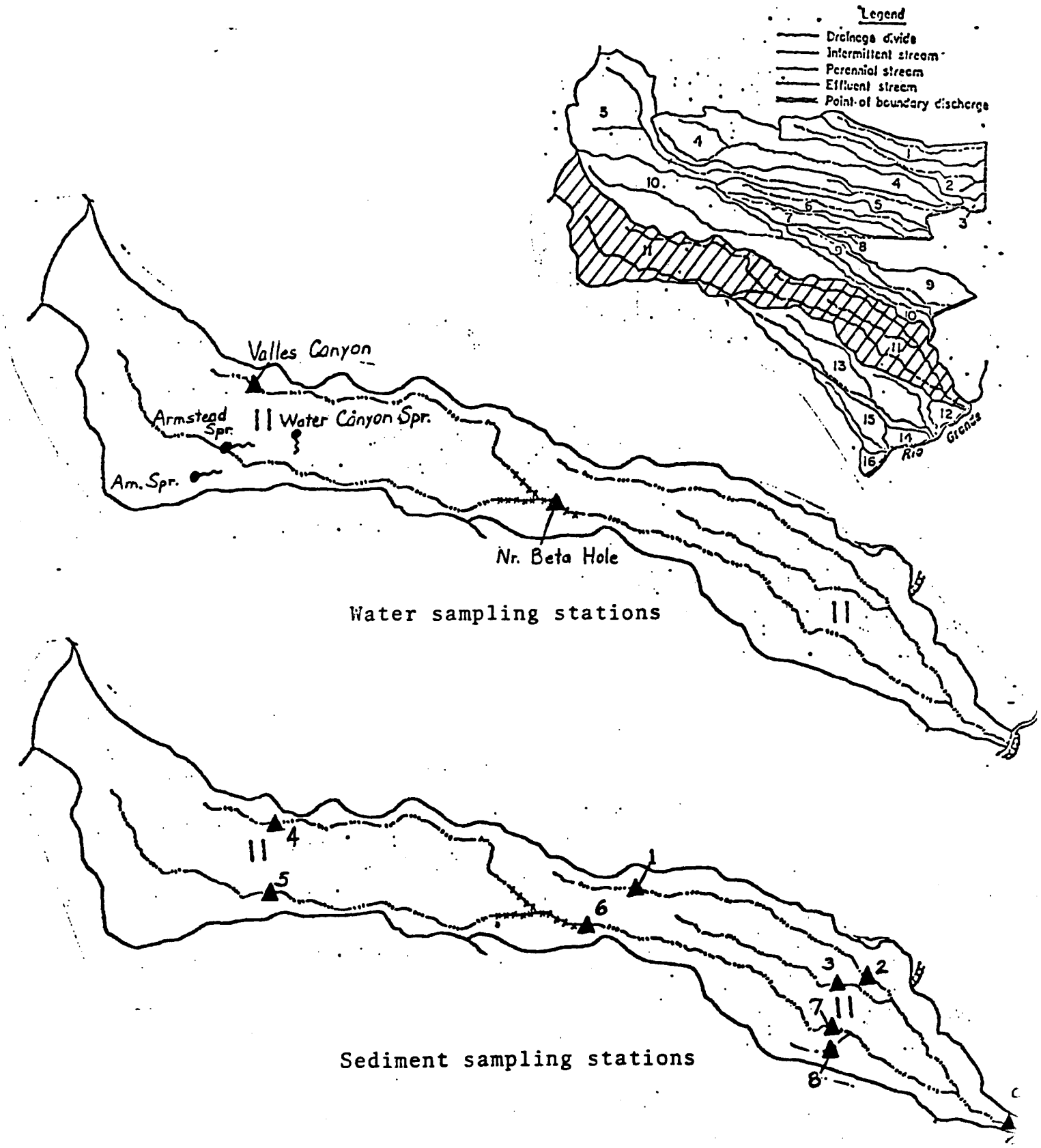


Fig. 17. Drainage Area 11 (Water Canyon) showing locations of san stations.

1. Chemical Quality of Surface Water

Springs that discharge from perched zones in the Bandelier Tuff on the flanks of the mountains are American Springs, Armstead Spring, and Water Canyon (S-Site Water Supply). Other sources of surface water is waste water near Beta Hole. Beta Hole is drilled through a thin section of alluvium near the north side of the canyon and completed 187 ft into the tuff, and is dry. The following table presents the chemical quality of water.

Chemical Quality of Surface Water
(mg/l except as noted)

Sources	Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
Am. Spr.	1952	1	5	2	0.4	0.7	80[c]	120	7.1
Am. Spr.	1967	1	8	3	<.4	.4	112	100	7.4
Am. Spr.	1969	1	10	3	<.4	.2	147	105	7.4
Am. Spr.	1970	1	4	1	<.4	.1	80[c]	120	7.2
Armstead Spr.	1958	1	6	2	.4	.5	70[c]	105	7.4
Armstead Spr.	1961	1	4	1	.2	.2	65[c]	100	6.9
Armstead Spr.	1969	1	5	2	<.4	.2	123	130	7.3
Valle Canyon	1961	1	3	<1	<.4	<.1	-	70	6.9
Water Canyon	1952	1	2	5	1.0	<.1	-	-	-
Water Canyon	1967	1	8	5	<.4	.2	37	70	7.9
Water Canyon	1969	1	9	<1	<.4	.1	112	140	7.5
Water Canyon	1970	1	4	<1	<.4	1.7	86	120	6.9
Water Canyon	1971	1	6	2	.9	.3	98	140	7.2
Water Canyon	1972	3	7	1	.9	.2	83	120	7.8
Near Beta Hole	1970	1	19	8	3.9	.2	255	280	7.8
Near Beta Hole	1971	1	25	5	.9	.2	160	150	7.3
Near Beta Hole	1972	1	27	14	.4	.1	162	190	7.0

[a] Micromhos at 25° C

[b] No Units

[c] Estimated

Select trace metal ion analyses have been made of water from Water Canyon (S-Site Supply) and at the station near Beta Hole.

Metal Ion Analyses
(In μg/l)

	Water Canyon		Near Beta Hole	
In Solution	1971	1972	1971	1972
Cadmium	0.40	<0.25	1.5	<0.25
Beryllium	<0.25	<0.25	<0.25	<0.25
Lead	1.3	<1.0	2.0	5.5
Mercury	<0.02	<0.02	<0.02	<0.02
Particulates				
Cadmium	<0.25	<0.25	0.44	<0.25
Beryllium	<0.25	<0.25	<0.25	<0.25
Lead	2.2	<1.0	2.2	<1.0
Mercury	<0.02	<0.02	<0.02	<0.13

The total dissolved solids concentration of surface water in the canyon is low, showing only minor deterioration of water used in processes at S-Site.

2. Radiochemical Quality of Surface Water

Radiochemical analyses of surface water were made of samples collected from American Springs, Water Canyon (S-Site Supply), Valle Canyon, and near Beta Hole. The results are shown on the following table.

Radiochemical Analyses
(pCi/1 except as noted)

Source	Year	No. of Analyses	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	Total Uranium[a/]
American Spr.	1967	1	2	7	<0.05	<0.05	0.4
American Spr.	1969	1	<1	3	<0.05	<0.05	0.5
American Spr.	1970	1	<1	10	<0.05	<0.05	0.4
Water Canyon	1967	1	2	6	<0.05	<0.05	1.3
Water Canyon	1969	1	4	6	<0.05	<0.05	2.5
Water Canyon	1970	1	2	5	<0.05	<0.05	0.4
Water Canyon	1971	1	<1	< 1	<0.05	<0.05	<0.4
Water Canyon	1972	3	<1	7	<0.05	<0.05	0.2
Valle Canyon	1967	1	<1	6	<0.05	<0.05	<0.4
Valle Canyon	1969	1	<1	2	<0.05	<0.05	0.6
Near Beta Hole	1970	1	1	2	<0.05	<0.05	2.1
Near Beta Hole	1971	1	2	2	<0.05	<0.05	0.7
Near Beta Hole	1972	1	<1	3	<0.05	<0.05	1.3

[a] μg/1

The analyses show only background amounts of radionuclides except for the one 1972 analysis from near Beta Hole where traces of plutonium 238 were reported in the water.

B. Radiochemical Analyses of Sediments

A number of canyons are tributary to Water Canyon. Sediment samples for particle-size distribution and radiochemical analyses were collected from channels in the tributary canyons as well as in Water Canyon.

Particle-size distribution from stations in the drainage area are shown on the following table while locations are shown on Fig. 17.

Particle-Size Distribution
(Percent by Weight)

Stations	1	2	3	4	5	6	7	8	9
Granules	7.0	3.0	3.5	40.0	25.0	3.0	2.5	11.0	3.0
Sand									
Very Coarse	51.5	35.5	50.5	27.0	34.5	30.5	28.0	32.5	27.0
Coarse	34.0	41.5	41.0	18.0	28.5	44.5	56.5	36.0	48.0
Medium	4.0	11.5	3.5	5.0	7.0	14.0	15.0	11.0	15.0
Fine	1.0	4.5	0.5	3.5	2.0	5.5	4.0	4.5	4.5
Very Fine	0.5	1.5	0.5	3.0	0.5	2.0	1.5	3.5	1.0
Silt and Clay	0.5	1.5	0.5	2.5	1.5	1.0	2.5	2.0	1.0

The following table presents radiochemical analyses of sediments collected in the drainage area in 1965.

Sediment Analyses, 1965
(Counts per minute per dry gram)

Station	Gross Alpha	Gross Beta	Gross Gamma
1	5	1	46
2	2	<1	34
3	1	2	24
4	2	<1	28
5	<1	8	36
6	<1	<1	2
7	1	18	4
8	2	<1	12
9	1	11	12

In 1970 a series of samples were collected at the same stations and analyzed for gross alpha and beta activity as well as plutonium.

Sediment Analyses, 1970
(Picocuries per dry gram)

Station	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
1	3	4	<0.002	0.006
2	1	2	<0.002	<0.002
3	3	3	<0.002	0.004
4	2	4	<0.002	0.011
5	4	4	<0.002	0.022
6	1	1	<0.002	0.050
7	2	2	<0.002	0.003
8	2	2	<0.002	<0.002
9	<1	<1	0.010	<0.002

Additional channel samples were collected at Station 1, near Beta Hole and Station 7 in 1971 and 1972.

Sediment Analyses, 1971 and 1972
(Picocuries per dry gram)

Station	Date	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{137}Cs	Total Uranium
1	10-71	11	8	0.005	0.007	<1.5	2.8
1	11-72	1	7	0.008	0.004	4.6	5.2
Near Beta Hole	5-71	1	1	0.004	0.001	-	-
Near Beta Hole	10-71	<1	4	<0.003	0.004	4.5	0.44
7	5-71	1	<1	<0.001	<0.001	-	-
7	10-71	5	4	<0.001	0.001	<1.5	0.15
7	10-72	3	14	<0.003	<0.003	4.8	0.09

The results of the radiochemical analyses of sediments indicate only background amounts of radionuclides except the total Uranium in samples from Station 1 which is in Potrillo Canyon. The uranium is probably due to tests or experiments that are or were done in the area.

C. Flood-Frequency and Maximum Discharge

Water Canyon heads on the flanks of the mountains at an altitude of 3 170 m, Some perennial flow occurs in the main stem of Valles and Water Canyons on the flanks of the mountains. The remainder of the channel carries only intermittent storm runoff. The flood-frequency and maximum discharge is based on the following data:

Drainage Area 33.2 km^2
Main Channel Slope-0.050

Frequency	Maximum Discharge m^2/sec
2-Year	2.8
5-Year	6.8
10-Year	9.6
25-Year	14
50-Year	18

XIII. DRAINAGE AREA 12

Drainage area 12 is a steep canyon wall on the west side of the Rio Grande and contains no well defined drainage (Fig. 18). The area is about 1.3 km^2. No data has been collected in the area.

XIV. DRAINAGE AREA 13 (ANCHO CANYON)

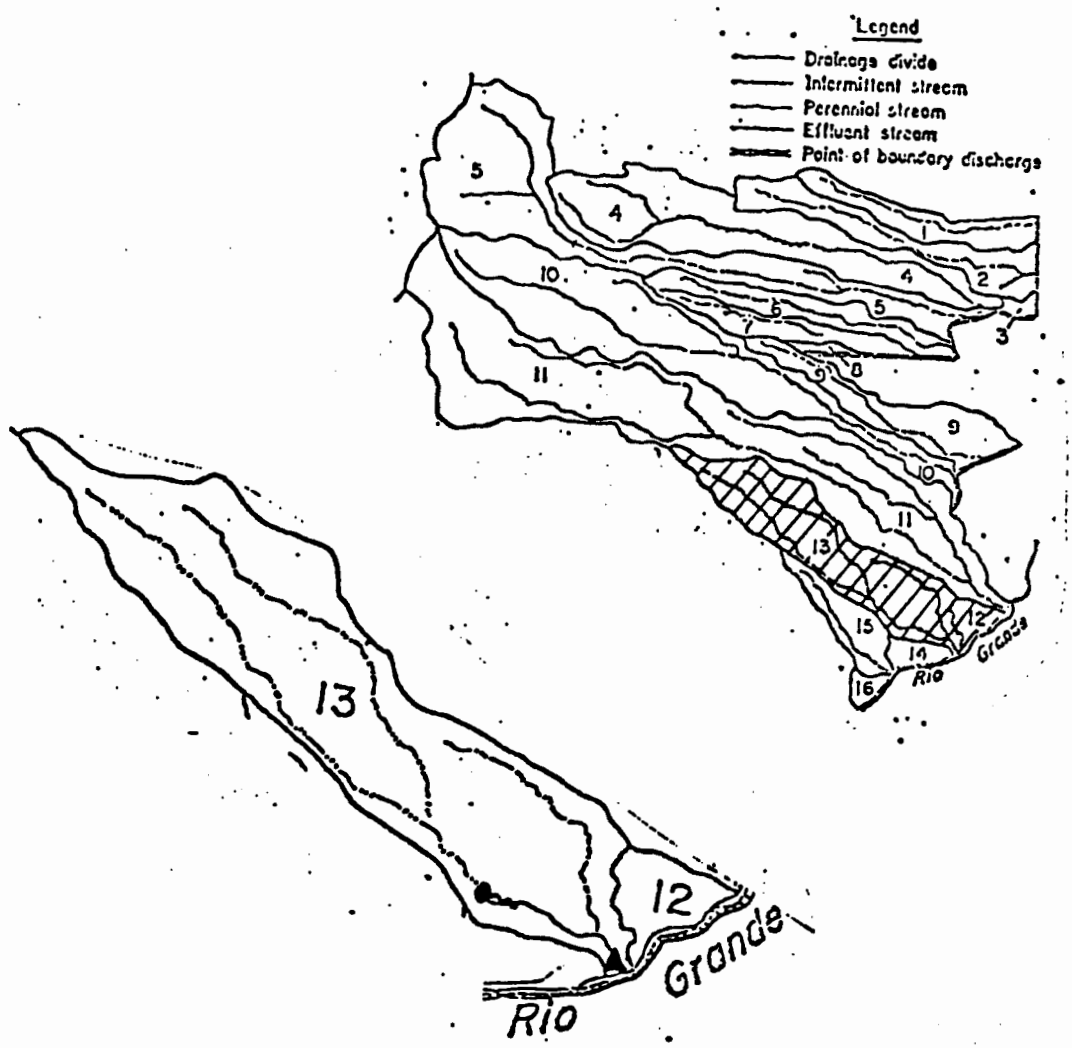
Ancho Canyon heads on the middle of the Pajarito Plateau. The canyon is cut into the Bandelier Tuff on the plateau, and through the basaltic rocks of Chino Mesa and Tesuque Formation at the eastern edge as the channel drops into the Rio Grande.

A. Surface Water

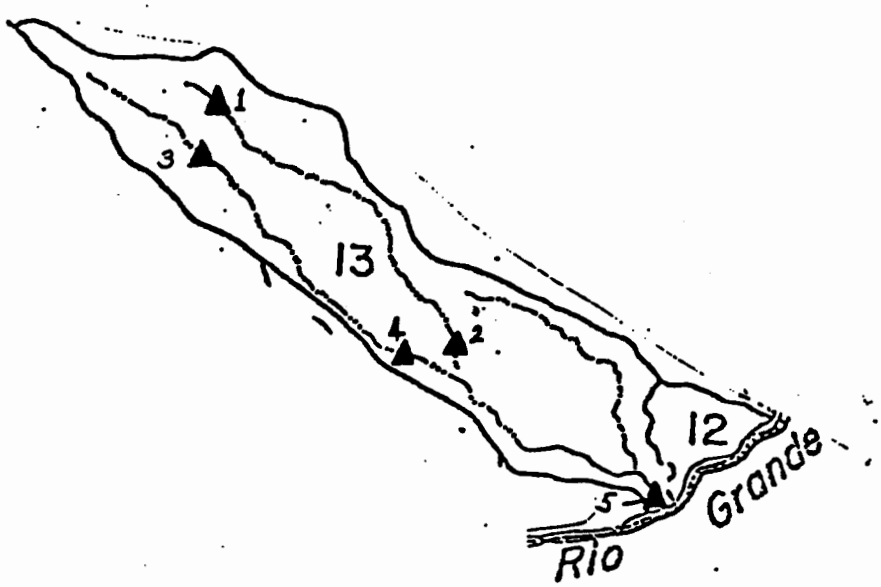
Stream flow in the channel on the plateau is intermittent. In the lower reaches of the canyon is a perennial stream fed by springs in the Totavi Lentil (Fig. 18). The stream reaches the Rio Grande. There are no known releases of effluent from Technical Areas within the drainage area. There is probably some small volumes of water perched in the alluvium seasonally.

1. Chemical Quality of Surface Water

Spring and surface water stations are located in the lower reach of the canyon. Ancho Spring discharges from the Totavi Lentil which is overlain by basalt. The underlying Tesuque Formation also adds to the volume of flow. The chemical analyses from these two stations are shown on the following table.



Water sampling stations



Sediment sampling stations

Fig. 18. Drainage Area 12 and Drainage Area 13 (Ancho Canyon) showing locations of sampling stations.

Chemical Quality of Surface Water
(Average of a number of analyses in mg/l except as noted)

Source	Year	No. of Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
Ancho Spr.	1952	2	7	6	1.6	.2	146	-	7.7
Ancho Spr.	1953	4	8	4	.3	.5	168	-	7.8
Ancho Spr.	1954	2	9	2	.4	.6	115	-	7.5
Ancho Spr.	1955	1	9	2	.4	.2	673	-	7.2
Ancho Spr.	1956	3	12	3	.4	.5	148	-	7.9
Ancho Spr.	1957	1	12	3	.5	.4	148	-	7.9
Ancho Spr.	1959	2	10	2	.4	.4	90[c]	140	7.7
Ancho Spr.	1960	1	10	3	.4	.5	85[c]	130	7.8
Ancho Spr.	1961	1	10	3	.4	.9	85[c]	130	7.8
Ancho Spr.	1962	1	8	3	.4	2.2	183	165	7.6
Ancho Spr.	1963	1	13	3	.4	3.6	124	140	7.6
Ancho Spr.	1965	1	7	3	.5	2.2	124	140	7.7
Ancho Spr.	1969	1	19	3	.1	.4	206	260	8.5
Ancho Spr.	1971	1	12	2	.1	.9	162	200	7.9
Near Rio Grande	1963	1	15	5	.8	.4	204	240	8.1
Near Rio Grande	1964	1	11	4	.4	.4	271	240	8.8
Near Rio Grande	1967	1	17	1	.8	.4	203	260	7.6
Near Rio Grande	1969	1	21	2	.5	.4	156	270	8.4
Near Rio Grande	1971	1	12	2	.1	.4	158	140	8.6

[a]Micromhos at 25° C
[b]No Units
[c]Estimated

Select trace metal ions analyses were made from Ancho Spring and the stream near the Rio Grande in 1971.

Metal Ion Analyses
(In μg/l)

	Ancho Spring	Stream Near Rio Grande
In Solution		
Cadmium	1.7	1.5
Beryllium	< .25	< .25
Lead	<1.0	<1.0
Mercury	< .02	< .02
Particulates		
Cadmium	< .25	.25
Beryllium	< .25	< .25
Lead	<1.0	2.6
Mercury	< .02	< .02

The chemical quality of water from the spring is low in total dissolved solids and shows no effect of Laboratory operations.

2. Radiochemical Quality of Surface Water

Radiochemical analyses of surface water were made of samples collected from Ancho Spring and from the stream near the Rio Grande. The results of samples from 1960 through 1967 are shown on the following table.

Radiochemical Analyses, 1960-1967
(pCi/l except as noted)

Source	Year	Gross Beta	Total Plutonium	Total Uranium a/
Ancho Spr.	1960	<14	<0.4	<0.5
Ancho Spr.	1961	<14	< .4	< .5
Ancho Spr.	1962	<14	< .4	.5
Ancho Spr.	1963	<14	< .4	3.1
Ancho Spr.	1965	<14	< .4	< .5
Nr. Rio Grande	1963	27	< .4	< .5
Nr. Rio Grande	1964	6	< .4	< .5
Nr. Rio Grande	1967	4	< .4	< .5

a/ μg/l

Radiochemical analyses from the two stations from 1969 and 1971 are shown on the following table.

Radiochemical Analyses, 1969-1971
(Picocuries per liter, except as noted)

Source	Year	Gross Alpha	Gross Beta	238 Pu	239 Pu	Total Uranium
Ancho Spr.	1969	<1	1	<0.05	<0.05	0.4
Ancho Spr.	1971	<1	<1	<0.05	<0.05	<0.4
Nr. Rio Grande	1969	<1	2	<0.05	<0.05	0.7
Nr. Rio Grande	1971	<1	1	<0.05	<0.05	<0.4

The analyses show only background concentrations of radionuclides.

B. Radiochemical Analyses Sediments

The sediments in the canyon at stations 1, 2, 3, and 4 are derived from weathering of the Bandelier Tuff while those at Station 5 are a combination of weathering of the Bandelier Tuff, basaltic rocks of Chino Mesa, Puye Formation, and Tesuque Formation. Particle-size distribution from stations in the drainage are shown on the following table.

Particle-Size Distribution
(Percent by Weight)

Station	1	2	3	4	5
Granules	3.0	1.0	10.5	8.5	5.5
Sand					
Very Coarse	48.5	21.0	53.5	26.0	43.0
Coarse	35.0	44.5	29.5	27.5	41.5
Medium	9.0	16.5	4.0	13.5	6.5
Fine	3.0	8.5	2.0	10.0	1.5
Very Fine	1.0	4.5	1.0	4.5	1.0
Silt and Clay	0.5	3.0	1.0	5.0	1.0

The following table presents radiochemical analyses of sediments collected in the drainage area in 1965. Locations are shown on Fig. 18.

Sediment Analyses, 1965
(Counts per minute per day gram)

Station	Gross Alpha	Gross Beta	Gross Gamma
1	2	<1	12
2	2	14	46
3	1	<1	26
4	1	15	14
5	1	1	8

Similar stations were sampled and analysed in 1970. The results are shown on the following table.

Sediment Analyses, 1970
pCi per dry gram

Station	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu
1	2	<1	<0.002	<0.002
2	2	2	<0.002	<0.002
3	<1	1	<0.002	0.006
4	1	<1	<0.002	<0.002
5	1	1	0.010	0.007

The results of the analyses indicate that radiochemical concentrations in the sediment in the drainage area are background.

C. Flood-Frequency and Maximum Discharge

Ancho Canyon heads on the Pajarito Plateau at an altitude of 2 220 m. Stream flow in the canyon is intermittent except in the lower reach. In the lower reach to the Rio Grande, the stream flow is perennial at less than 0.2 m^2/sec. Flood-frequency and maximum discharge is based on the following data:

Drainage Area 17.4 km^2
Main Channel Slope-0.045

Frequency	Maximum Discharge (m^2/sec)
2-Year	2.3
5-Year	5.4
10-Year	8.2
25-Year	14
50-Year	17

XV DRAINAGE AREA 14

Drainage area 14 is a steep wall on the west side of the Rio Grande and contains no well defined drainage (Fig. 19). The area is about 1.6 km^2. No data has been collected in this drainage.

XVI. DRAINAGE AREA 15 (CHAQUEHUI CANYON)

Chaquehui Canyon heads on the eastern part of the Pajarito Plateau. The canyon is cut into the Bandelier Tuff and through the basaltic rocks of Chino Mesa and Tesuque Formation as the Channel drops steeply to the Rio Grande. There are no observation holes in the canyon though there is water perched locally in the alluvium.

A. Surface Water

Stream flow in the channel is intermittent. Near the eastern reaches of the canyon water from springs and seeps in the Tesuque Formation maintains a small stream and several large pools which infiltrate into the alluvium prior to reaching the Rio Grande (Fig. 19). There are no release of effluents into the drainage area.

1. Chemical Quality of Surface Water

A sampling station has been established from one of the pool areas below the spring discharge from the sandstones and silt-

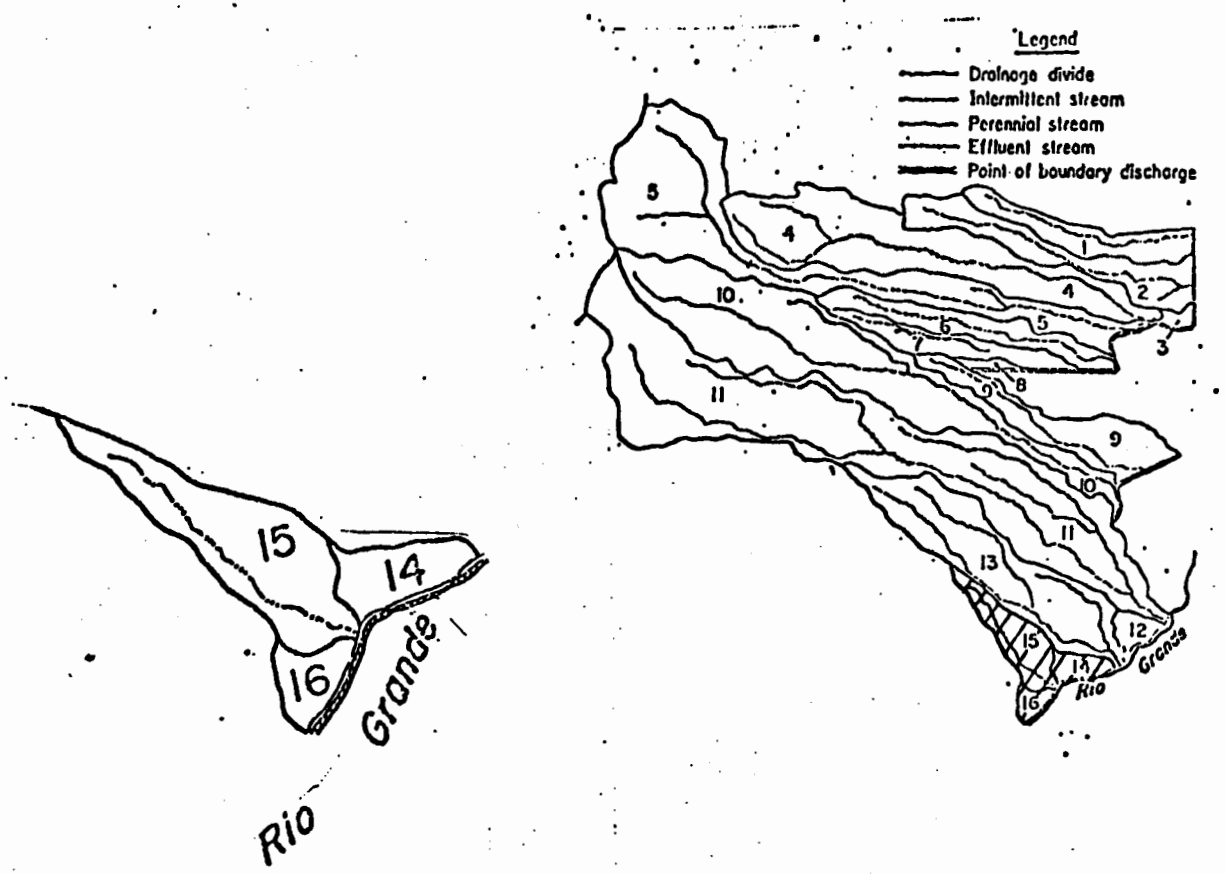


Fig. 19. Drainage Area 14, Drainage Area 15 (Chaquehui Canyon), and Drainage Area 16.

stones of the Tesuque Formation. The following table recaps the chemical analyses from this station which is called Doe Spring.

Chemical Quality of Water from Doe Spring
(In mg/l except as noted)

Year	Analyses	Na	Cl	F	NO_3	TDS	Conductance[a]	pH[b]
1956	1	15	2	0.3	2.6	180	240[c]	7.6
1957	1	11	2	.6	2.6	170[c]	260	7.8
1959	1	11	2	.4	1.3	160[c]	250	7.7
1960	1	12	2	.5	.4	170[c]	260	7.3
1961	1	11	1	.5	.4	165[c]	240	7.7
1962	1	9	2	.4	.9	186	220	7.5
1963	1	10	2	.4	.4	129	140	7.5
1965	1	13	5	.2	.4	218	240	7.8
1967	1	23	1	.3	.9	304	320	7.9
1969	1	22	3	.2	<.4	153	180	8.4
1971	1	21	4	.3	.9	219	260	8.0

[a] Micromhos at 25° C
[b] No Units
[c] Estimated

Trace metal ion analyses were made from Doe Spring in 1971.

Metal Ion Analyses
(In μg/l)

In Solution	Doe Spring
Cadmium	1.9
Beryllium	<0.25
Lead	<1.0
Mercury	<0.02
Particulates	
Cadmium	<0.25
Beryllium	<0.25
Lead	<1.0
Mercury	<0.25

The chemical quality of water from the spring is low. The increase in total dissolved solids in 1965 and 1967 may show the effect of residual from storm runoff in the pool.

2. Radiochemical Quality of Surface Water

The recap of radiochemical analyses from 1957 through 1967 are presented as follows:

Radiochemical Analyses of Water
from Doe Spring, 1957-1967
(pCi/1 except as noted)

Year	Gross Beta	Total plutonium	Total Uranium[a]
1959	<14	<.4	<.5
1960	<14	<.4	<.5
1962	<14	<.4	<.5
1963	<14	<.4	1.2
1965	<14	<.4	<.5
1967	26	<.4	.5

[a] μg/1

The recap of radiochemical analyses 1969 and 1971.

Radiochemical Quality of Water from Doe Spring
1969-1971
(pCi/1, except as noted)

	1969	1971
Gross Alpha	<1	<1
Gross Beta	1	3
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	0.4	0.6

[a] μg/1

The analyses show no radionuclide above limits of detection except uranium which is natural occurring in the discharge from the spring aquifer.

B. Radiochemical Analyses of Sediments

There were no particle-size distribution made of sediments in the canyon. One set of sediment analyses were analyzed from the mouth of the canyon in September 1969.

Radiochemical Analyses of Sediments
(pCi per dry gram)

Gross Alpha	2
Gross Beta	3
^{238}Pu	0.003
^{239}Pu	0.003

The levels of radioactivity are background or in the case of plutonium are no greater than world-wide fallout from atmospheric testing.

C. Flood Frequency and Maximum Discharge

Chaquehui Canyon heads on the Pajarito Plateau at an altitude of m Stream flow is intermittent except for a short reach near the eastern reach (Fig. 19). The flood-frequency and miximum discharge is based on the following data:

Drainage Area 4.7 km^2
Main Channel Slope-0.078

Frequency	Maximum Discharge (m^2/sec)
2-year	1.1
5-year	3.0
10-year	4.5
25-year	8
50-year	10

XVII DRAINAGE AREA 16

Drainage Area 16 is a steep wall on the west side of the Rio Grande and contains no well defined drainage (Fig. 19). The area is about 1.0 km^2.

No data has been collected in this drainage.

XVIII PERCHED WATER IN THE PUYE FORMATION

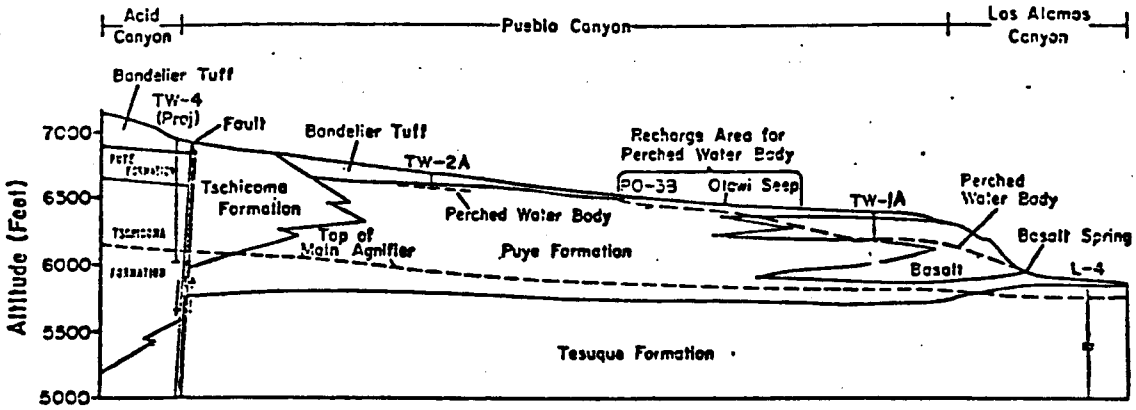
The only known body of water perch in the Puye Formation above the main aquifer occurs in the mid-reach of Drainage Area 4 (Pueblo Canyon). Other areas of perched water in the Puye may occur, but the limited number of deep test holes (seven test holes 300 m) did not encounter water perched in the Puye (Fig. 20).

Test well 2 A was drilled in 1947 to a depth of 40.5 m. The well has been equipped with a pump. The hole penetrated alluvium, Bandelier Tuff, and was completed in the fanglomerate. The fanglomerate is a slightly cemented unit of sand, gravels, and boulders with silt and clay lenses. The following table presents the geologic log.

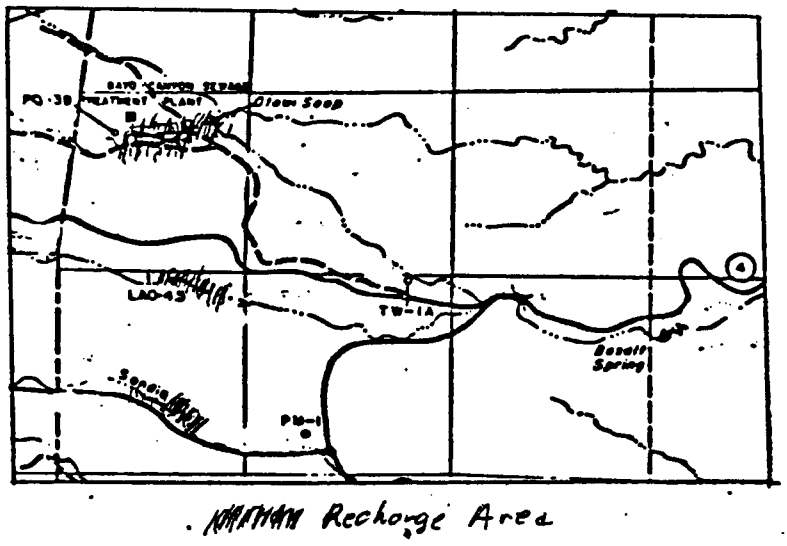
Geologic Log of TW-2A
(Altitude of Land Surface 2026 m)

Unit	Thickness (m)	Depth (m)
Alluvium	3.4	3.4
Bandelier Tuff		
Otowi Member	6.4	9.8
Guaje Member	9.8	19.6
Puye Formation (fanglomerate)	21.3	40.9

The following table presents some of the hydrologic characteristics as were determined by an aquifer test.



Cross-Section showing perched water in Puye Formation and Basaltic Rocks of Chino Mesa.



Location of Recharge Area to perched aquifer at TW-1A, PM-1 and Basalt Spring.

Figure 20. Cross-section and map showing perched water in the Puye Formation and Basaltic Rocks of Chino Mesa.

Aquifer Test TW-2A (1952)

Thickness of Aquifer (m)	1.5
Duration of Test (hrs)	4.5
Pumping rate (l/sec)	0.018
Water level prior to Test (m)	35.4
Total Drawdown (m)	3.1
Specific Capacity [(l/sec)/(m)]	
First 4 hr	0.062
Entire Test	0.062
Transmissivity (m^2/day)	0.62
Hydrologic Conductivity (m/day)	0.41

The aquifer is of limited areal extent. The changes in water levels over a period of time indicate that the aquifer is hydraulically connected to the stream flow in Pueblo Canyon. The water level response to recharge to the aquifer is estimated at 4 to 6 months at Test Well 2A.

A. Chemical Quality of Water

Water samples have been collected from the test hole from 1951 through 1965. The following table presents a summary of the chemical quality to 1965.

Chemical Quality of Water TW-2A
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1951	1	-	2	0.4	2	109
1952	2	-	2	.2	2	115
1953	8	-	3	.4	.2	116
1956	8	12	7	.5	2	144
1957	2	11	8	.4	.4	130[a]
1958	4	8	27	.6	4	140[a]
1959	7	11	16	.5	4	130[a]
1960	6	14	15	.4	31	170[a]
1961	4	16	16	.7	7.9	179
1962	3	15	14	.5	14	164
1963	3	20	16	.6	19	188
1964	3	16	16	.5	24	148
1965	2	18	10	.9	15	172

[a] Estimated

The quality of water has change over the period of year probably reflecting the quality of water in the stream. The most noticeable increase has been in chlorides, nitrates and total dissolved solids.

B. Radiochemical Quality of Water

A summary of the radiochemical analyses from 1958 through 1965 are presented in the following table.

Radiochemical Quality of Water, TW-2A
(Average of a number of Analyses in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium
1958	2	14	0.5	0.5
1959	10	14	0.5	0.5
1960	10	14	0.5	0.5
1961	2	14	0.5	0.5
1962	4	14	0.5	0.5
1963	3	14	0.5	0.5
1964	3	14	0.5	0.5
1965	2	14	0.5	0.5

[a] mg/l

The results of the analyses show that the concentrations of radioactivity were below limits of detection.

XIX PERCHED WATER IN BASALTIC ROCKS

Perched water was encountered in the basaltic rocks of Chino Mesa penetrated by Test Well 1A in the lower part of Pueblo Canyon (Fig. 20). The pilot hole for Supply Well PM-1 at Sandia Canyon also penetrated the same body of water in the basalts at a depth of 136 to 141 m. The section of perched water was cased and grouted with cement slury out of the supply well. The geologic log of a section of PM-1 is as follows.

Partial Geologic Log of PM-1
(Altitude of Land Surface 1987 m)

Unit	Thickness (m)	Depth[a] (m)
Bandelier Tuff		
Otowi Member	36.6	36.6
Guaje Member	13.7	50.3
Basaltic Rocks of Chino Mesa	104.2	154.5
Puye Formation (silt and clay)	13.1	167.6

[a] Total depth of Well 762.3 m

Test Well 1 A was drilled in 1949 to a depth of 68.6 m. The test hole penetrated the Puye Formation and Basaltic rocks of Chino Mesa as shown on the geologic log.

Geologic Log of TW-1A
(Altitude of Land Surface 1942 m)

Unit	Thickness (m)	Depth (m)
Puye Formation (fanglomerate)	15.2	15.2
Basaltic Rocks of Chino Mesa	35.1	50.3
Puye Formation (fanglomerate)	3.4	53.7
Basaltic Rocks of Chino Mesa	14.9	68.6

The well is equipped with a pump. The following table summarizes the hydrologic characteristics of the aquifer that occurs in an interflow breccia, the contact between two basalt flows. The water in the aquifer is under artesian head.

Aquifer Test TW-1A (1952)

Thickness of aquifer (m)	0.9
Duration of Test (hrs)	1128
Pumping Rate (l/sec)	0.21
Water Level Prior to Test (m)	55.7
Total Drawdown (m)	1.4
Specific Capacity [(l/sec)(m)]	
(First 4 hrs)	2.1
(Entire Test)	0.16
Transmissivity (m^2/day)	103
Hydrologic Conductivity (m/day)	114

No aquifer tests were made at Supply Well PM-1; however a bailing test indicated a yield of about 3×10^{-1} l/sec with a drawdown of 2 m.

Recharge to the aquifer occurs in Pueblo Canyon in the area from Observation Hole PO-3B to Otowi Seep and in Los Alamos Canyon in the vicinity of Observation Hole LAO-4.5 (Fig. 20). The surface flow in the recharge reach of Pueblo Canyon is mainly effluent from the Bayo Sewage Treatment Plant while storm runoff in Los Alamos Canyon contributes most of the recharge. The movement of water is eastward where a part is discharged from the basaltic rocks at Basalt Spring. The discharge of the spring varies according to the volume of recharge entering the aquifer. The discharge ranges from 0.9 to 2.1 l/sec during the year. Based on water-level response to stream flow it was estimated that the recharge from near Observation Hole PO-3B to Otowi Seep takes one to two months to reach Test Well 1A with another 2 to 3 months to reach Basalt Spring.

A. Chemical Quality of Water

Water samples for analyses were collected from 1951 through 1971 from test 1A. The following table presents an annual summary.

Chemical Quality of Water TW-1A
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1951	4	46	24	0.6	27	298
1952	3	34	19	.5	23	243
1953	9	26	12	.5	14	216
1954	5	-	15	.8	26	465
1955	6	-	10	1.1	27	311
1956	5	-	13	.6	18	279
1957	2	-	31	.6	14	230[a]
1958	10	25	26	.5	12	195[a]
1959	8	15	54	.5	-	165[a]
1960	6	36	23	.6	19	230[a]
1961	4	40	25	.6	24	319
1962	3	53	26	.7	31	340
1963	1	60	27	1.2	62	388
1964	4	53	30	1.2	35	313
1968	2	85	33	2.1	18	318
1969	1	77	27	1.8	13	339
1971	2	60	37	2.1	31	318

[a] Estimated

A summary of the average chemical quality of water from Basalt Spring is shown on the following table.

Chemical Quality of Water, Basalt Spring
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1951	1	-	16	0.5	8	220
1952	4	-	15	.4	13	215
1953	3	-	16	.4	10	198
1954	3	-	16	.4	15	195[a]
1955	2	-	16	.5	12	198[a]
1956	18	17	17	.6	18	212
1957	3	16	13	.5	14	191[a]
1958	6	13	13	.6	11	169[a]
1959	5	14	15	.4	10	190[a]
1960	2	15	13	.5	8	175[a]
1961	1	14	14	.5	8	174[a]
1962	2	20	17	.8	13	256
1963	2	24	20	1.2	13	198
1964	1	20	20	.8	13	229
1965	2	10	14	.8	13	197
1967	1	25	15	.3	13	150
1968	1	24	14	.6	13	168
1969	2	24	14	.3	9	207
1971	2	15	11	.6	13	220
1972	2	19	14	.4	10	197

[a] Estimated

The chemical quality of water from Test Well 1A is quite similar to that in the stream at Pueblo 3. The concentrations of the chemical have generally increased with time.

The quality of water from Basalt Spring is quite similar though the concentrations are lower. This is probably due to changes that occur during transit in the aquifer that reduces the concentrations in the aquifer material.

The following table presents results of metal ion analyses for TW-1 and Basalt Springs.

Metal Ion Analyses
(Average of a number of Analyses in μg/l)

Year	TW-1A 1971	Basalt Springs 1971	Basalt Springs 1972
No. of Analyses	2	2	2
In Solution			
Cadmium	4.3	2.8	0.65
Beryllium	.31	<0.25	<0.25
Lead	1.6	<1.0	<1.0
Mercury	<0.02	<0.02	<0.02
Particulates			
Cadmium	8.8	0.33	<0.25
Beryllium	.48	<0.25	<0.25
Lead	470	0.65	2.2
Mercury	0.07	<0.02	0.04

The 470 μg/l of lead in particulates from TW-1A is probably from pump column or lead packer connecting screen to casing at the bottom of the well.

B. Radiochemical Quality of Water

One sample of water was collected from a depth of ≈140 m in the inflow breccias at Supply Well PM-1 for total plutonium and tritium analyses. Plutonium was below limits of detection of <0.5 pCi/l as was the tritium $<50 \times 10^3$ pCi/l.

The following table presents an annual summary of the radiochemical analyses of water from Test Well 1A from 1958 through 1964.

Radiochemical Quality of Water, TW-1A
(Average of a number of analyses in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium[a]
1958	3	<14	<0.5	<0.5
1959	8	<14	<0.5	<0.5
1960	8	<14	<0.5	<0.5
1961	2	<14	<0.5	<0.5
1962	4	<14	<0.5	<0.5
1963	1	<14	<0.5	<0.5
1964	4	<14	<0.5	<0.5

[a] μg/l

The analyses results were below limits of detection. A summary of the analyses made in 1968, 1969, and 1971 are shown below:

Radiochemical Quality of Water, TW-1A
(Average of a number of analyses in pCi/l, except as noted)

Year	1968	1969	1971
No. of Analyses	2	1	2
Gross Alpha	1	2	1
Gross Beta	12	7	- [a]
^{238}Pu	<0.05	<0.05	<0.05
^{239}Pu	<0.05	<0.05	<0.05
Total Uranium[b]	1.1	1.3	0.4

[a] Sample 6-1, 189 pCi/l; 9-1, 7 pCi/l. Sample 6-1 is probably analytical error or cross contamination of sample.

[b] μg/l

An annual summary of the radiochemical analyses of water from Basalt Spring from 1957 through 1965 is shown on the following table.

Radiochemical Quality of Water, Basalt Springs
(Average of a number of analyses in pCi/1, except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium[a]
1957	1	<14	<0.5	<0.5
1958	4	<14	<0.5	<0.5
1959	5	<14	<0.5	<0.5
1960	4	<14	<0.5	<0.5
1961	2	<14	<0.5	<0.5
1962	2	<14	<0.5	1.0
1963	2	<14	<0.5	1.5
1964	1	<14	<0.5	2.0
1965	2	<14	<0.5	0.6

[a] μg/1

The annual summary of radiochemical analyses from 1967 through 1972 are shown on the following table.

Radiochemical Quality of Water, Basalt Springs
(Average of an number of analyses in pCi/1 except as noted)

Year	1967	1968	1969	1970	1971	1972
No. of Analyses	1	1	2	1	2	2
Gross Alpha	1	1	<1	<1	1	<1
Gross Beta	4	4	4	5	2	4
^{238}Pu	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
^{239}Pu	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Uranium[a]	1.2	1.0	1.6	0.4	1.6	3.0

[a] μg/1

The radiochemical analyses show natural or less than detectable amounts of radionuclides. The total uranium is natural occurring. The variation in concentration probably has to do with seasonal change in discharge from the spring and time of year samples are collected.

XX MAIN AQUIFER OF THE LOS ALAMOS AREA

Eleven (11) test holes have been drilled on the plateau to determine the thickness of the geologic units and water-bearing formations (Fig. 21). Seven (7) of the test holes have been completed as wells and are used in part for monitoring the chemical and radiochemical quality of water in the main aquifer. The geologic logs and hydrologic characteristics of the units penetrated by the test holes are presented. A summary of the chemical and radiochemical quality of water in the main aquifer is included in the following sections. Complete chemical and radiochemical quality of water data or of the last samples analyzed are found in Appendix G and H respectively.

A. Test Well 1

Test Well 1 was completed in 1950. It was the one of a series of test holes drilled in the period 1949 to 1950 to determine geologic and hydrologic characteristics of the main aquifer.[23] The test hole is located in lower Pueblo Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated the Puye Formation and Basaltic Rocks of Chino Mesa as shown by the log.

Geologic Los of TW-1
(Altitude at Land Surface 1942 m)

Unit	Thickness (m)	Depth (m)
Puye Formation (fanglomerate)	15.2	15.2
Basaltic Rocks of Chino Mesa	35.0	50.2
Puye Formation (fanglomerate)	3.4	53.6
Basaltic Rocks of Chino Mesa	24.1	77.7
Puye Formation (fanglomerate)	47.2	124.9
Basaltic Rocks of Chino Mesa	30.5	155.4
Puye Formation (fanglomerate)	29.0	184.4
Puye Formation (conglomerate)	11.3	195.7

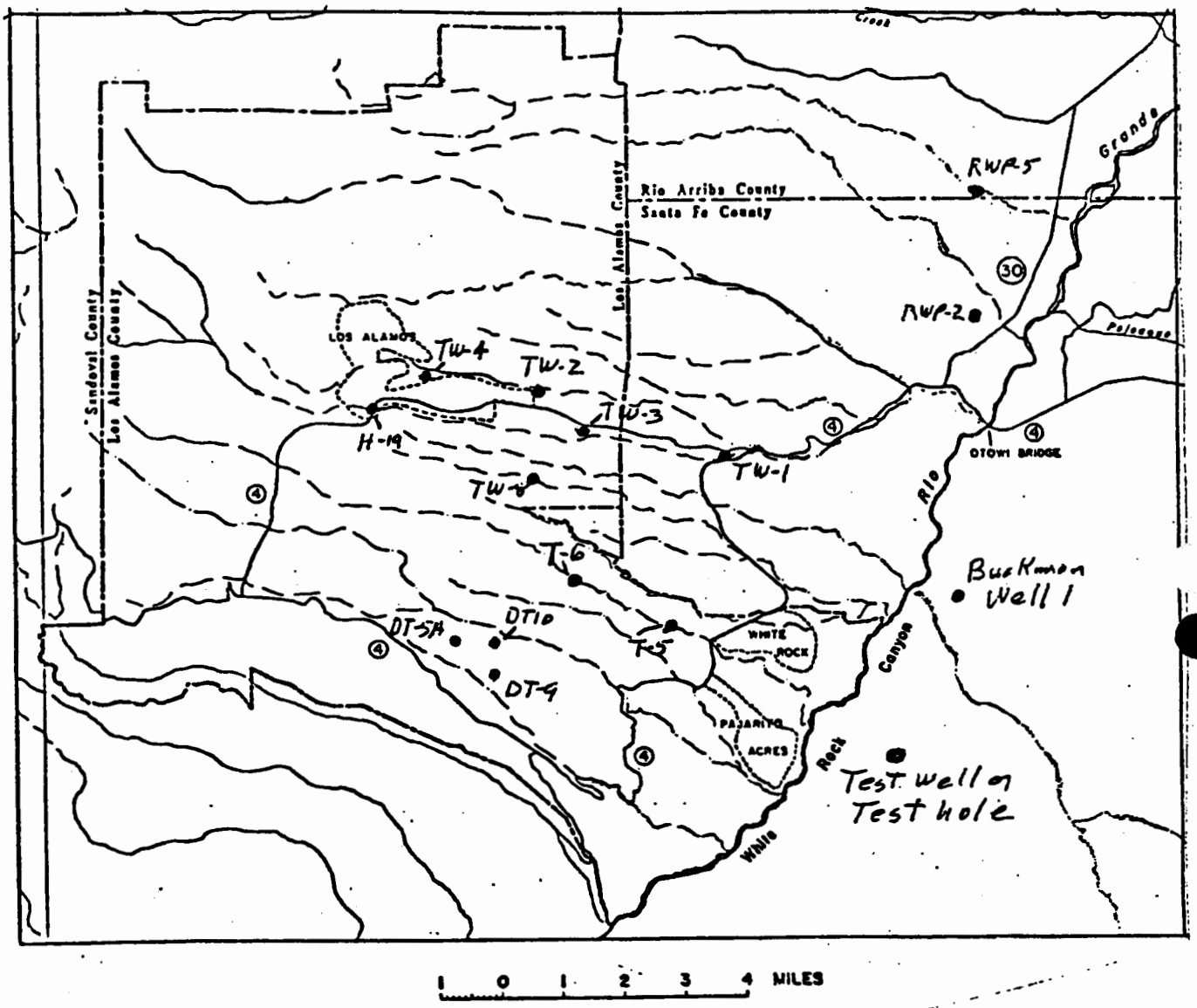


Figure 21. Location of test wells and test holes

The well was equipped with a pump until 1960. The following table summarizes the hydrologic characteristics of the aquifer that occurs in a conglomerate of sand, gravels, and boulders of the Puye Formation.

Aquifer Test TW-1 (1952)

Thickness of Aquifer (m)	5.8
Duration of test (hrs)	246
Pumping Rate (l/sec)	0.15
Water level prior to test (m)	180.4
Total Drawdown (m)	11.8
Specific Capacity [(l/sec)/(m)]	
(First 4 hrs)	0.1
(Entire test)	0.01
Transmissivity (m^2/day)	2.5
Hydrologic Conductivity (m/day)	0.45

2. Chemical Quality of Water

Chemical analyses of water form TW-1 were made from 1952 through 1970 as shown on the following table.

Chemical Quality of Water TW-1
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1952	18	16	8	1.3	1.8	161
1953	10	18	5	1.1	2.2	161
1954	2	--	10	1.3	2.5	147
1955	1	--	10	1.1	3.4	194
1956	8	20	5	1.4	3.5	191
1957	10	20	5	1.1	3.1	131
1958	6	17	5	1.0	7.4	120[a]
1959	2	18	4	1.1	6.9	120[a]
1960	3	18	5	1.0	6.8	120[a]
1961	5	17	4	1.3	4.3	149
1962	1	19	4	1.2	10.4	178
1963	1	34	6	0.8	0.4	186
1965	1	17	8	0.7	0.8	149
1967	1	21	14	0.7	0.4	173
1969	1	33	8	0.1	0.4	188
1970	1	11	8	0.5	0.4	161

[a] Estimated

The samples prior to 1961 were pumped while after that date, samples were collected with a sampling bailer. There has been no significant change in the chemical quality of water from 1952 through 1970.

3. Radiochemical Quality of Water

The following table presents the radiochemical quality of water from 1958 through 1964.

Radiochemical Quality of Water TW-1
(Average of a number of analyses in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium[a]
1958	2	<14	<0.5	0.5
1959	3	<14	<0.5	--
1960	6	<14	<0.5	--
1961	2	<14	<0.5	<0.5
1962	2	<14	<0.5	1.5
1963	1	<14	<0.5	0.7
1965	1	<14	<0.5	<0.5
1967	1	<14	<0.5	<0.5

[a] μg/l

A similar table presents data collected in 1969 and 1970.

Radiochemical Quality of Water TW-1
(Analyses in pCi/l except as noted)

	1969	1970
Gross Alpha	1	<1
Gross Beta	4	5
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	<0.4	<0.4

[a] μg/l

Analyses indicate natural or less than detectable amounts of radionuclides.

B. Test Well 2

Test Well 2 was completed in 1949. It was also one of the series of test holes drilled in the period of 1949 through 1950.[23] The test hole is located in the mid reach of Pueblo Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated the alluvium, Bandelier Tuff, and was completed in the lower part of the Puye Formation as shown by the log.

Geologic Log of TW-2
(Altitude of Land Surface 2026 m)

Units	Thickness (m)	Depth (m)
Alluvium	3.4	3.4
Bandelier Tuff		
Otowi Member	6.1	9.5
Guaje Member	9.7	19.2
Puye Formation (fanglomerate)	194.1	213.3
Puye Formation (conglomerate)	27.1	240.4

The well is equipped with a pump. The following table summarizes the hydrologic characteristics of the aquifer that occurs in a conglomerate of sand, gravels, and boulders in the Puye Formation.

Aquifer Test TW-2 (1952)

Thickness of Aquifer (m)	7.3
Duration of Test (hrs)	760
Pumping Rate (l/sec)	0.42
Water Level prior to Test (m)	231.8
Total Drawdown (m)	2.3
Specific Capacity [(l/sec)/(m)]	
(First 4 hrs)	0.23
(Entire Test)	0.21
Transmissivity (m^2/day)	87
Hydrologic Conductivity (m/day)	12

2. Chemical Quality of Water

Chemical analyses of water from TW-2 were made from 1951 through 1972 as shown on the following table.

Chemical Quality of Water TW-2
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1951	10	8	6	0.5	0.5	159
1952	14	8	5	0.7	0.4	158
1953	3	9	4	0.5	0.3	146
1954	1	-	4	0.8	0.5	172
1955	1	-	3	0.4	3.0	164
1958	1	9	7	0.4	0.1	-
1960	3	10	3	0.4	0.3	102[a]
1961	4	10	2	0.7	0.5	158
1962	4	11	3	0.9	1.9	152
1963	3	10	2	0.4	1.7	119
1964	3	9	3	0.5	1.3	130
1968	1	19	4	1.0	1.2	95[a]
1969	1	17	3	0.1	<0.4	90
1970	1	11	5	0.5	1.6	98
1971	1	10	5	0.8	<0.4	86
1972	1	10	6	0.5	0.4	78

[a] Estimated

In general, the chemical quality of the water has changed slightly with a decrease in total dissolved solids. Other ions have remained about the same concentration.

Metal ion analyses are presented in the following table.

Metal Ion Analyses
(Analyses in g/l)

In Solution	6-1-71
Cadmium	1.1
Beryllium	<0.25
Lead	11
Mercury	<0.02
Particulates	
Cadmium	2.1
Beryllium	<0.25
Lead	43
Mercury	<0.02

The concentration of lead in the particulates is probably due to pump column or lead packer connecting screen to casing.

3. Radiochemical Quality of Water

The following table presents the radiochemical quality water from 1958 through 1964.

Radiochemical Quality of Water TW-2
(Average of a number of analyses in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium[a]
1958	1	<14	<0.5	<0.5
1959	1	<14	<0.5	<0.5
1960	7	<14	<0.5	-
1961	8	<14	<0.5	--
1962	3	<14	<0.5	1.5
1963	3	<14	<0.5	0.8
1964	3	<14	<0.5	<0.5

The following table presents data collected from 1968 through 1972.

Radiochemical Quality of Water TW-2
(Analyses in pCi/l except as noted)

	1968	1969	1970[a]	1971	1972
Gross Alpha	<1	1	<1	2	<1
Gross Beta	2	1	1	2	<1
^{238}Pu	<0.05	<0.05	<0.05	<0.05	<0.05
^{239}Pu	<0.05	<0.05	<0.05	<0.05	<0.05
Total Uranium[b]	1.1	0.4	0.7	0.4	<0.4

[a] Average of 2 analyses
[b] μg/l

Radioactivity is background or below limits of detection.

C. Test Well 3

Test Well 3 was completed in 1949. It was one of the series of test holes drilled during the period 1949-1950.[23] The test hole is located in the mid-reach of Los Alamos Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated the Bandelier Tuff, and was completed in the lower part of the Puye Formation as shown by log.

Geologic Log of TW-3
(Altitude of Land Surface 2019 m)

Units	Thickness (m)	Depth (m)
Bandelier Tuff		
Otowi Member	42.7	42.7
Guaje Member	10.7	53.4
Puye Formation (fanglomerate)	27.7	81.1
Basaltic Rocks of Chino Mesa	21.9	103.0
Puye Formation (fanglomerate)	126.5	229.5
Puye Formation (conglomerate)	18.9	248.4

The well is equipped with a pump. The following table summarizes the hydrologic characteristics of the aquifer that occurs in a conglomerate of sand, gravels, and boulders of the Puye Formation.

Aquifer Test TW-3 (1952)

Thickness of Aquifer (m)	7.6
Duration of Test (hrs)	720
Pumping Rate (l/sec)	0.42
Water Level prior to Test (m)	228.9
Total Drawdown (m)	4.6
Specific Capacity [(l/sec)/(m)]	
(First 4 hrs)	0.10
(Entire Test)	0.10
Transmissivity (m^2/day)	97
Hydrologic Conductivity (m/day)	13

2. Chemical Quality of Water

Chemical analyses of water from TW-3 were made from 1951 through 1972 as shown on the following table.

Chemical Quality of Water TW-3
(Average of a number of analyses in mg/l)

Year	Analyses	Na	Cl	F	NO_3	TDS
1951	7	25	4	0.5	1.1	186
1952	4	17	6	0.6	1.8	194
1953	3	11	4	0.7	0.5	195
1954	3	--	5	0.3	0.6	185
1956	7	16	6	0.5	1.6	200
1957	5	14	4	0.4	0.8	205
1958	1	13	7	0.4	1.1	200
1959	4	13	5	0.5	0.7	140[a]
1960	3	14	5	0.4	0.7	145[a]
1961	3	16	5	0.6	0.4	176
1962	3	14	5	0.6	2.6	199
1963	1	17	5	0.4	2.4	200
1964	2	13	5	0.4	0.7	199
1965	2	11	5	0.7	1.3	156
1967	3	24	10	0.4	1.3	160
1968	1	24	4	0.4	1.2	201
1969	1	22	5	<0.1	0.4	124
1970	1	15	5	<0.1	3.1	180
1971	1	15	5	0.6	0.4	106
1972	1	19	6	0.5	<0.4	94

[a] Estimated

Chemical concentrations varied slightly over the years but showed no significant changes in concentrations. Total dissolved solids decreased in concentrations during the past few years.

Metal Ion Analyses
(Analyses in μg/l)

In Solution	6-3-71
Cadmium	2.8
Beryllium	<0.25
Lead	3.5
Mercury	<0.02
Particulates	
Cadmium	5.6
Beryllium	<0.25
Lead	8.2
Mercury	<0.02

3. Radiochemical Quality of Water

The following table presents the radiochemical quality of water from 1958 through 1965.

Radiochemical Quality of Water TW-3
(Average of a number of analyses in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium
1958	2	<14	<0.5	--
1959	8	<14	<0.5	--
1960	10	<14	<0.5	--
1961	8	<14	<0.5	--
1962	4	<14	<0.5	1.1
1963	1	<14	<0.5	5.0
1964	2	<14	<0.5	<0.5
1965	2	<14	<0.5	<0.5

The following table presents data collected from 1967 through 1972.

Radiochemical Quality of Water TW-3
(Average of a number of analyses in pCi/l except as noted)

	1967	1968	1969	1970	1971	1972
No. of Analyses	2	1	2	2	1	1
Gross Alpha	<1	<1	<1	3	2	<1
Bross Beta	5	3	2	3	4	2
^{238}Pu	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
^{239}Pu	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Uranium[a]	1.3	2.4	0.4	0.7	0.4	<0.4

[a] μg/l

There were no significant concentrations of radionuclides as indicated by the analyses.

D. Test Well 4

Test Well 4 was completed in 1950. It was one of a series of test holes drilled in the period 1949-1950.[23] The test hole is located on the western part of the plateau near the old Waste Treatment Plant (TA-45) at the head of Acid Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated the Bandelier Tuff, Puye Formation and is completed into the Tschicoma Formation as shown by the log.

Geologic Log of TW-4
(Altitude of Land Surface m)

Units	Thickness (m)	Depth (m)
Bandelier Tuff		
Tshirege Member	85.3	85.3
Otowi Member	26.8	112.1
Guaje Member	8.2	120.3
Puye Formation (fanglomerate)	73.2	193.5
Tschicoma Formation	173.7	367.2

The well has been equipped with a pump. It was removed in 1973. The following table summarizes the hydrologic characteristics of the aquifer that occurs in a brecciated zone in the volcanic flow rocks of latite of the Tschicoma Formation.

Aquifer Test TW-4 (1952)

Thickness of Aquifer (m)	6.4
Duration of Test (hrs)	720
Pumping Rate (l/sec)	0.18
Water Level prior to Test (m)	255.6
Total Drawdown (m)	1.5
Specific Capacity [(l/sec)/(m)]	
(First 4 hrs)	0.24
(Entire Test)	0.12
Transmissivity (m^2/day)	9.3
Hydrologic Conductivity (m/day)	1.5

2. Chemical Quality of Water

The pump on TW-4 was installed in 1952. It was out of service from 1954 through 1960. It failed again in 1966 and was removed from the well in 1973. Chemical analyses of water from the well were made during the period when the pump was in service as shown on the following table.

Chemical Quality of Water TW-4
(Average of a number of analyses in mg/l)

Year	No. of Analyses	Na	Cl	F	NO_3	TDS
1952	8	8	5	0.2	0.3	101
1953	1	5	2	0.1	0.3	180
1961	1	11	5	0.3	0.4	95[a]
1962	2	10	3	0.6	3.9	191
1963	4	12	3	0.5	1.4	172
1964	4	9	2	0.4	4.4	141
1965	3	15	3	0.6	1.3	129

[a] Estimated

Chemical concentrations and total dissolved solids varied in concentrations but indicated no significant changes occurred from 1952 to 1965.

3. Radiochemical Quality of Water

The following table presents the radiochemical quality of water from TW-4 from 1961 through 1965. No analyses have been made since the pump failed in 1965.

Radiochemical Quality of Water TW-4
(Average of a number of analsyes in pCi/l except as noted)

Year	No. of Analyses	Gross Beta	Total Plutonium	Total Uranium[a]
1961	1	<14	<0.5	<0.5
1962	2	<14	<0.5	<0.5
1963	4	<14	<0.5	0.5
1964	4	< 14	<0.5	1.8
1965	3	<14	<0.5	0.9

No significant concentrations of activity were detected.

E. Test Hole T-5

Test Hole T-5 was completed in 1950. It was one of the series of test holes drilled in the period 1949-1950.[23] The test hole is located in the

Lower reach of Pajarito Canyon near State Road 4 (Fig. 21).

1. Geologic Characteristics

The test hole penetrated the alluvium and Bandelier Tuff and was completed into the Basaltic Rocks of Chino Mesa as shown by the log.

Geologic Log of TH-5
(Altitude of Land Surface 2009 m)

Units	Thickness (m)	Depth (m)
Alluvium	7.0	7.0
Bandelier Tuff		
Tshirege Member	5.2	12.2
Otowi Member	36.6	48.8
Guaje Member	3.4	52.2
Basaltic Rocks of Chino Mesa	28.0	80.2

The test hole did not encounter any water bearing zone beneath the alluvium. Water in the alluvium was cased from the hole.

F. Test Hole T-6

Test hole T-6 was completed in 1950. It was part of the series of test holes drilled in the period 1949-1950.[23] The test hole is located in mid reach of Pajarito Canyon (Fig. 21) and State Road 4 (Fig. 21).

1. Geologic Characteristics

The test hole penetrated the alluvium, Bandelier Tuff, and is completed in the Puye Formation as shown by the log.

Geologic Log of T-6
(Altitude of Land Surface 2042 m)

Units	Thickness (m)	Depth (m)
Alluvium	7.6	7.6
Bandelier Tuff		
Tshirege Member	18.3	25.9
Otowi Member	54.9	80.8
Guaje Member	6.1	86.9
Puye Formation (fanglomerate)	4.6	91.5

The test hole did not encounter any water in the geologic units penetrated beneath the alluvium.

G. Test Hole T-7

Test hole T-7 was completed in 1950. It was also part of a drilling program of 1949-1950.[23] The test hole is located in the midreach of Ancho Canyon (Fig. 21).

1. Geologic Characteristics

The test hole penetrated alluvium, Bandelier Tuff, and were completed in the Basaltic Rocks of Chino Mesa as shown by the log.

Geologic Log of T-7
(Altitude of Land Surface 1897 m)

Units	Thickness (m)	Depth (m)
Alluvium	3.0	3.0
Bandelier Tuff		
Otowi Member	10.7	13.7
Basaltic Rock of Chino Mesa	3.0	16.7

The lower Guaje Member of the Bandelier Tuff was not penetrated at the test hole. The unit was eroded off or never deposited prior to the deposition of the Otowi Member.

The test hole did not encounter any water in any of the units penetrated.

H. Test Well 8

Test well 8 was completed in 1960. The test hole was drilled to delineate the geologic and hydrologic characteristics of units underlying Mortandad Canyon (Fig. 21). The test hole was completed prior to use of the canyon as a area to receive treated industrial effluents.[16,24]

1. Geologic and Hydrologic Characteristics

The test hole penetrated alluvium, Bandelier Tuff, Puye Formation, Basaltic Rocks of Chino Mesa and is completed in the Puye Formation as shown by the log.

Geologic Log of TW-8
(Altitude of Land Surface 2095 m)

Units	Thickness (m)	Depth (m)
Alluvium	12.0	12.0
Bandelier Tuff		
Tshirege Member	6.1	18.1
Otowi Member	117.3	135.4
Guaje Member	13.7	149.1
Puye Formation (fanglomerate)	27.4	176.5
Basaltic Rocks of Chino Mesa	44.2	220.7
Puye Formation (fanglomerate)	103.6	324.3

The well was not equipped with a pump until January of 1973. The following data summarizes the hydrologic characteristics of the aquifer that occurs in a fanglomerate of sand, gravels, and boulders of the Puye Formation.

Aquifer Test TW-8 (1960)

Thickness of Aquifer (m)	24.4
Duration of Test (hrs)	2.0
Bailing Rate (l/sec)	1.0
Water Level prior to Test (m)	293.4
Total Drawdown (m)	0.10[a]
Specific Capacity [(l/sec)/(m)]	
Estimated	2[b]
Transmissivity (m^2/day)	30
Hydrologic Conductivity (m/day)	1.2

[a]Residual drawdown 5 min after bailing ended
[b]Estimated

2. Chemical Quality of Water

There was no pump on TW-8 during the period of the report. Samples were collected with a sampling bailer. The following table presents the chemical quality of water.

Chemical Quality of Water TW-8

(Analyses in mg/l)

Year	Na	Cl	F	NO_3	TDS
1960	12	2	0.7	3.0	216
1961	15	2	0.4	2.0	463
1963[a]	15	2	0.4	2.2	187
1965	10	3	0.2	0.9	113
1967	13	1	0.1	0.4	141
1969	23	3	0.1	1.8	148

[a] Average of 2 analyses

The concentrations have varied slightly; however, as samples are bailed from the well, the indication is that there has been no significant change in the quality during the period.

3. Radiochemical Quality of Water

The following table presents the radiochemical quality of water from 1960 through 1965.

Radiochemical Quality of Water TW-8
(Analyses in pCi/l except as noted)

Year	Gross Beta	Total Plutonium	Total Uranium[a]
1960	<14	<0.5	<2.5
1961	<14	<0.5	<2.5
1963[b]	<14	<0.5	<0.5
1965	<14	<0.5	<0.5

[a] μg/l

[b] Average of 2 analyses

The following table presents data collected at different dates during 196

Radiochemical Quality of Water TW-8
(Analyses in pCi/l except as noted)

	1-10-69	1-14-69	2-14-69	11-6-69
Gross Alpha	<1	2	<1	<1
Gross Beta	2	3	1	3
^{238}Pu	<0.05	<0.05	<0.05	<0.05
^{239}Pu	<0.05	<0.05	<0.05	<0.05
Total Uranium[a]	0.5	0.4	0.4	0.4

[a] μg/l

No significant concentration of radionuclides were detected.

I Test Well DT-5A

Test well DT-5A was completed in 1960. It was drilled as a series of 3 deep test holes (DT-9, DT-10) to determine the geologic and hydrologic characteristics of the rock units underlying a small test area.[24,25] The test hole is located on the Pajarito Plateau south of Water Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated rocks of the Bandelier Tuff, Puye, Tschicoma, and Tesuque Formations as shown by the log.

Geologic Log of DT-5A
(Altitude of Land Surface 2177 m)

Units	Thickness (m)	Depth (m)
Bandelier Tuff		
Tshirege Member	195.4	195.4
Otowi Member	60.4	255.8
Guaje Member	27.7	283.5
Puye Formation (fanglomerate)	72.2	355.7
Tschicoma Formation	38.4	394.1
Puye Formation (fanglomerate)	42.1	436.2
Tschicoma	7.9	444.1
Puye Formation (fanglomerate)	5.5	449.6
Puye Formation (conglomerate)	15.8	465.4
Tesuque Formation	89.6	555.0

The well was equipped with a pump for the aquifer test. It was later removed. The following data summarizes the hydrologic characteristics of the aquifer which occurs in the Puye Formation (fanglomerate and conglomerate), Tschicoma and Tesuque Formations.

Aquifer Test DT-5A (1960)

Thickness of Aquifer (m)	106.7[a]
Duration of Test (hrs)	25
Pumping Rate (l/sec)	5.1
Water Level prior to Test (m)	357.5
Total Drawdown (m)	4.3
Specific Capacity [(l/sec)/(m)] (Entire Test)	1.2
Transmissivity (m^2/day)	136
Hydrologic Conductivity (m/day)	1.2

[a] Saturated section that should yield water readily to the well.

2. Chemical Quality of Water

Except for the sample collected in 1960 which was pumped, the remainder of the samples were collected with a smapling bailer. The following table presents the chemical quality of water.

Chemical Quality of Water DT-5A
(Analyses in mg/l)

Year	Na	Cl	F	NO_3	TDS
1960	14	1	0.2	2.0	147
1963	13	1	0.4	0.9	185
1967	14	4	0.4	<0.4	126
1969	19	3	<0.1	<0.4	120
1970	11	5	0.4	0.4	101

There has been no significant change in the quality of water during the period 1960 through 1970.

3. Radiochemical Quality of Water

The following table presents radiochemical quality of water as determined upon completion of the well in 1960.

Radiochemical Quality of Water DT-5A[a]
(Analyses in pCi/l except as noted)

	5-1-60
Alpha Activity	<1.3
Beta Activity	7.3
Radium (Ra)	<0.1
Total Uranium[b]	0.9

[a] Analyses U. S. Geol. Survey
[b] μg/l

The data collected in 1960, 1963, and 1967 is presented as follows:

Radiochemical Quality of Water DT-5A
(Analyses in pCi/l except as noted)

Year	Gross Beta	Total Plutonium	Total Uranium[a]
1960	<14	<0.5	1.0
1963	<14	<0.5	<0.5
1967[b]	<14	<0.5	<0.5
1967[c]	<14	<0.5	<0.5

[a] μg/l
[b] Zone Sample 390 m
[c] Zone Sample 527 m

Data for samples collected in 1969 and 1970 are shown as follows:

Radiochemical Quality of Water DT-5A
(Analyses in pCi/l except as noted)

	2-24-69	4-24-70
Gross Alpha	<1	3
Gross Beta	3	2
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	0.4	0.4

[a] μg/l

Analyses detected no significant concentrations of radionuclides.

J. Test Well DT-9

Test well DT-9 was completed in 1960. The well drilled for geologic and hydrologic data as previously mentioned. It is located on the plateau south of Water Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test well penetrated rock units of the Bandelier Tuff, Puye, Tschicoma and Tesuque Formations as shown by the log.

Geologic Log of DT-9
(Altitude of Land Surface m)

Units	Thickness (m)	Depth (m)
Bandelier Tuff		
Tshirege Member	206.0	206.0
Otowi Member	38.4	244.4
Guaje Member	14.6	259.0
Puye Formation (fanglomerate)	22.6	281.6
Tschicoma Formation	72.5	354.1
Puye Formation (fanglomerate)	47.8	401.9
Puye Formation (conglomerate)	11.6	413.5
Tesuque Formation	43.9	457.4

The well was equipped with a pump for the aquifer test. After the test, the pump was removed. The well has been equipped with a semi-continuous water stage recorder to determine the regional trends of water-level change of the

main aquifer. The well is located in a remote area away from the influence of pumpage for water supply. The regional decline from 1960 through 1968 has been about 0.61 m or 7.6 cm per year. The recorder has shown that the aquifer is very sensitive to atmospheric pressure changes, earth shocks, and probable earth tide effects.[26] The following data recaps the hydrologic characteristics of the aquifer which occurs in the Puye Formation (fanglomerate and conglomerate) Tschicoma and Tesuque Formation.

Aquifer Test DT-9 (1960)

Thickness of Aquifer (m)	91.4[a]
Duration of Test (hrs)	24
Pumping Rate (l/sec)	5.6
Water Level prior to Test (m)	305.7
Total Drawdown (m)	1.2
Specific Capacity [(l/sec)/(m)] (Entire Test)	4.6
Transmissivity (m^2/day)	760
Hydrologic Conductivity (m/day)	8.2

[a] Saturated section that should yield water readily to the well.

2. Chemical Quality of Water

Except for the sample collected in 1960 which was pumped, the remainder of the samples were collected with a sampling bailer. The following table presents the chemical quality of water.

Chemical Quality of Water
(Analyses in mg/l)

Year	Na	Cl	F	NO_3	TDS
1960	12	2	0.3	<0.4	136
1969	19	3	<0.1	1.3	160
1970	10	5	<0.1	<0.4	120
1971	14	4	<0.1	0.9	160

There was no significant change in quality of water during the period 1960 through 1971.

3. Radiochemical Quality of Water

The following table presents radiochemical data as determined upon completion of the well in 1960.

Radiochemical Quality of Water DT-9[a]
(Analyses in pCi/l except as noted)

	5-7-60
Alpha Activity	1.4
Beta Activity	3.6
Radium (Ra)	<0.1
Total Uranium[b]	0.8

[a] Analyses U. S. Geol. Survey
[b] μg/l

Samples were collected during the aquifer test at intervals of 4, 12, 16, and 24 hrs after pumping began. Gross Beta was <14 pCi/l; total Plutonium was <0.5 pCi/l and total uranium was <0.5 μg/l in the four samples analyzed.

The following table presents analyses collected in 1969 and 1970.

Radiochemical Quality of Water DT-9
(Analyses in pCi/l except as noted)

	2-20-69	4-28-70
Gross Alpha	<1	<1
Gross Beta	1	2
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	0.8	0.9

[a] μg/l

No significant concentrations of radionuclides were detected in the analyses.

K. Test Well DT-10

Test well DT-10 was completed in 1960 as a part of the three wells located south of Water Canyon, to determine geologic and hydrologic conditions underlying the plateau (Fig. 21).

1. Geologic and Hydrologic Conditions

The test hole penetrated rock units of the Bandelier Tuff, Basaltic Rocks of Chino Mesa, Tschicoma, and Puye Formations as shown by the log.

Geologic Log of DT-10
(Altitude of Land Surface 2139 m)

Units	Thickness (m)	Depth (m)
Bandelier Tuff		
Tschirege Member	204.8	204.8
Otowi Member	47.8	252.6
Guaje Member	10.7	263.3
Puye Formation (fanglomerate)	32.9	296.2
Tschicoma Formation	12.2	308.4
Basaltic Rocks of Chino Mesa	82.0	390.4
Puye Formation (fanglomerate)	22.9	413.3
Puye Formation (Conglomerate)	14.0	427.3
Tesuque Formation	2.1	429.4

The well was equipped for test purposes only. The following test purposes only. The following data recaps the hydrologic characteristics of the aquifer

that occurs in the Puye (fanglomerate and conglomerate) and Tschicoma Formations. The well only penetrated a thin section of the Tesuque Formation (2 m).

Aquifer Test DT-10 (1961)

Thickness of Aquifer (m)	60.9[a]
Duration of Test (hrs)	16
Pumping Rate (l/sec)	4.9
Water Level prior to Test (m)	330.7
Total Drawdown (m)	1.5
Specific Capacity [(l/sec)/(m)]	
Entire Test	3.3
Transmissivity (m^2/day)	447
Hydrologic Conductivity (m/day)	7.4

[a] Saturated section that should yield water readily to the well.

2. Chemical Quality of Water

Samples were collected from the well with a sampling bailer. The following table presents the chemical quality of water.

Chemical Quality of Water DT-10
(Analyses in mg/l)

Year	Na	Cl	F	NO_3	TDS
1960	11	3	0.2	1.0	138
1963	14	3	0.4	0.9	185
1967	12	6	0.1	<0.4	141
1969	19	3	<0.1	0.9	155
1970	10	3	0.4	<0.4	118

There was no significant change in the quality of water during the period 1960 through 1970.

3. Radiochemical Quality of Water

The following table presents radiochemical data as determined upon

completion of the well in 1960.

Radiochemical Quality of Water DT-10[a]
(Analyses in pCi/l except as noted)

	5-5-60
Alpha Activity	<0.8
Beta Activity	8.7
Radium (Ra)	<0.1
Total Uranium[b]	1.0

[a] Analyses U. S. Geol. Survey
[b] μg/l

The following data was collected in 1960 and 1963.

Radiochemical Quality of Water DT-10
(Analyses in pCi/l except as noted)

Date	Gross Beta	Total Plutonium	Total Uranium[a]
5-5-60	<14	<0.5	<1.0
9-20-60[b]	<14	<0.5	<4.0
11-13-63	<14	<0.5	0.7
2-15-67	<14	<0.5	<0.5

[a] μg/l
[b] 4 samples collected during aquifer test.

The following data was collected in 1969 and 1970.

Radiochemical Quality of Water DT-10
(Analyses in pCi/l except as noted)

	2-24-69	4-30-70
Gross Alpha	<1	<1
Gross Beta	1	2
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	1.2	0.4

[a] μg/l

There were no significant concentrations of radioactivity detected in the aquifer at Well DT-10 during the period 1960 through 1970.

L. Test Hole H-19

Test hole H-19 was completed in 1949. It was drilled for geologic and hydrologic information related to the development of possible water supply.[1] The test hole is located in upper Los Alamos Canyon (Fig. 21).

1. Geologic and Hydrologic Characteristics

The test hole penetrated rock units of alluvium, Bandelier Tuff, Puye and Tschicoma Formation as shown by the log.

Geologic Log of H-19
(Altitude of Land Surface 2188 m)

Units	Thickness (m)	Depth (m)
Alluvium	8.2	8.2
Bandelier Tuff		
Tshirege Member	52.7	60.9
Otowi Member	65.5	126.4
Guaje Member	17.4	143.8
Tschicoma Formation	105.8	249.6
Puye Formation (fanglomerate)	119.2	368.8
Tschicoma Formation	82.3	451.1
Puye Formation (conglomerate)	3.0	454.1
Tschicoma Formation	155.4	609.5

The test hole encountered a large thickness of relatively impermeable latites and rhyolites of the Tschicoma Formation which decreased the hydrologic Conductivity of the main aquifer. The yield would not be sufficient for completion as a supply well. The top of the main aquifer is about 295 m in the test hole. No records exist of aquifer tests. The hole was abandoned and casing pulled in 1949.

M. San Ildefonso Stock Wells

Two stock wells located to the northeast of the Los Alamos area were sampled to obtain background data on the chemical and radiochemical quality

of water in the main aquifer. The wells are located in the flat area east of the Puye Escarpment (Fig. 21).

Well RWP-2 is at an altitude of 1680 m. The well is completed into the Tesuque Formation and has a reported water level of 40.0 m. Well RWP-5 is at an altitude of 1742 m and is also completed into the Tesuque Formation. The water-level is reported at a depth of 32.0 m. Both wells are equipped with windmills.

1. Chemical Quality of Water

The following table summarizes the chemical quality of water in 1967.

Chemical Quality of Water, RWP-2, RWP-5
(Analyses in mg/l)

	RWP-2	RWP-5
Na	47	79
Cl	8	10
F	0.1	0.2
NO_3	0.9	3.1
TDS	170	253

Chemical quality indicates low to moderate TDS which is characteristic of water in the Tesuque Formation.

2. Radiochemical Quality of Water

The following table summarizes the radiochemical Quality in 1967.

Radiochemical Quality, RWP-2, RWP-5
(Analyses in pCi/l except as noted)

	RWP-2	RWP-5
Gross Alpha	4	2
Gross Beta	10	14
^{238}Pu	<0.05	<0.05
^{239}Pu	<0.05	<0.05
Total Uranium[a]	1.8	2.3

[a] μg/l

There is no significant concentrations of radionuclides as seen by the analyses.

N. Buckman Well

This is an abandoned well that was used for water to service the railroad that ran from Alamosa, Colorado to Santa Fe. The railroad was abandoned in 1940. The well is located across the Rio Grande from Los Alamos (Fig. 21).

The well is completed in the main aquifer which is the Tesuque Formation. The total depth is unknown, but when sounded in 1964, it was only open to 13.1 m. The well was flowing about 0.3 l/sec on August 25, 1964.

1. Chemical and Radiochemical Quality of Water

The following tables summarize the quality of water from the well.

Chemical Quality
(Analyses in mg/l)

	8-25-64
Na	48
Cl	4
F	0.4
NO_3	5.3
TDS	247

Radiochemical Quality
(Analyses in pCi/l except as noted)

	8-25-64
Gross Beta	<14
Total Plutonium	< 0.5
Total Uranium[a]	2.0

[a] μg/l

There were no significant concentrations of ions or radionuclides in the water when compared with other waters of the main aquifer.

XXI SUMMARY

The surface water and ground water in the alluvium are separated from water in the main aquifer by several hundred meters of unsaturated volcanic tuff and sediments. The surface water recharges the shallow aquifers in the alluvium in the canyon drainage areas. As the stream flow is intermittent and mainly dependent on the release of effluents from sewage and industrial treatment plants, the quality of water in the stream and the shallow aquifer is dominated by the quality of the effluents released after treatment. The water in the stream and in the alluvium is not a source of municipal, industrial, or agriculture use. There is no surface flow of effluents beyond the Laboratory boundaries. The following section summarizes the conditions in the drainage areas.

Drainage Area 1 (Barranca Canyon)

The drainage area of about 4.9 km^2 receives no effluent discharges. The canyon contains only intermittent storm runoff. No water samples have been collected and analyzed. Radiochemical analyses of sediments show only background concentrations of radionuclides.

Drainage Area 2 (Bayo Canyon)

The drainage area of about 9.8 km^2 receives no effluent discharges. The canyon was used as a test area until 1964. It contains only intermittent storm runoff. Chemical concentrations of storm runoff taken while the area was in operation are normal. Radiochemical analyses of sediments show no indication of contamination from the operations of the test area.

Drainage Area 3

The drainage area of 0.3 km^2 contains no well defined channel nor receives any effluent discharge.

Drainage Area 4 (Acid-Pueblo Canyon)

The drainage area of 22.3 km^2 receives effluent from two community sewage treatment plants and did receive industrial effluents containing radionuclides from 1943 through 1964. The release of sewage effluents maintain a base flow in a part of the canyon and recharges the water in the alluvium, a small body of perched water in the Puye Formation in the mid-reach of the canyon, and a second body of perched water in the Basaltic Rocks of Chino Mesa in the lower part of the canyon. The chemical quality of water in the stream, aquifers in alluvium, perched water in the volcanic sediments, and basalts is dominated by the quality of sewage effluents released. The intermittent release of industrial effluents during the period of operation of the treatment plant elevated for short periods of time the chemical concentrations of the sewage effluents in the canyon.

The industrial effluents contained some mixed fission products, but the major concern is the amount of plutonium released. In general, these concentrations decreased downgradient in the canyon from the effluent outfall both in solution and in sediments of the channel. This is due mainly to the uptake of the radionuclide by sediments in the stream channel. The concentrations are normally higher near the outfall decreasing downgradient in the channel. The accumulation of radionuclide and sediments are flushed and dispersed down the canyon by storm runoff.

The maximum reported concentration of plutonium in solution during the period 1958 through 1972 was 18.2 pCi/l that occurred in 1963 in the shallow water in the alluvium. About 8 pCi/l occurred in 1971 in surface flow at Acid Weir. This later analyses indicate resuspension of the plutonium into solution from the sediments or underlying tuff bedrock. The concentration guides for uncontroled areas for plutonium in solution is 5×10^3 pCi/l.

Thus, the highest concentraion reported in the canyon is below recommended levels for uncontrolled areas.

The total amount of plutonium released in the canyon during the period 1943 to 1964 was estimated at 170 mCi. The major amounts remaining in the canyon are believed to be adsorped by or attached to the channel sediment. An inventory made in 1972 indicated that the sediments only contain about 12 mCi. The remaining 168 mCi have been flushed by storm runoff into Los Alamos Canyon.

Drainage Area 5 (DP-Los Alamos Canyon)

The drainage area of 27.5 km^2 receives effluent from two sewage treatment plants (one near TA-21 and the other near TA-41) and an industrial waste treatment plant that processes radioactive influents. The volume of the sewage and industrial effluents released into DP and Los Alamos Canyon are low. They rapidly infiltrate into the alluvium. The stream flow in Los Alamos Canyon is impounded by a dam on the flanks of the mountain to the west of the plateau. Stream flow is intermittent in the canyons of the plateau. The major volumes of stream flow occur during the summer from heavy showers; however, a heavy snow pack can produce runoff for one to two months during the late spring.

The chemical quality of water in the short reaches of base flow below the plants is reflected in the similar quality of water in the alluvium. This is quite evident as the industrial and sewage effluent from DP Canyon move into the mid-reach of Los Alamos Canyon. As in Pueblo Canyon, the chemical quality of the water improves downgradient in the canyon.

Plutonium is the major radionuclide in the industrial effluents. The highest concentration of plutonium in solution was about 77 pCi/l reported in 1967. In 1972, the highest concentration was about 6 pCi/l. These concentrations decrease downgradient in the canyon. The concentration of plutonium

recommended for uncontrolled areas is 5×10^3 pCi/l thus, the highest concentration reported is below this level.

The total amount of plutonium released in the canyon during the period 1952 to 1972 was about 30.8 mCi. An inventory in 1972 indicated an estimated 3.7 mCi remained in the canyon to the junction of Pueblo Canyon. The remainder 27.1 mCi was flushed during storm runoff events into the lower reach of Los Alamos Canyon and to the Rio Grande.

Drainage Area 6 (Sandia Canyon)

The drainage area of 7.0 km^2 receives sewage effluent and blow-down of process water from the TA-3 power plant. The stream in the upper reach of the canyon is perennial with the release of the effluents. The chemical quality of the water in the stream and alluvium reflects the quality of effluent released. No radionuclides are released into the canyon. Sediments analyses indicate only background concentration of radioactivity.

Drainage Area 7 (Mortandad Canyon)

The drainage area of 4.7 km^2 receives cooling or waste water from TA-48 and industrial effluent from the waste treatment plant at TA-50. The stream below the effluent outfall is perennial for in short reach due to the release of effluents. The chemical quality of water in the stream and alluvium reflects the quality of the effluents released from the treatment plant. The average annual total dissolved solids in the stream range from about 320 to 1300 mg/l while that in the alluvium ranged from 360 to 1130 mg/l. In general the chemical quality improved downgradient in the canyon. The water is the poorest quality in any of the drainage areas; however, it is not used for any type of supply nor does the water move past the Laboratory boundary as surface flow or through the aquifer in the alluvium. The volume of surface water and effluent recharge to the aquifer in the alluvium is only sufficient to maintain the aquifer of limited extent within the upper reach

of the canyon.

Radionuclides released with the effluent are bound to sediments in the stream channel. The sediments are subject to transport by storm runoff; however, since hydrologic observations began in 1960, storm runoff has not reached the Laboratory boundary. In general, the concentration of radioactivity in solution and sediments decrease downgradient in the canyon.

Plutonium is a major radionuclide released with the effluents. The highest concentration reported in solution has been about 30 pCi which is below recommended levels for uncontrolled areas.

About 42.1 mCi of plutonium, 449 mCi of strontium 89, and 315 mCi of strontium 90 have been released into the canyon from the plant at TA-50. An additional 1,326 mCi of strontium 89 and 223 mCi of strontium 90 were released from 10-Site into a small tributary canyon to Mortandad. There has been little or no transport of these radionuclides into Mortandad. All radionuclide released have remained in the canyon as volume of storm runoff has been to small to allow transport to the Laboratory boundary.

Drainage Area 8

The drainage area of 0.5 km^2 contains no well defined channel nor receives any effluent discharge.

Drainage Area 9

The drainage area of 8.8 km^2 receives only a small volume of effluents from a cooling process.

The chemical quality of the water in a small reach of the stream is good and contains only natural concentrations of radionuclides. The analyses of channel sediments also show no indication of contamination by radionuclide from Laboratory operations.

Drainage Area 10 (Pajarito Canyon)

The drainage area of 27.5 km^2 receives a small volume of sewage effluent. As the canyon has a large drainage area on the flanks of the mountain intermittent snow melt and summer thundy showers provide enough runoff to recharge a small body of water in the alluvium.

The chemical quality of water in the stream is not objectional (low TDS) nor does it contain concentrations of radionuclides that indicate contamination.

Drainage Area 11 (Water Canyon)

The drainage area of 33.3 km^2 receives small volumes of sewage and industrial process water. The volume is sufficient to maintain a small reach of perennial flow in the mid reach of the canyon. The chemical quality of the surface flow is not objectionable (low TDS) nor does it contain concentrations of radionuclides that indicate contamination. Sediment analyses show only background concentrations of radionuclides except in one canyon that is trubutary canyon from the north that contains above background concentration of total uranium. This is due to testing adjacent mesas and transport into the canyon by runoff.

Drainage Area 12

The drainage area of 1.3 km^2 contains no well defined channel nor receives any effluent discharge.

Drainage Area 13 (Ancho Canyon)

The drainage area of 17.4 km^2 contains a perennial stream in its lower reach to the Rio Grande. The canyon receives no effluent releases. The chemical and radiochemical quality of the water are normal. Sediment analyses show only natural or background concentrations of radionuclides.

Drainage Area 14

The drainage area of 1.6 km^2 contains no well defined channel nor

receives any effluent discharge.

Drainage Area 15 (Choquehui Canyon)

The drainage area of 4.7 km^2 contain a small spring bed reach of perennial flow above the Rio Grande. The canyon receives no effluent releases. Chemical and radiochemical analyses of water are normal showing no indication of Laboratory operations. Sediment analyses show only natural or background concentrations of radionuclides.

Drainage Area 16

The drainage area 1.0 of km^2 contains no well defined channel nor does it receive any effluent discharge.

The chemical quality of the surface and ground water in the alluvial aquifer pore no environmental or health problems as the result of past Laboratory activities. The water are contained with in the Laboratory areas. The chemical quality in some canyon may be poor; however, the quality generally improves as it moves downgradient.. The water is not a source of municipal, industrial, or agricultural useage.

The areas of present release of radioactive industrial effluents is controlled. The largest concentrations of plutonium found in solution are below recommended limits for uncontrolled areas. The bulk of radionuclides is attached or absorbed in alluvial materially in the channels below the plaint outfall. Estimated inventories of plutonium in Acid-Pueblo and DP-Los Alamos Canyons indicate that about 195 mCi have been transported past the Laboratory boundries by storm runoff into Lower Los Alamos Canyon and to the Rio Grande in the past 30 years. Trace of plutonium above the limits of detection ($\approx$ 0.05 pCi/g) can be found in sediments of lower Los Alamos Canyon.

Sediment volumes in the Rio Grande at Otowi Bridge have ranged from 0.6×10^6 to 6.8×10^6 t with an average of about 2.2×10^6 t for the 24 year period from 1948 through 1971. Considering the mixing of 195 mCi of plutonium with the average annual sediment load for a single year the average plutonium concentration in sediment of the river would be 9×10^{-5} pCi/g. Using an average annual release of 6.5 mCi of plutonium (195 mCi/30 years) with the average annual sediment load the sediment concentration in the river would be about 2.7×10^{-5} pCi/g. Thus it appears due to the dispersion of the radionuclide the effect that can be measured of transport of radionuclides in the Rio Grande would be slight.

Four test wells completed into the main aquifer in canyon receiving radioactive industrial effluent exhibit no change in chemical quality nor any trace of radionuclides that can be attributed to the release of the effluents. The chemical and radiochemical quality of water from the remainder of the test wells completed into the main aquifer also show no effect of the Laboratorys or Community release of industrial or sewage effluents.

The industrial and sewage effluents infiltrate into the alluvium of the Canyon to recharge bodies of water perched on the tuff. As the water move downgradient some is lost to evapotranspiration and the remainder move into the underlying tuff. The movement of water in the tuff is downward and the rates of movement vary due to the different hydrologic characteristics of the tuff. The volcanic debris of the Paye Formation and Basaltic Rocks of Chino Mesa contain lenses of silt and clay that would tend to perch and distribute over a large area any water moving downward to the main aquifer. In general several hundred meters of unsaturated tuff, volcanics debris and basalts separate the water in the alluvium and main aquifer.

The movement of water in the main aquifer is at about 110 m/yr. toward the natural discharge area of the Rio Grande. It would take over 100 years

based on this rate of movement for the water in the main aquifer to reach the river from the central part of the plateau. Thus if any contaminates, chemical or radiochemical, should reach the aquifer the transit time from point of contamination to discharge area would allow chemical and ion or base exchange reactions to take place so no contamination would remain in the water at the natural discharge area.

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Appendix A

Physical Characteristics of the Bandelier Tuff

The Bandelier Tuff is formed by a series of ash flows and ash falls which are described as nonwelded, moderately welded, and welded tuff. The nonwelded, moderately welded, and welded tuff grade one into the other both vertically and horizontally.

The upper Tshirege Member, is about 250 m thick along the western edge of the Pajarito Plateau and thins eastward to less than 15 m. Individual moderately welded and welded ash flows in the upper part of the Tshirege Member range from 6 to 40 m thick. Some of the uppermost ash flows are beveled off by erosion eastward across the plateau. Outliers of tuff overlie the Puye formation along Puye Escarpment. Most all ash flows thin eastward from the source area (Sierra de los Valles). Nonwelded ash flows of the Otowi Member may be as much as 90 m thick near the center of the plateau.[1/]

I. Welding

The welding process of an ash flow tuff begins after emplacement. The major factors affecting welding are heated at the time of emplacement, amount of volatiles in the mass, rate of cooling, and thickness of the ash flow.[2/] The degree of welding ranges from incipient stages marked by the sticking together or cohesion of glassy fragments to complete welding marked by the cohesion of the surfaces of glassy fragments accompanied by their deformation and elimination of pore space.

Zonal variation of welding occurs vertically within individual flows or within a series of flows that have cooled as a single unit.[3] Single ash flows that have cooled as a unit may show a greater degree of welding near the center than near the upper and lower contacts. A series of ash flows that have been emplaced in rapid succession may cool as a single unit with

the greatest degree of welding near the center.

Variation of welding occurs horizontally within individual flows with greater degree welding near the mountains (the source area). The degree of welding becomes less eastward across the plateau.

The tuffs in the Los Alamos area are classified according to the degree of welding--i. e., nonwelded, moderately welded, and welded tuffs. Welding results in increased cohesion and deformation of the glassy fragments in the tuff. Nonwelded tuff has high porosity, only slight cohesion of the glassy fragments, and crumbly fracture; moderately welded tuff has lesser porosity, moderate cohesion, slight deformation of the glassy fragments, and a somewhat brittle fracture; and welded tuff has lower porosity, good cohesion, a high degree of deformation by flattening of glassy fragments, and a brittle fracture.[4]

The degree of welding influences most of the physical characteristics of the individual ash-flow tuff units.

The following shows a large range in porosity in each of the variations of tuff indicating that welding is only one of several factors determining porosity.

	Range in porosity (percent by volume)
Nonwelded tuff	40 to 60
Moderately welded tuff	30 to 55
Welded tuff	15 to 40

The surface of ex-osed tuff (nonwelded to welded) becomes "case hardened" as it is exposed to the weather. In this process, due to the porosity of the tuff, moisture is absorbed and some minerals are dissolved. The minerals are returned to the surface by evaporation as the tuff dries out where they are precipitated to form a rind. This rind forms a protective surface which resist the wearing away of the surface by wind and water. However, exposed

pumice fragments weather out rapidly leaving small covities in tuff surface.

II. Density

The density of nonwelded tuff is lower than in welded tuff. This is due to the compaction of the matrix (glass shards and ash) and closer arrangement of the quartz and samidine, crystals, and rock fragments in the process of welding of a welded tuff. The specific gravity of the tuff matrix averages about 2.55. The range in bulk density of nonwelded to welded tuff depends on the porosity (i. e., the larger a porosity the smaller the density).

The following table shows a comparison of the densities of pumice and the tuff (nonwelded to welded) with other rock types.

Rock Type	Range in density (gm/cm^3)
pumice (nonwelded)	< 1.0
Nonwelded tuff	1.02-1.52
Moderately welded tuff	1.15-1.84
Welded tuff	1.52-2.16
Granite	2.64-2.76
Marble	2.60-2.84
Sandstone	2.14-2.36
Basalt	2.4 -3.1

III. Bearing capacities

The bearing capacities of a tuff are dependent upon the density of tuff (i. e., the greater bearing capacities occur with the tuff of greater density). The density of the tuff is related to welding (i. e., density of the tuff increases from nonwelded tuff to welded tuff).

Data are available on the bearing capacities of the moderately welded tuff. The following table shows the relationship of density change to the resistance to crushing of a moderately welded tuff.

Density (gm/cm^3)	Resistance to crushing (kg/m^2)
1.73	2.4×10^5
1.74	3.7×10^5
1.77	3.9×10^5
1.79 (probably with pumice inclusion)	3.4×10^5
1.81	4.8×10^5
1.83	5.6×10^5

Rock inclusions of pumice, rhyolite, and latite are found in the tuff. The frequency of occurrence of the rock fragments differs in individual ash flows and at different locations within the same ash flow.

The pumice fragments may be as much as 5 cm in length and 2 cm in diameter. The pumice is soft and friable. Pumice fragment inclusion in a small sample of the tuff would decrease the bearing capacity as failure would most likely occur within the pumice fragment. The rhyolite and latite fragments are dark gray, hard, and may be as much as two or three inches across. These large rock fragments would add strength to the matrix of tuff.

The following table is a comparison of the bearing capacities of a moderately welded tuff (density 1.73 and ~ 1.82 g/cm^3) and miscellaneous rock type. The bearing capacity is computed as 1/5 of rupture strength of the material.

Rock Type	Bearing capacity (kg/m^2)
Moderately welded tuff (1.73 g/cm^3)	4.7×10^4
Moderately welded tuff (1.82 g/cm^3)	1.1×10^5
Sandstone	3.4×10^5
Limestone	8.4×10^5
Marble	1.1×10^6
Granite	1.4×10^6

IV. Thermal Conductivity

The thermal conductivity of the tuff is related to porosity, thus, the

thermal conductivity of a nonwelded tuff would be less than a welded tuff as more pore space is available for insulation.

The only data available on the thermal conductivity was made of a moderately welded tuff in one area investigated. The following table is a companion of the thermal properties of the tuff and miscellaneous rock types. A decrease in thermal conductivity increases the insulating value.

Rock Type	Range of thermal conductivity $\left(\frac{\text{cal, gm-cm}}{\text{hr x cm}^2 \text{ x } ^\circ\text{C}}\right)$
Moderately welded tuff	0.38-0.47
Limestone	4.9 -11
Sandstone	9.9 -20
Marble	17-25
Granite	16-35

V. Mineral composition

The tuff is rhyolitic in composition and contains small rock fragments of rhyolite, latite and devitrified pumice and crystals and crystal fragments of sanidine, and quartz, in a matrix of glass shards and welded ash. Dark minerals are scarce although traces of crystal fragments of biotite, hornblende, and pyroxene have been observed.[2]

Seven samples of a moderately welded tuff were analyzed petrographically by C. S. Ross (written communication, July 7, 1960). Ross recalculated the proportions of phenocrysts in terms of proportion by weight. The results of all seven were similar, one of which is presented here:

Pore space	about 30 percent by volume
Phenocrysts	about 20 percent by weight
Sanidine	12 percent by weight
Quartz	6 percent by weight
Magnetite	1 percent by weight
Pyroxene	0.5 ± percent by weight

The ground mass is typical devitrified welded tuff. The devitrification

products are very fine grained, but show typical cristobalite feldspar structure. Cavities contain radial groups of feldspar and tridymite. The rocks contain a few areas of altered andesite, and some brown firefracting clay like material (probably montmorillonite).

VI. Chemical composition

The color of the tuff ranges from very light gray to medium dark gray. Some units range from pinkish gray to light pink. Large fragments of pumice that appear much darker than the matrix in some units enhance the color of the tuff. Moderately welded units are generally lighter in color than the welded units. The coloring is inherent in the tuff and probably the result of minor changes in the chemical constituents and heat of emplacement.

In general the tuff is composed namely of silica and alumina. The range in chemical constituents is shown on the following table.

Chemical constituents	Range (in percent)
Silica (SIO_2)	72.0-78.2
Alumina (Al_2O_3)	11.2-13.8
Ferric oxide (Fe_2O_3)	1.1--2.1
Ferrous oxide (FeO)	.21--.75
Magnesium oxide (MgO)	.02-..33
Calcium oxide (CaO)	.26-1.17
Sodium oxide (Na_2O)	3.5-4.5
Potassium oxide (K_2O)	4.2-4.7
Water (H_2O)	.15-2.8
Titanium oxide (TiO_2)	.10- .32
Phosphorous oxide (P_2O_5)	.10- .07
Manganese oxide (MnO)	.00- .98
Carbon dioxide (CO_2)	<..05

VII. Joints

Joints and joint systems are prominent in the Tshirege Member. The joints divide the rocks into multitudinous polygonal blocks, many of which are prismatic or columnar.

The joints can be classified into two groups, master joints and minor joints. The term "master joint" signifies those joints that are numerically predominant, are most persistent in length, and pass through several groups of beds.[5]

The master joints can be traced vertically across two or more units of the Tshirege Member. They are vertical or near vertical, dipping more than 80°. The overall vertical trends of the individual master joints are relatively straight; however, they curve slightly through individual units and upon entering a unit of different degree of welding, may be deflected slightly.

The minor joints dip at angles from about 40° to 80° and in most instances, intersect the master joints. These joints are not as persistent as master joints.

Master joint systems in Mortandad Canyon display orientation differences of about 60°.[6] Joint systems mapped at Mesita del Buey also indicate orientation differences of 60°.[7] The angular differences between these joint systems suggest that these sets are conjugate tension joints caused by shrinkage during cooling of the rocks.

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Appendix B

Hydrologic Characteristics of the Bandelier Tuff

The natural moisture content of the tuff forming the mesas between the eastward-trending canyons is generally less than five percent by volume. Thus, movement of moisture is under unsaturated conditions. The low moisture content of the tuff is caused by the protective cap of clay soil derived by weathering of the tuff near the surface. The hydrologic characteristics of the tuff depend largely upon the degree of welding of the individual ash flows.

I. Hydrologic Effects of Soil

The surfaces of the finger-like mesas which form the Pajarito Plateau are covered by a clayey soil derived by weathering of the underlying tuff of the Tshirege Member. The soil is thickest near the axes of the mesas and thins toward the edges where the tuff is exposed. Thick sections of soil have also developed along slow draining arroyos cut into the surfaces of mesas and in relatively flat areas where water collects and stands. The greatest known thickness of woil is at Frijoles Mesa where 2.7 m was logged in a shallow test hole located in a relatively flat area.

Petrographic examination of the soil derived from the Tshirege Member was made by Staritzky of the Los Alamos Scientific Laboratory.[1] He found that the size distribution of the "sand" fraction (greater than 50 microns in diameter) varied between 15 and 38 percent, the "silt" fraction (2 to 50 microns in diameter) varied between 58 and 73 percent, and the "clay fraction" (less than 2 microns in diameter) varied between 4 and 12 percent. Mineralogicall the principal constituents of the soil were quartz and feldspar, and the most important secondary constituents are the clay minerals, montmorillonite and illite. Monmorillonite is known to have the highest base-exchange capacity

(85 to 100 millequivalents per 100 grams) and illite the next highest (25 to 30 millequivalents per 100 grams) among the clay minerals.

A study of the natural distribution of moisture in soil and in near surface tuff was made at Frijoles Mesa during a 2-year period. The moisture content in the soil cover, including the transition zone from the soil to weathered tuff, varied according to prevailing weather conditions. The moisture content was highest in March and April as the result of late winter snows and thawing and was generally lowest in the months of August through October owing to high evapotranspiration rates. Water from precipitation rarely infiltrated through the undisturbed soil cover into the underlying tuff and only in an extremely low moisture range (less than 5 percent moisture by volume) within the upper 1 m of the tuff.[2]

The upper two units of moderately welded tuff (thickness about 36.5 m) at Frijoles Mesa blow air through open joints in response to a declining atmospheric pressure therefore, the soil cover, which prevents most of the precipitation from infiltrating into the underlying tuff, also impedes the exchange air from the atmosphere to the tuff.[3]

II. Hydrologic Characteristics of Nonwelded, Moderately Welded and Welded Tuff

The hydrologic characteristics of tuff related to porosity, specific yield, specific retention, pore size distribution and hydrologic conductivity were determined of in six units of the Tshirege member at Frijoles Mesa. These hydrologic characteristics were determined in the laboratory under saturated conditions. As saturated conditions rarely occur in the tuff, these parameters maybe of only general interest.

The porosity of the tuff at Frijoles Mesa ranged from 19 to 54 percent by volume; the lowest porosities are in the welded tuffs. Specific yield and specific retention decrease with a decrease in porosity. Specific yield is

greater than specific retention in a nonwelded tuff (high porosity); however, as the porosity decreases the difference become smaller and low porosity specific retention in a welded tuff may be greater than specific yield.

The relationship of porosity to pore size depends on the degree of welding, thickness of the flow, and position in the flow. The larger pore sizes and greater porosities are near the top of the flow and decrease vertically through the flow. This is due to the larger pores formed by escaping gases near the top and compaction and baking of the middle and lower portion of the flow as it cools.

The hydrologic conductivity is indirectly related to porosity depending upon pore size and the degree of interconnection of the pores. The permeability of the tuff matrix decreases with depth for the same reasons that the porosity decreases.

Hydrologic characteristics of the Tshirege Member of the Bandelier Tuff, as determined in the laboratory are shown in the following table.

Hydrologic characteristics of
of the Tshirege Member
at Frijoles Mesa

Hydrologic Characteristics						
Unit	Depth below surface of mesa (m)	Degree of welding	Porosity (percent)	Specific yield (percent)	Specific retention (percent)	Range of Hydrologic Conductivity (m/day)
6	0-19.5	Moderate	38-54	18-34	16-27	0.004-0.25
5	19.5-20.1	None (sand)	-	-	-	1.4 -2.4
4	20.1-41.1	Moderate	33-54	11-43	12-22	0.012-0.53
3	41.1-53.3	Nonwelded	48	34	14	0.9
2	53.3-83.5	Welded	19-37	.6-26	11-21	.08-2 0.003-0.08
1B	83.5-152.7	Nonwelded	-	-	-	50-2.1

III. Movement of Water

The Tshirege Member is dry beneath the surfaces of the finger like mesas. The moisture content of the tuff generally is less than 5 percent by volume, even though the specific retention ranges from 11 to 27 percent. Beneath the canyons, which contain perennial or intermittent streams, the moisture content of the tuff may be as much as 60 percent by volume; however, the water movement through the tuff is as unsaturated flow. Test holes drilled through alluvium and into the tuff in Water and Mortandad Canyons penetrated thick sections (up to 55 m) of wet tuff (up to 60 percent moisture by volume); however, no free water moved into the test holes.

Holes through which instruments can be used to measure moisture content of the bore wall were holes constructed in the tuff beneath the stream channel in upper Mortandad Canyon and these holes contained no free water, although the welded tuff beneath the stream contained as much as 25 percent moisture by volume. Specially constructed moisture access holes in the tuff underlying water perched in the alluvium in lower Mortandad Canyon had moisture contents of the tuff as much as 45 percent by volume but the rock yielded no free water. The welded and nonwelded tuff in the canyon are transmitting water downward into the tuff by unsaturated flow.

The water in the tuff moves an unsaturated flow. The majority of the pores are of capillary size. The energy relationship with moisture content of a moderately welded tuff was determined by Abrahams[4] (Fig. 1). The saturated moisture content of the tuff was about 41 percent by volume. When moisture contents are below 4 percent there is no movement of water; from 4 to 8 percent moisture is redistributed by diffusion; from 8 to 23 percent distribution is by gravity and capillarity and above 23 percent the movement is by drainage from gravity.

A study of the movement of water through the tuff was made at Mesita del

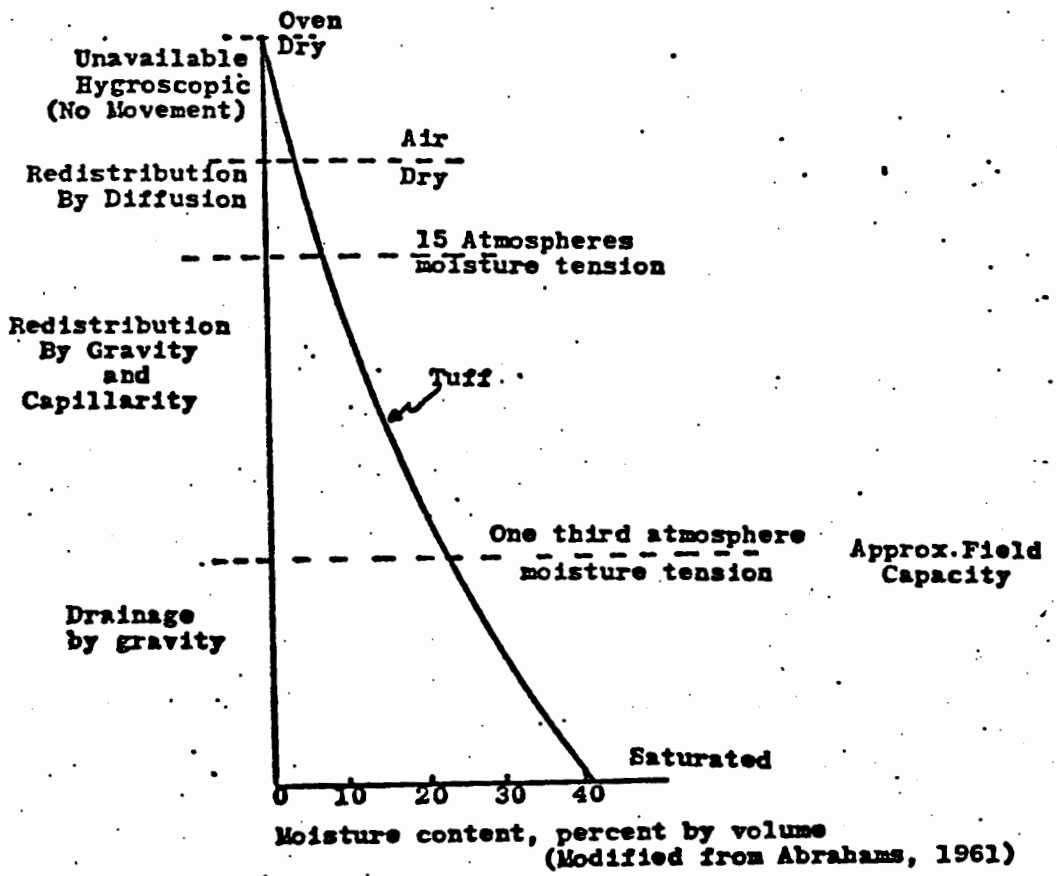

Figure 1. Energy relationships with moisture content of tuff.

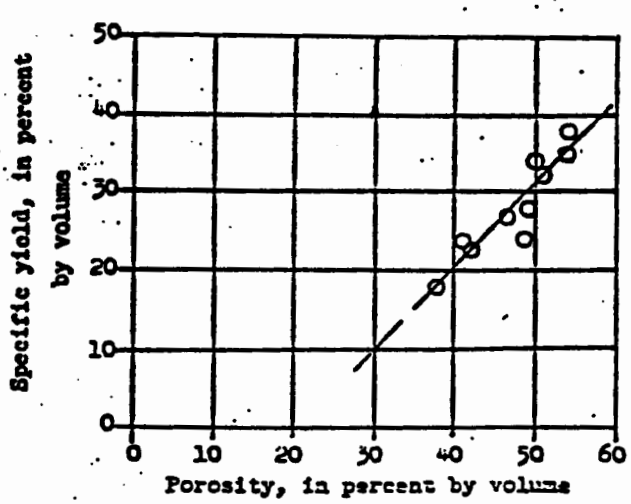

Figure 2. Relationship of specific yield to porosity of the tuff.

Buey. The movement of water from an infiltration pit was monitored by a series of moisture access tubes set in the tuff and a neutron-scattering moisture prob and scaler. The average infiltration rate from a m^3 pit under a constant head of 23 cm of water averaged about 0.34 m/day for a period of about 160 days. The wetted front moving into the tuff was sharpest during the first part of the test. After about 2 months of infiltration moisture had moved downward more than 4.5 m moisture content ranged as follows: 35 percent by volume at 0.6 m below the pit, 30 percent at 0.9 m, 25 percent at 4 m, and 20 percent at 4.6 m.

IV. Hydrologic effects of welding

The uppermost ash flow at Frijoles Mesa exhibits zonal variations of welding in a single cooling unit by vertical changes in porosity. The moderately welded flow is about 24 m thick near the center of the mesa. The greatest porosities are in the upper and basal parts of the flow. Lesser porosities (zone of denser welding) are in the lower one third of the flow, and the pore size decreases with increased depth. The following table presents the hydrologic characteristics at different intervals in a single ash flow tuff.

Hydrologic characteristics of an ash-flow tuff at Frijoles Mesa

Height above base of flow (m)	Porosity (percent)	Specific yield (percent)	Specific retention (percent)	Hydrologic Conductivity (m/day)		Pore size distribution (percent of porosity)	
				vertical	horizontal	> .01 mm	< .01 mm
17.9	54	35	19	10.082	-	-	-
47 14.3	50	34	16	0.12	0.12	39	61
47 14.3	54	38	16	0.25	0.21	26	74
12.2	51	34	17	0.16	0.16	20	80
	49	28	21	0.041	-		
6.7	41	24	17	0.004	0.082	20	80
6.1	47	27	20	0.082	0.082	15	85

Hydrologic characteristics of an ash-flow tuff at Frijoles Mesa (cont'd)

Height above base of flow (m)	Porosity (percent)	Specific yield (percent)	Specific retention (percent)	Hydrologic Conductivity (m/day)		Pore size distribution (percent of porosity)	
				vertical	horizontal	>.01 mm	<.01 mm
5.8	42	23	19	0.041	0.033		
3.6	38	18	20	0.037	0.041		
1. 0.3	51	33	18	0.041	-	17	83
1. 0.3	49	24	25	0.037	0.082	20	80

A decrease in porosity in an ash-flow tuff results in a decrease in specific retention increases proportionately (Fig. 2). The hydrologic conductivity is related to pore size and pore-size distribution rather than porosity. The permeability of the tuff matrix decreases at increased depth with a general decrease in the percentage of pore sizes greater than 0.1 mm.

Variations in vertical and horizontal permeability in the lower one third of the flow may be due to movement and compaction of the ash flow as it cooled. Movement of flow as it cools could result in elongation of the pores in a horizontal plant, and the greatest permeability probably is in this direction. Three of the five horizontal hydrologic conductivities in the lower one third of the flow are greater than the vertical conductivities, however, the conductivity measurements were taken in random directions and no attempt was made at orientation to the probable direction of movement of the flow.

V. Hydrologic effects of joints and contacts

Joints and the fractures in the tuff are capable of transmitting fluid and may offset the relative inability for the adjacent rock to transmit fluid. The interconnection of the joint system is an important aspect of the

hydrologic regime.

Joints in moderately welded to welded tuff of the Tshirege Member range from closed to open. Locally the amount of opening is as much a 5 cm, however, the majority of joints are open less than 1 cm. All joints terminating at the base of the soil zone, which covers the surfaces of the mesas, are filled with a light-brown clay. The depth of clay filling varies from 0.9 to 1.2 m below the soil zone at Mesita del Buey and Frijoles Mesa. The joint openings are plated with clay to depths of 21 m at Frijoles Mesa. Some of the joints are filled or plated with a light-gray clay. The light-gray clay is derived from weathering of the tuff and is composed of minerals leached from the tuff by water. This clay was precipitated along the joint openings prior to the development of the soil zone. The joints are interconnected and master joints transect one or more flows. Joints are more numerous and open in ash flows of moderately welded to welded tuffs than in nonwelded tuff.

Joints that are interconnected in the moderately welded and welded units of tuff could provide paths for rapid movement, water was introduced directly into these open joints. Water would be dispersed through joint systems.

Joints in the moderately welded to welded tuffs will transmit water depending upon the amount of opening and the degree of interconnection between different joint systems. More than 15,000 m^3 of drilling fluid was lost while drilling 300 m of Bandelier Tuff at Frijoles Mesa. Most of the loss was in the upper 150 m in the Tshirege Member which here consist of moderately welded to welded tuff in which open joints are numerous. During grouting of a casing in a large diameter hole at Frijoles Mesa (a 76 cm dia., 15.2 m depth casing filled with water to prevent collapse) the bottom seal in the casing ruptured, and the water from within the casing drained into the formation within 3 hours. The number and orientation of joints in the hole were determined before the casing was installed. A joint near the bottom was open 1 to 3 cm for about

1.2 m. The 6.9 m^3 of water moved into the joint and downward into the joint systems of the underlying flow. Abbreviation of another large-diameter hole 15.2 deep and located 7.6 m to the north failed to disclose and trace of the water.

The experiment at Mesita del Buey indicated that water from the infiltration pit moved downward through a moderately welded tuff into a pumice zone which is more porous and permeable. Movement in the pumiceous zone was lateral. Infiltration into a moderately welded tuff underlying the pumice zone was from near the center of the saturated area in the pumiceous lense. The moisture content of the top moderately welded tuff was much lower than the underlying pumiceous zone, which indicates that specific retention of the pumice zone is greater.

Vertical infiltration through the Tshirege Member would be affected by zonal variations of welding as well as by horizontal contacts between flows.

Vertical changes in hydrologic conductivity caused by contacts between flows tend to perch infiltrating water. In the stream channel in Mortandad Canyon, water is returned to the surface from underflow in the alluvium and in a moderately welded tuff at the contact with a nonwelded tuff.

Industrial wastes discharged into surface water in Acid Canyon move into the joints and tuff of the Tshirege Member, are perched on the top of the Otowi Member, and then move laterally along the contact into a seep area at the junction of Acid and Pueblo Canyons.

Results of an infiltration experiment in the soil near TA-50 indicated that precipitation that is not removed by surface drainage infiltrates into the soil on the mesas of the Pajarito Plateau; however, the downward movement of this water is impeded or stopped by the dense transition zone between the soil and tuff and the water is returned to the atmosphere by evapotranspiration.[2]

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3. W. D. Purtymun and Others, "Air Volume and Energy Transfer Through Test Holes and Atmospheric Effect on the Main Aquifer," Los Alamos Scientific Laboratory Rept. LA-5725-MS (1974).
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Appendix C

Low Flow Investigations in Santa Clara, Guaje, Los Alamos, and Frijoles Canyons

Surface water drainage accross the Pajarito Plateau is eastward from the Sierra de los Valles to the Rio Grande, the master stream in north-central New Mexico (Fig. 1). The eastward trending intermittent and perennial streams have cut deep canyon into the plateau. Two of the major canyons, Santa Clara and Frijoles, contain surface water which during a part of the year discharge into the Rio Grande, Guaje and Los Alamos Canyon contain perennial streams in their upper reaches. Only during periods of excessive precipitation (heavy snow melt or summer thunder showers) cause surface water in these two canyons to reach the Rio Grande.

The geology and hydrology of the area have been discussed in previous sections of this report. The low flow investigations were made in 1958, 1959, and 1960.[1,2] While the State Engineer summarizes stream flow at the gaging station in Santa Clara Canyon for the years 1937 through 1941 and 1950.[3] The U. S. Geological Survey summarizes the stream flow at gaging stations in Frijoles Canyon for the years 1960 through 1967.[4] The present study utalizes data from these investigations and reports. Low flow data has been supplemented by additional measurements in Santa Clara and Guaje Canyons and by the collection of water samples for chemical and radiochemical analyses.

Geologic sections were prepared along the stream channels of Santa Clara, Guaje, Los Alamos, and Frijoles Canyons using existing geologic maps modified by field investigations. Subsurface correlations were interpreted from outcrops and logs of near-by wells or test holes. The low-flow stations are shown on cross-section and results of measurements on tables of respective sections in the text.

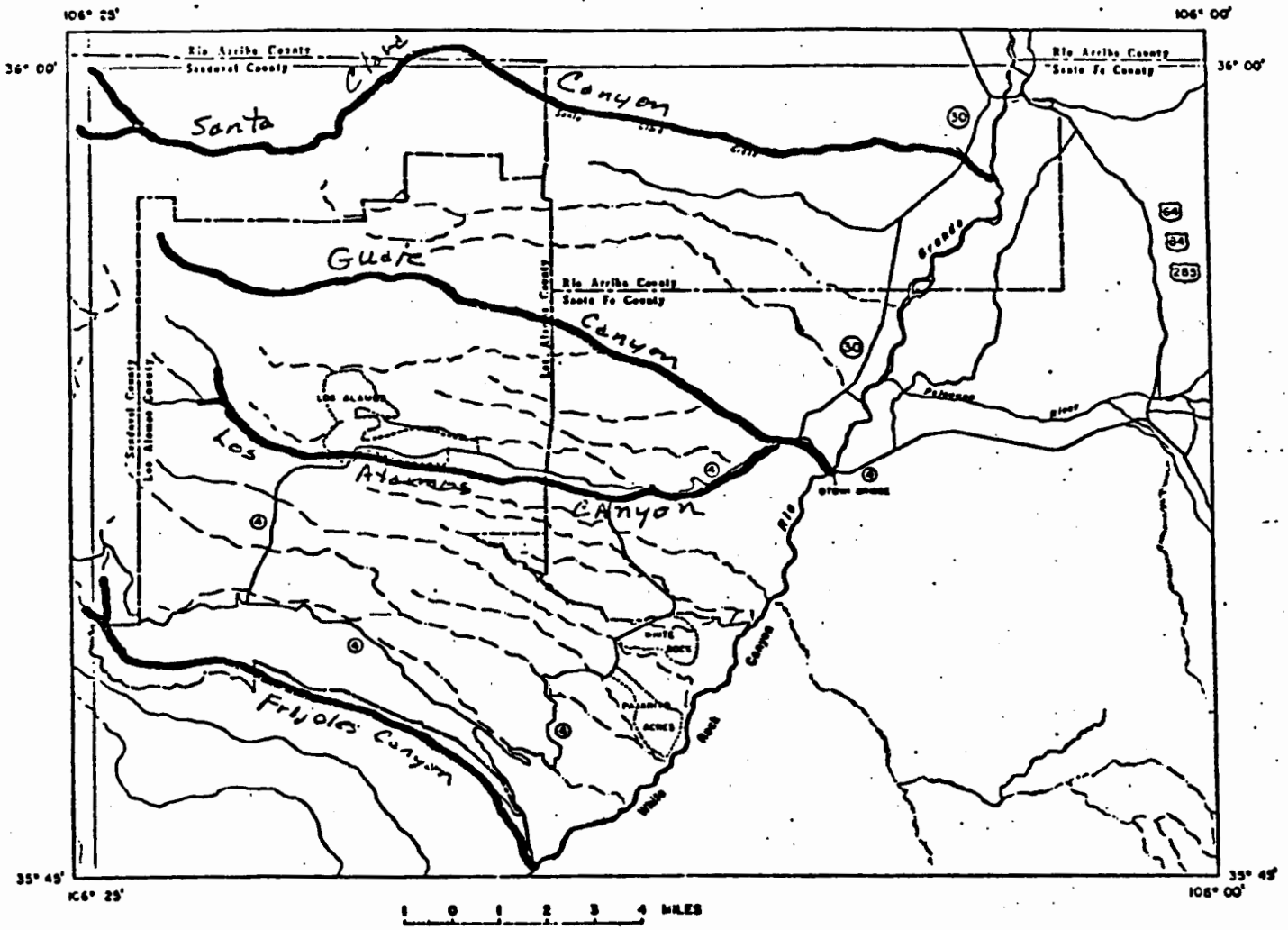

Figure 1. Map of Los Alamos Area showing location of low-flow investigations in Santa Clara, Guaje, Los Alamos, and Frijoles Canyons.

The purpose of the low flow studies was to relate geology and geologic structure to loss or gain in stream flow in evaluating recharge or discharge to stream connected aquifers (aquifers in the alluvium) or the main aquifer.

Low-flow measurements were made with a pygmy current meter except as noted. The report is presented in English units to correspond with initial studies. The conversion factors to metric are presented if conversion is desired

Conversion of English to Metric Units

Multiply	By	To Obtain
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	0.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (sq. mi)	2.59	Square Kilometers (km^3)
Cubic feet/sec (cfs)	28.32	Liters/sec (l/sec)
Acre-feet (Ac. ft)	1233	Cubic Meters (m^3)

I. SANTA CLARA CANYON

The effective drainage area (area in which base flow increases, generally in mountain front underlain by the Tschicoma Formation) of Santa Clara Canyon is about 27 sq. mi. The canyon contains the largest stream flow of the three canyons. The stream is fed by precipitation percolating through the coalluvium overlying the Tschicoma Formation on the Canyon walls and emerging in the stream channel as surface flow. The flow starts about 1.2 mi west of the initial point at an altitude of about 9,200 ft (Fig. 2). The largest flow increase, in reach investigated, is between stations 3 and 8 and generally continues to increase to station 26 (Table 1). In this reach of the canyon the gradient of the stream channel is about 230 ft/mi and is underlain by the Tschicoma Formation. East of station 26 there is a steady decline in flow as the gradient of the channel decrease to an average of about 115 ft/mi where the

Puye and Tesuque Formations underlie the stream. It is evident that the alluvium begins to thicken east of station 26 thus a part of the flow is lost into the stream connected aquifer in the alluvium and underlying Puye while the rest is lost to evapotranspiration.

Two small recreational reservoirs (3 and 4) were built in the canyon by Santa Clara Pueblo above station 26 prior to the 1958 through 1960 seepage investigations (Figure 3). Two additional reservoirs were built between stations 3, 8, and 11 prior to seepage run made in June 1967. There was no apparent loss of water from the reservoirs into the underlying formations as indicated by the 1967 measurements. Water below station 34 is diverted from the stream for irrigation during a part of the year. A shallow well near station 31 (48 ft deep in alluvium) is used to fill stock tanks on the plateau south of the canyon.

A gaging station was operated by the U. S. Geological Survey near station 34 for the water year (October through September) 1937, 1938, 1939, 1940 and 1951 (New Mexico State Engineer, 1959 p. 229). The annual runoff (volume of water to cover entire watershed) ranged from 1.3 to 3 inches (Table 2).

II. GUAJE CANYON

Guaje Canyon has an effective drainage area of about 6 sq mi above the reservoir. Base flow in the canyon is maintained by two springs which discharge at an altitude of about 8,850 ft (between stations 4 and 6 above reservoir) from a zone at the base of the Bandelier Tuff.[5] A small amount of flow is added to the stream from coalluvium on the canyon walls above the reservoir (Fig. 3). Surface water losses occur eastward from the reservoir (Table 3). The amount of flow is sufficient (with no diversion from the reservoir) to extend near mile 6 before being depleted to evapotranspiration and infiltration into the underlying alluvium and formations. The gradient of the stream channel underlain by the Tschicoma Formation is about 300 to 500 ft/mi decreasing to

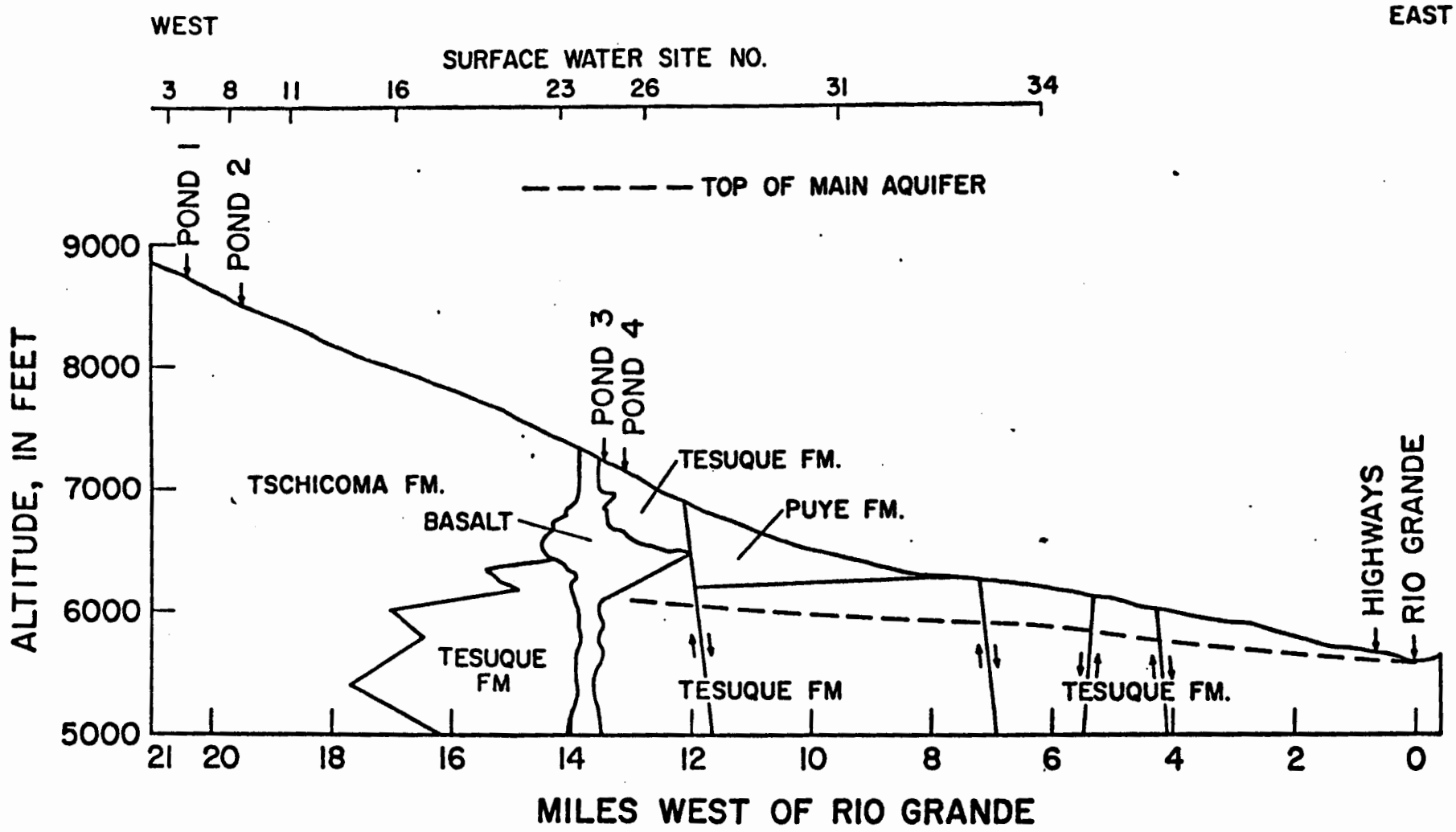

Figure 2. Geologic section of Santa Clara Canyon showing location of low flow measurements.

Table 1. Santa Clara Canyon Low Flow Measurements
(cubic feet per second)

	1958	1959				1960		1967
	Oct. 14-15	Apr. 14	June 2	Aug 31	Oct 12-14	May 16-17	June 20-22	June 30
3	2.0	2.2	2.7	2.6	2.2	5.4	1.9	--
8	4.0	4.0	4.9	4.1	3.4	7.1	2.0	3.6
11	4.0	4.1	5.2	4.8	3.8	8.6	2.8	3.5
16	4.6	5.4	4.9	5.6	4.5	8.6	2.8	3.4
23	4.5	5.4	5.2	6.1	4.3	7.9	3.7	3.4
26	3.9	6.0	5.3	4.9	4.2	8.8	4.3	3.2
31	5.5	5.0	4.6	5.3	3.4	8.3	3.6	2.7
34	3.1	3.6	3.9	4.3	3.2	7.4	2.1	--

Table 2. Annual Runoff at Gaging Station in
Santa Clara Canyon

WATER YEAR	ANNUAL RUNOFF	
	(Acre-feet)	(Inches)
1937	3,368	1.8
1938	3,039	1.7
1939	2,630	1.4
1940	2,825	1.5
1941	5,602	3.0
1950	2,460	1.3

Drainage area 34.5 sq. mi.

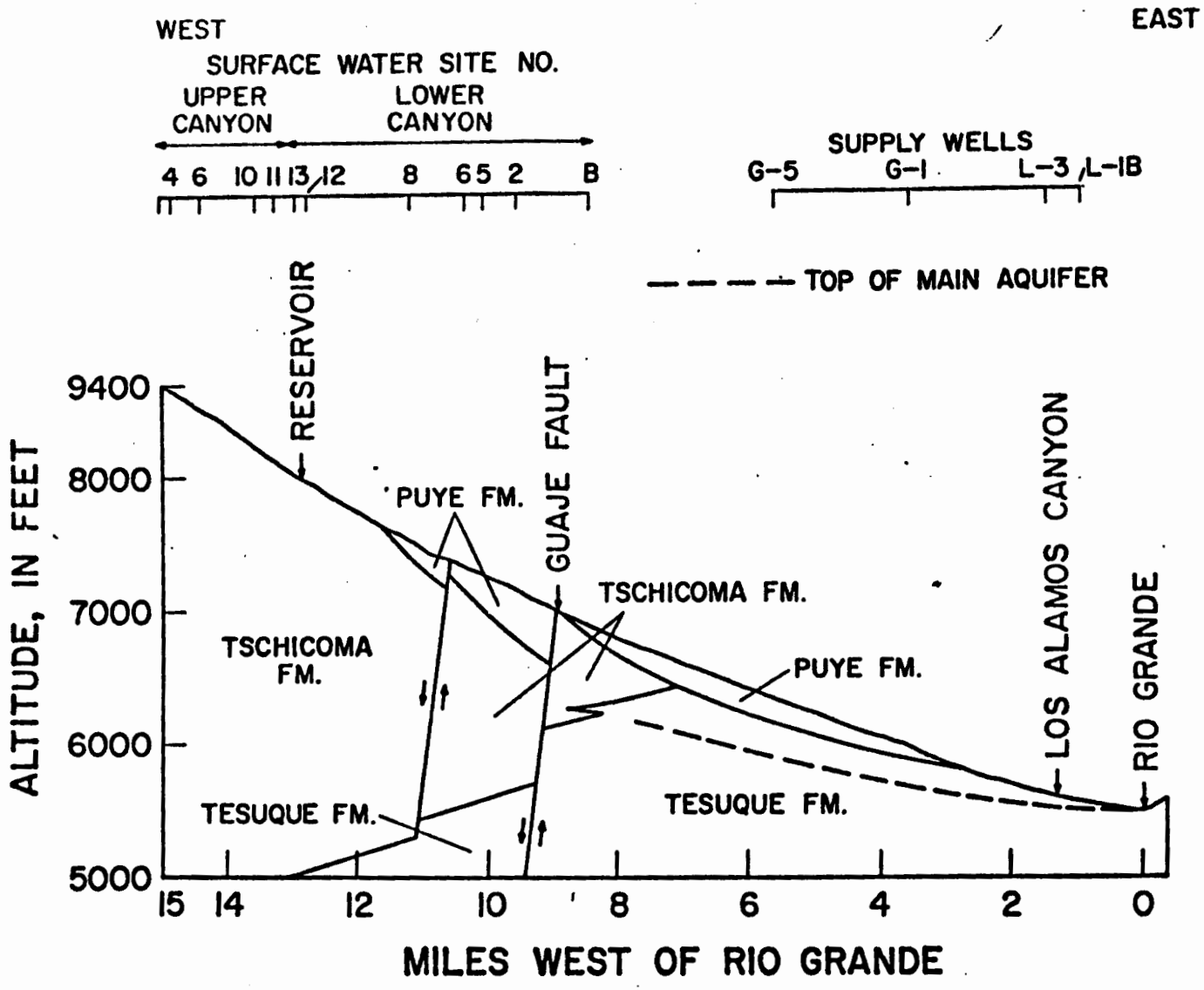

Figure 3. Geologic section of Guaje Canyon showing location of low flow measurements.

Table 3. Guaje Canyon Low Flow Measurements
(cubic feet per second)

	1958	1959				1960		1967	
Site No.	Oct 17	Apr 15	June 3	Sept 1&4	Oct 12-14	May 16-17	June 20-22	May 3a/	June 9a/
4	0.2	0.2	0.3	0.5	0.2	0.4	0.3		
6	0.4	0.4	0.4	1.0	0.4	1.0	0.5		
10	0.4	0.4	0.5	2.0	0.4	1.1	0.5		
11	0.5	0.5	0.5	2.0	0.4	1.0	0.6		
13	0.4	0.6	0.4	2.7	0.5	1.5	0.5	0.34	0.31
Dam b/									
12	0.3	0.7	0		0	0.9	0	0.36	0.34
8	0.3	0.8	0.04		0.01	0.8	0.04	0.29	0.26
6	0.2	0.5	0.02		0	1.0	0.05	0.24	0.21
5	0.03	0.3	0		0	1.0	0	0.17	0.15
2	0.05	0.4	0.04		0.08	1.2	0.1	0.21	0.18
B	0	—	0		0	0.9	0	0	0

a/ Measurements with par~~tial~~shell flume

b/ Water diverted to Los Alamos on all runs except Apr. 15, 1959

about 210 ft/mi where the channel underlain by the Puye to 100 ft/mi where underlain by the Tesuque Formation. The alluvium is thin overlying the Tschicoma and thickens eastward accross the plateau.

North-south trending faults form two small structural basins accross the canyon between mile 3 and 6 (Fig. 3). The channels in these basins are underlain by as much as 20 ft of alluvium and an unknown thickness of volcanic debris of the Puye Formation and are in the area of surface water loss by evapotranspiration and infiltration into the underlying rocks. Return flow occurs in small amounts along the trace of the eastern most fault. This flow rapidly infiltrates into alluvium east of the fault. A test hole drilled near Station 2 in the structural basin encountered about 17 ft of alluvium and was completed at a depth of about 103 ft in the Puye. Both the alluvium below the stream channel and underlying conglomerate appeared to be saturated. The return flow at the fault trace indicates a impermeable boundary formed by the Tschicoma Formation to the eastward movement of water in the alluvium and upper part of the Puye.

A structural feature influencing the movement of water in the main aquifer is the two structural basins formed by faulting in Guaje Canyon. The surface of the main aquifer rises north-westward in the Guaje well field east of the structural basins; however, a change in direction of movement of water indicated by the contours to the south of the structural basins shows that the impermeable rocks of the Tschicoma Formation form a boundary to the eastward movement of water in the main aquifer (Fig. 3, main test of report). Surface water infiltrating into the volcanic debris of the structural basins would move north-south around the Tschicoma Formation. There appears to be a saturated thickness of volcanic debris (about 100 ft) where surface water loss to the alluvium and underlying rock may be a part of direct recharge to the main aquifer.

Guaje Reservoir is contained by a small concrete dam about 25 ft along and 11 ft high with a storage capacity of about 250,000 gal. It is located in a narrow part of the canyon at an altitude of about 8,020 ft. Water can be diverted from the reservoir through a pipe line up to the plateau to Los Alamos. The water was used as a part of the water supply unit 1959. Since that time it has been used periodically for irrigation during the summer. Discharge measurements of the stream above and below the dam (when no water was being diverted) indicated no loss from the reservoir by infiltration into the underlying rocks.

III. LOS ALAMOS CANYON

Los Alamos Canyon has effective drainage area of about 6 sq mi above the reservoir. Base flow in the canyon is maintained by a spring between stations 6 and 9 at an altitude of about 8,000 ft from fractured zone in the Tschicoma Formation (Fig. 4). Base flow above the reservoir is small; however, with snowmelt runoff the excess flow which tops the reservoir will extend across the plateau to near state highway 4 (Table 4). The gradient of the channel underlain by the Tschicoma Formation is about 310 ft/mi on the flanks of the mountains while across the plateau where the channel is underlain by the Bandelier tuff the gradient decreases to about 160 ft/mi (Fig. 5). The channel crosses the Pajarito Fault Zone near Mile 2. Near Mile 7.8 there is some return flow as the alluvium thins where it is underlain basalt interbedded with the Puye Formation. The basalts form a series of falls in the channel between mile 9.5 and 10.5 (Fig. 4). Near mile 10.5 there is a spring in the basalt that discharges about 25 gpm into the stream channel; the flow only moves about one quarter of a mile downstream before infiltrating into the underlying alluvium.

Eight shallow observation wells are drilled through the alluvium into the tuff or basalt between Miles 5 and 9. The stream flow which during the spring tops the reservoir and during heavy summer thunder showing maintain some water

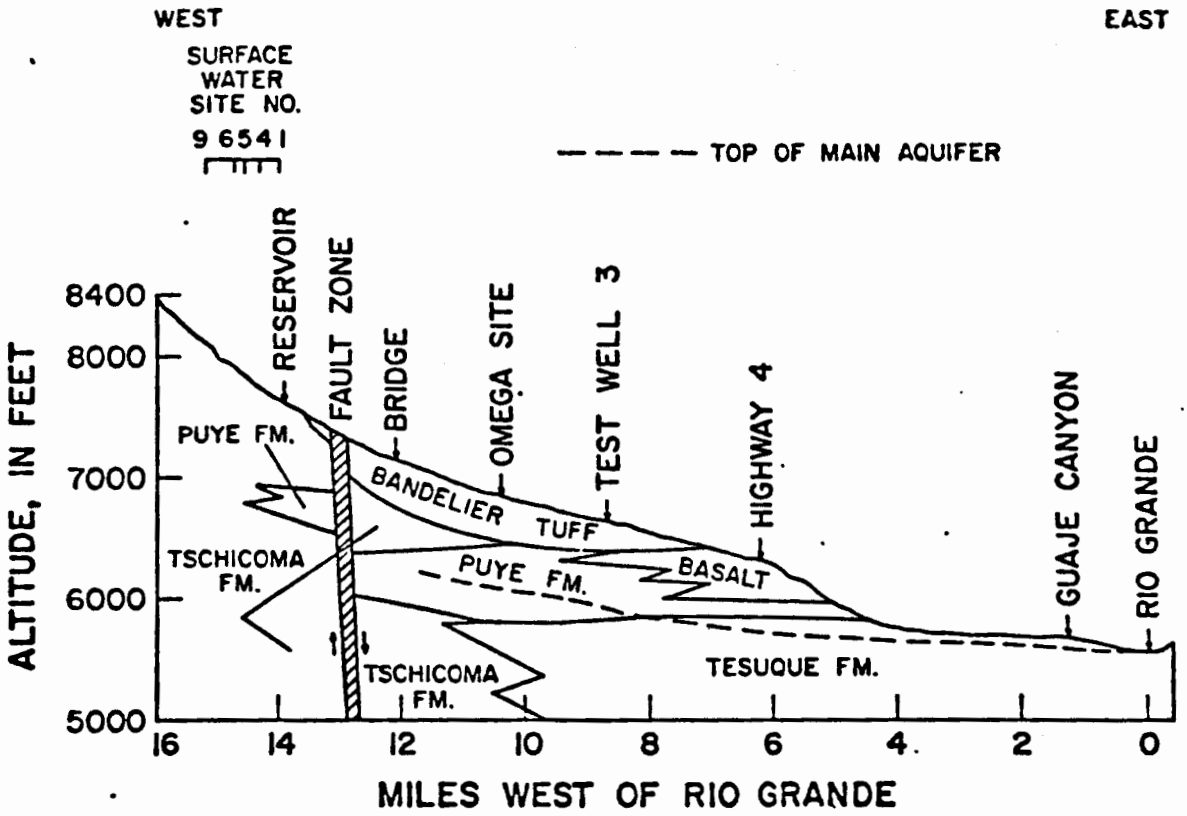

Figure 4. Geologic section of Los Alamos Canyon showing location of low flow measurements.

Table 4. Los Alamos Canyon Low Flow Measurements (cubic feet per second)

	1958		1959		1961
Site No.	May 23	Oct. 30	Apr. 15	May 15	Apr. 27
9	--	0.0	0.0	0.0	--
6	--	0.4	0.3	0.4	--
4	--	0.1	0.4	0.4	--
2	--	0.1	0.4	0.4	--
1	--	0.1	0.5	0.5	--
Dam					
1	--	--	--	--	3.2 a/
2	--	--	--	--	3.2
3	9.0 a/	--	--	--	2.9
4	--	--	--	--	3.1
5	6.3	--	--	--	1.2
6	5.5	--	--	--	0.3

a/ Runoff over dam.

in the alluvium of this stream connected aquifer. The amount of water in the aquifer is seasonal dependent in stream flow. As the water in the alluvium some is lost to evapotranspiration while the rest moves into the tuff and basalt. Stream flow lost into the basalt is the source of recharge for water discharge from the spring near mile 10.5. There is no apparent perched water between the stream connected aquifer in the alluvium and basalt and the main aquifer based on data from a test hole near mile 6.5 which penetrates about 60 ft into the top of the main aquifer.

Los Alamos Reservoir is contained by an earth filled dam that has a storage capacity of about 13 million gal. Water is diverted through a pipe line to Los Alamos. The water was used as a part of the water supply until 1959.

IV. FRIJOLES CANYON

Frijoles Canyon has an effective drainage area of about 9 sq mi on the flanks of the mountains west of the Pajarito Fault Zone (Fig. 5). The canyon differs, however, as it is cut into the Bandelier Tuff on the flanks of the mountains. The slope of the channel west of the fault zone is about 380 ft/mi while to the west it decreases to about 150 ft/mi on the western two thirds of the plateau where the channel is underlain by tuff. In the eastern third the slope of the channel increase to about 390 ft/mi where it is underlain by basalt interbedded with the Puye Formation. The basalt forms two falls which have retarded the down cutting of the canyon to the west.

The base flow in the canyon is maintained by springs emerging from densely welded tuff from an altitude of about 8,430 ft in both the north and west fork of the canyon. The flow increases eastward from seepage from the coalluvium on the canyon walls (Table 5). The increase is to the fault zone, which may be attributed to water moving down along the brecciated zone from higher elevations or to thinning of the tuff and alluvium near the fault. The surface water losses across the plateau appear to be mainly from evapotranspiration.

The alluvium in the canyon appears to be thin as there is no increase in flow between stations 26 and 30 where channel is cut on basalt and conglomerate. The tuff underlying the channel west of the fault zone and western part of the plateau is probably small as the permeability of the tuff is low.

A gaging station was operated near the Pajarito fault zone during water years 1960, 1961, and 1962 (Table 6). The station was moved during the latter part of 1962 to near station 22 in the lower reach of the canyon. Records were obtained for the water year 1964 through 1969. The annaul runoff for the upper gaging station ranged from 2.5 to 2.8 in and from 0.6 to 1.3 in at the lower station for the years of record.

V. CHEMICAL AND RADIOCHEMICAL QUALITY OF WATER

Water samples were collected during the low-flow investigations 1958 and 1960. They were analyzed for bicarbonate, sodium, and chloride ions as well as conductance to determine if changes in quality of the surface flow could be correlated with increase gain or loss of flow in the stream.[6,7] The results of these analyses indicated no particular trends to increased gain or loss with flow as gain or loss were small. The results did show a general increase in these ions and specific conductance down gradient in the stream as ions were adsorbed by the water from the channel material.

Chemical and radiochemical analyses of surface water from the stream in the four canyons are shown on Table 7. The low concentration of ions and total dissolved solids are as one would expect of high mountain streams. The quality of water from a stream connected aquifer in the alluvium in Guaje Canyon is quite simialr to the quality of surface water in the canyon.

The radiochemical quality of the water shows only traces of natural occuring activity. Results of analyses ^{238}Pu and ^{239}Pu in the four smaples were below limits of detection of 0.05 pCi/1.

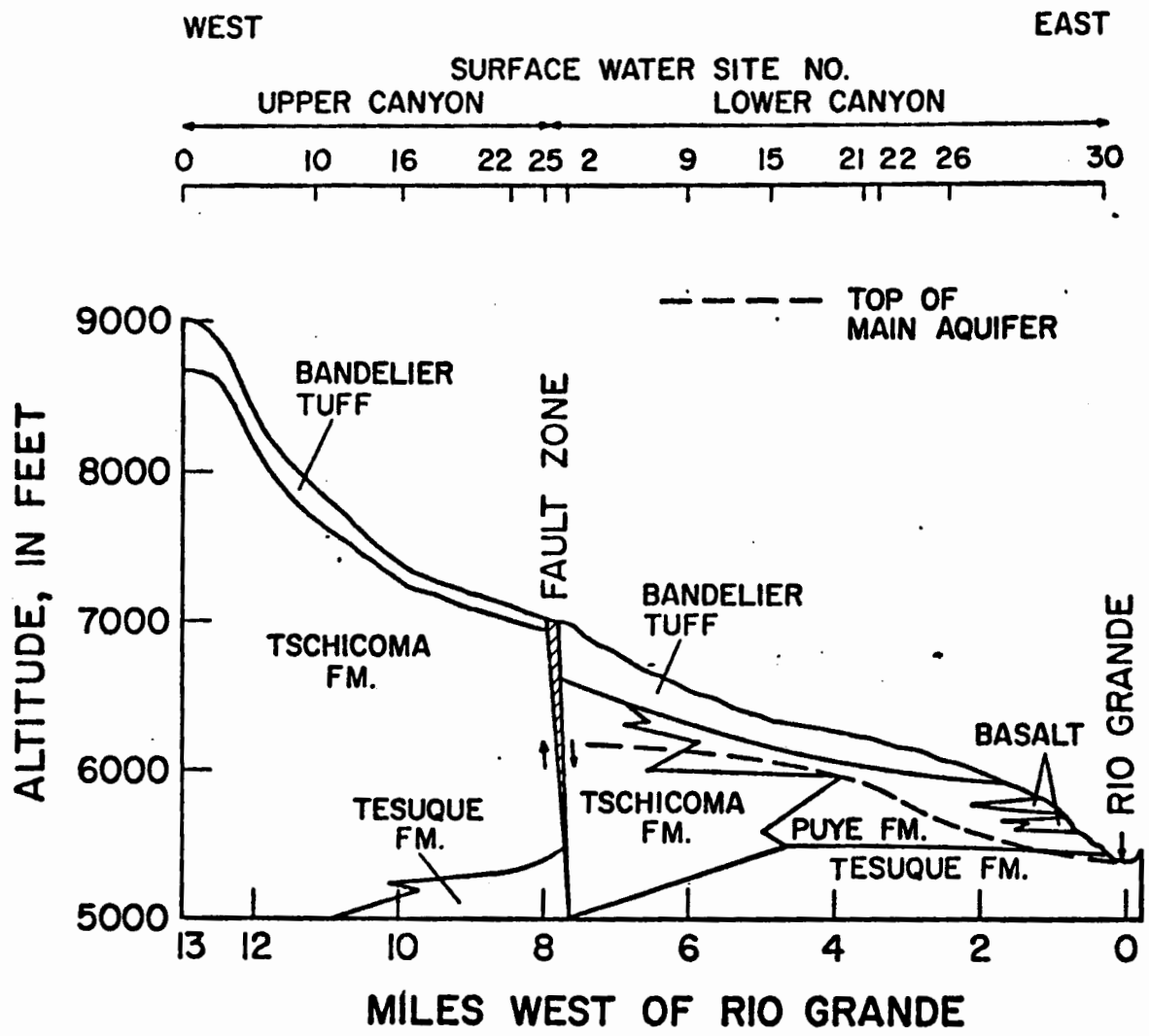

Figure 5. Geologic section of Frijoles Canyon showing location of low flow measurements.

Table 5. Frijoles Canyon Low Flow Measurements (cubic feet per second)

	1958	1959					1960	
Site No.	Oct. 20	Apr. 16	Apr. 29	June 2 & 3	Sept. 2 & 3	Oct. 12 -14	May 16-17	June 20-22
10	--	--	0.9	0.5	0.3	0.1	0.9	0.5
16	--	--	1.4	0.9	0.6	0.6	1.4	0.9
25	--	--	2.1	1.5	1.2	1.2	1.6	1.2
2	1.9	2.7	--	1.6	--	1.4	2.1	1.2
9	1.2	2.6	--	1.5	1.2	1.0	1.5	0.8
15	1.5	2.4	--	1.1	1.2	1.1	--	0.9
21	1.2	2.2	--	1.3	1.2	1.0	1.7	1.0
22	1.3	2.6	--	1.1	1.1	1.0	1.5	0.8
26	1.2	1.6	--	1.1	1.2	0.8	1.4	0.8
30	--	--	--	--	0.7	0.5	1.2	0.3

Table 6. Annual Runoff at Gaging Station in Frijoles Canyon

Water Year	Annual Runoff	
	Acre Feet	Inches
1960	1,332	2.8
1961	1,180	2.5
1962	1,240	2.6
1963	--	
1964	580	0.6
1965	830	0.8
1966	735	0.8
1967	673	0.7
1968	1260	1.3
1969	1040	1.1

Gaging station moved in 1963; drainage area 1960 - 1962, 8.9 sq. mi.; 1964 - 1967, 17.5 sq. mi.

Table 7. Chemical and Radiochemical Quality of surface and ground water in alluvium.

	Santa Clara Station 16	Guaje Station 13	Los Alamos Station 1	Frijoles Station 25	Guaje Canyon near Station 2 (Alluvium)
Date Collected	4-25-69	4-24-69	4-23-69	5-13-69	4-15-70
Chemical (Milligrams per liter)					
Calcium	6	6	6	6	12
Magnesium	.5	3.0	2.0	3.0	5
Sodium	10	9	6	13	7
Carbonate	0	0	0	0	0
Bicarbonate	22	38	26	34	36
Chloride	1	1	2	1	0
Fluoride	0.0	0.0	0.0	0.2	0.4
Nitrate	0.1	0.1	0.1	0.1	0.2
Dissolved Solids	82	120	86	111	111
Total Hardness as C_aCO_3	16	26	21	28	50
Conductance in Micromhos at 25°C	54	75	56	80	80
pH	7.3	7.8	7.3	7.4	7.7
Radiochemical					
Gross Alpha 1/	0.00±0.76	0.00±0.58	0.35±0.89	0.00±0.87	0.0±1.2
Gross Beta 1/	3.1 ±1.9	2.4 ±1.2	2.2 ±1.3	3.9 ±1.3	2.4±1.3
Uranium (Natural) 2/	0.2 ± 0.4	0.5 ±0.4	0.6 ±0.4	0.8 ±0.4	0.0±0.4

1/ Picocuries per liter
2/ Micrograms per liter

VI. SUMMARY

Precipitation on the slopes of the mountains is the source of surface flow found in canyons cut into the Pajarito Plateau. The major loss of stream flow on the plateau is due to evapotranspiration; however, eastward across the plateau surface flow recharges stream connected aquifers in the alluvium. The amount of water in the alluvium is seasonal dependent on stream flow. As the water in the alluvium moves downgradient some infiltrates into the underlying rocks and some is lost to evapotranspiration. An aquifer perched in basalts in Los Alamos Canyon is recharged in part from water in the alluvium.

The main aquifer and stream connected aquifers are separated by a thickness of unsaturated rocks. The slope on the surface of the main aquifer indicates recharge area is on the flanks of the mountains, brecciated zone along major faults that along the western edge of the plateau, and deep canyons cut into the flanks of the mountains and western part of the plateau. The structural basin in Guaje Canyon may be a part of the recharge area to the main aquifer.

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Appendix D

Geologic, Hydrologic and Waste Disposal Reports

(Selected Report no listed in References)

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Chemical Analyses of Surface and Near Surface Ground-Water in the Drainage Areas 1967 through 1972

Source DRAINAGE AREA 4 (ACID-PUEBLO CANYON)	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
Acid Weir	4-17-70	56	14	147	0	60	310	.4	1.3	629	200	280	7.8
"	11-17-70	23	0	50	0	125	20	3	1.3	244	58	248	7.6
"	10-14-71	16	2	41	0	104	52	.9	5.3	278	48	216	7.1
"	4-5-72	29	6	72	0	88	114	1.11	11.8	370	96	480	7.4
"	10-11-72	19	4	100	0	160	32	.7	5.3	240	64	310	7.4
Pueblo 1	4-16-70	20	5	78	0	16	40	3.8	52.8	340	70	400	7.0
"	11-19-70	19	5	84	0	74	39	5.	39.6	407	70	400	7.0
"	10-14-71	16	7	82	0	96	28	6.0	56.8	476	68	400	7.0
"	4-5-72	14	9	75	0	68	48	5.94	51.3	446	72	440	7.1
"	10-11-72	16	2	75	0	96	34	.7	54.6	386	48	420	7.1
Pueblo 2	4-16-70	16	7	78	0	64	50	3.6	37.4	319	70	420	7.9
"	11-19-70	15	6	84	0	94	37	5	83.6	486	63	400	7.2
"	10-15-71	14	5	72	0	96	28	4.6	24.6	330	56	340	7.3
"	4-5-72	18	6	75	0	92	44	5.43	42.9	378	68	420	7.8
"	10-11-72	14	4	71	0	108	34	.7	26.8	346	52	370	7.6
Pueblo 3	4-16-70	20	5	83	0	80	20	4	57.2	376	70	288	6.8
"	11-19-70	18	7	84	0	120	23	5	70.4	377	75	400	7.1
"	10-14-71	13	7	74	0	96	26	4.8	65.6	416	60	380	6.9
"	4-5-72	16	4	75	0	96	34	5.57	41.1	392	56	420	7.3
"	10-11-72	18	3	78	0	156	44	1.1	44.9	378	56	480	7.3
Ham. Bend Sprs.	4-17-70	16	10	78	0	132	30	2.6	4.4	612	80	340	7.8
"	11-19-70	17	4	70	0	100	43	4	22.0	341	57	370	7.2
"	4-5-72	16	7	67	0	120	38	2.59	18.1	370	68	380	7.7
"	10-11-72	19	5	71	0	120	42	.8	19.4	370	68	380	7.6

APPENDIX E

(Continued)

Source DRAINAGE AREA 4 (ACID-PUEBLO CANYON)	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
Acid Weir	4-17-70	56	14	147	0	60	310	.4	1.3	629	200	280	7.8
"	11-17-70	23	0	50	0	125	20	3	1.3	244	58	248	7.6
"	10-14-71	16	2	41	0	104	52	.9	5.3	276	48	216	7.1
"	4-5-72	29	6	72	0	88	114	1.11	41.8	370	96	480	7.4
"	10-11-72	19	4	100	0	160	32	.7	5.3	240	64	310	7.4
Pueblo 1	4-16-70	20	5	78	0	16	40	3.8	52.8	340	70	400	7.0
"	11-19-70	19	5	84	0	74	39	5.	39.6	407	70	400	7.0
"	10-14-71	16	7	82	0	96	28	6.0	56.8	476	68	400	7.0
"	4-5-72	14	9	75	0	68	48	5.94	51.3	446	72	440	7.1
"	10-11-72	16	2	75	0	96	34	.7	54.6	386	48	420	7.1
Pueblo 2	4-16-70	16	7	78	0	64	50	3.6	37.4	317	70	420	7.9
"	11-19-70	15	6	84	0	94	37	5	83.6	486	63	400	7.2
"	10-15-71	14	5	72	0	96	28	4.6	24.6	330	56	340	7.3
"	4-5-72	16	6	75	0	92	44	5.43	42.9	378	68	420	7.8
"	10-11-72	14	4	71	0	108	34	.7	26.8	346	52	370	7.6
Pueblo 3	4-16-70	20	5	83	0	80	20	4	57.2	376	70	288	6.8
"	11-19-70	18	7	84	0	120	23	5	70.4	377	75	400	7.1
"	10-14-71	13	7	74	0	96	26	4.8	65.6	416	60	380	6.9
"	4-5-72	16	4	75	0	96	34	5.57	41.1	392	56	420	7.3
"	10-11-72	18	3	78	0	156	44	1.1	44.9	378	56	480	7.3
Ham. Bend Sprs.	4-17-70	16	10	78	0	132	30	2.6	4.4	612	80	340	7.8
"	11-19-70	17	4	70	0	100	43	4	22.0	341	57	370	7.2
"	4-5-72	16	7	67	0	120	38	2.59	18.1	370	68	380	7.7
"	10-11-72	19	5	71	0	120	42	.8	19.4	370	68	380	7.6

Source DRAINAGE AREA 4 (ACID-PUEBLO CANYON)	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
Acid Weir	4-17-70	56	14	147	0	60	310	.4	1.3	629	200	280	7.8
"	11-17-70	23	0	50	0	125	20	3	1.3	244	58	248	7.6
"	10-14-71	16	2	41	0	104	52	.9	5.3	273	48	216	7.1
"	4-5-72	29	6	72	0	88	114	1.11	11.8	370	96	480	7.4
"	10-11-72	19	4	100	0	160	32	.7	5.3	240	64	310	7.4
Pueblo 1	4-16-70	20	5	78	0	16	40	3.8	52.8	340	70	400	7.0
"	11-19-70	19	5	84	0	74	39	5.	39.6	407	70	400	7.0
"	10-14-71	16	7	82	0	96	28	6.0	56.8	476	68	400	7.0
"	4-5-72	14	9	75	0	68	48	5.94	51.3	446	72	440	7.1
"	10-11-72	16	2	75	0	96	34	.7	54.6	386	48	420	7.1
Pueblo 2	4-16-70	16	7	78	0	64	50	3.6	37.4	319	70	420	7.9
"	11-19-70	15	6	84	0	94	37	5	83.6	486	63	400	7.2
"	10-15-71	14	5	72	0	96	28	4.6	24.6	330	56	360	7.3
"	4-5-72	18	6	75	0	92	44	5.43	42.9	378	68	420	7.8
"	10-11-72	14	4	71	0	108	34	.7	26.8	346	52	370	7.6
Pueblo 3	4-16-70	20	5	83	0	80	20	4	57.2	376	70	288	6.8
"	11-19-70	18	7	84	0	120	23	5	70.4	377	75	400	7.1
"	10-14-71	13	7	74	0	96	26	4.8	65.6	416	60	380	6.9
"	4-5-72	16	4	75	0	96	34	5.57	41.1	392	56	420	7.3
"	10-11-72	18	3	78	0	156	44	1.1	44.9	378	56	480	7.3
Ham. Bend Sprs.	4-17-70	16	10	78	0	132	30	2.6	4.4	612	80	340	7.8
"	11-19-70	17	4	70	0	100	43	4	22.0	341	57	370	7.2
"	4-5-72	16	7	67	0	120	38	2.59	18.1	370	68	380	7.7
"	10-11-72	19	5	71	0	120	42	.8	19.4	370	68	380	7.6

APPENDIX B
(Continued)

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
PO-3B	4-17-70	24	14	29	0	84	30	4.0	1.8	274	120	280	7.0
"	11-19-70	28	7	34	0	86	32	8.8	30.8	341	100	260	7.1
"	10-14-71	21	8	28	0	40	34	4.0	15.0	258	84	240	6.7
"	4-5-72	30	8	26	0	72	32	1.3	13.3	288	108	284	7.3
"	10-11-72	32	11	23	0	100	30	2.2	.4	242	124	270	7.1
PO-4A	4-16-70	20	10	68	0	76	25	3	44	339	90	320	6.9
"	4-5-72	30	1	62	0	84	46	3.6	33.2	368	80	400	7.3
"	10-11-72	13	4	38	0	96	32	.8	23.8	324	48	320	7.3
PO-4B	4-17-70	12	10	66	0	116	30	1.0	5.7	299	70	360	7.0
Test Well TW-1A	5-1-68	32	7	90	0	134	37	1.3	13.2	288	110	420	7.7
"	6-10-68	22	12	91	0	114	29	3.0	17.6	347	104	500	7.4
"	2-25-69	20	11	77	0	132	27	2.6	15	339	94	340	7.3
"	6-1-71	27	7	42	0	80	45	1.8	12.3	262	96	380	7.2
"	9-1-71	29	9	75	0	124	30	2.5	57.2	374	108	420	7.4
Basalt Spring	12-6-67	36	14	25	0	86	15	0.3	13.2	150	210	225	7.4
"	5-1-68	32	10	24	0	86	14	.6	11.4	168	120	260	8.1
"	5-12-69	27	7	24	0	72	13	.3	8.8	212	98	240	8.7
"	8-11-69	27	9	24	0	84	14	.3	10.6	207	106	245	7.9
"	5-7-71	30	11	15	0	92	10	.3	12.3	214	120	240	7.5
"	8-31-71	27	13	15	0	88	12	.9	11.4	225	120	230	7.5
"	2-17-72	30	9	21	0	84	14	.2	12.2	238	112	220	7.9
"	7-31-72	30	10	17	0	88	14	.7	9.7	156	116	240	7.7

Source DRAINAGE AREA 5 (DP CANYON)	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
DPS-1	12-5-67	12	10	400	40	240	190	4	136.4	859	70	1080	10.0
"	4-30-68	20	17	900	500	900	225	12.6	981.2	3,130	120	4400	11.2
"	6-19-68	20	10	680	200	670	265	18	26.4	1698	90	2380	10.2
"	10-4-68	14	9	430	12	260	155	37	13.64	1024	38	1400	8.9
"	5-5-69	16	2	500	190	610	150	22	30.8	1264	50	1640	10.0
"	8-5-69	28	0	250	260	310	35	42	70.4	932	70	1760	11.1
"	6-24-70	8	2	250	90	340	165	10	35.2	982	30	1240	10.1
"	8-14-70	14	5	270	60	310	110	5	123.2	808	55	1200	9.4
"	9-24-70	14	2	140	50	230	65	3	8.8	442	45	620	9.4
"	11-17-70	20	1	295	45	220	220	6	255.2	1194	55	1200	9.8
"	12-1-70	24	2	250	20	220	140	6	176.0	964	70	1140	9.3
"	2-10-71	22	5	300	240	392	125	9.3	123.2	1222	76	1520	11.2
"	5-7-71	19	5	275	68	528	90	2.0	61.6	1098	68	1320	8.9
"	8-16-71	6	3	190	72	356	52	4.2	1.8	648	28	840	9.4
"	11-4-71	24	5	167	0	296	38	3.4	62.9	606	80	760	7.7
"	2-17-72	38	6	240	0	464	178	3.5	137.3	1284	120	1450	7.8
"	7-31-72	42	6	144	0	300	66	2.5	65.6	682	128	840	7.9
"	11-2-72	48	11	235	0	312	166	1.6	66.0	832	164	1100	7.9
DPS-2	12-5-67	16	12	290	0	240	75	8	140.8	669	90	900	8.5
"	4-30-68	20	5	250	38	258	80	8.8	158.4	778	70	1060	9.3
"	6-19-68	20	12	250	0	290	50	10	44.0	714	100	900	9.4
"	5-5-69	16	2	370	100	470	95	13	39.6	976	50	1220	9.6
"	8-5-69	16	10	195	70	220	110	11	13.2	456	80	620	9.9
"	2-16-70	28	10	145	20	350	60	17	48.4	700	110	840	9.0

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
DPS-2	8-14-70	22	2	230	50	320	110	9	48.4	728	65	1000	9.1
"	1-20-71	30	4	68	0	128	15	3.7	35.2	642	92	330	8.2
DPS-3	12-5-67	16	7	310	0	300	85	10	127.6	799	70	960	8.8
"	4-30-68	24	0	290	40	292	95	13.5	198.0	890	60	1260	9.3
"	6-19-68	40	22	360	0	360	80	17	96.8	462	190	1180	8.4
"	5-5-69	16	5	420	100	490	105	18	57.2	514	60	1300	9.6
"	8-5-69	12	10	165	0	220	45	6	4.4	304	70	560	8.4
"	2-16-70	24	12	150	50	350	65	12	96.8	860	110	1000	7.3
"	8-14-70	18	1	250	50	310	120	8	66.0	768	50	1000	7.3
DPS-4	12-5-67	36	10	210	0	240	85	8	74.8	575	130	780	8.3
"	4-29-68	32	10	210	0	218	115	8.5	70.4	658	120	980	8.1
"	9-30-68	25	8	190	0	250	55	3.8	457.6	556	94	720	8.1
"	5-5-69	24	2	230	0	270	80	1	48.4	276	70	760	8.2
"	8-4-69	20	10	165	0	250	40	8	22.0	504	90	560	7.9
"	2-16-70	28	12	94	20	200	40	5	30.8	482	120	520	7.0
"	6-24-70	20	2	103	0	230	45	8	17.6	452	60	540	8.2
"	8-14-70	24	2	109	20	260	40	7	8.3	446	70	600	8.9
"	11-17-70	23	7	105	0	225	55	4	13.2	444	85	540	7.8
"	2-12-71	22	11	115	0	200	45	5.9	39.6	612	100	600	7.5
"	5-7-71	24	4	120	0	220	70	5.6	44.0	536	76	800	8.2
"	8-16-71	27	4	123	0	256	40	4.8	22.4	570	84	680	8.1
"	11-4-71	19	2	94	0	188	30	3.7	21.1	434	56	480	7.4
"	2-16-72	27	2	143	0	188	88	4.2	49.3	564	76	680	7.8
"	7-31-72	21	6	128	0	240	46	4.7	19.4	486	76	600	8.4

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
DPS-4	11-2-72	21	5	100	0	212	40	34	22.0	428	72	520	7.8
DPE-STP	12-5-67	20	12	160	0	280	35	3	0.9	383	100	580	7.5
"	5-5-69	16	4	230	0	344	50	2	1.3	458	55	800	7.4
"	8-5-69	16	7	175	0	190	35	4	13.2	442	70	570	8.2

APPENDIX E

(Continued)

Source DRAINAGE AREA 5 (LOS ALAMOS CANYON	Date of Collection	Chemical Constituents Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
L.A. Reservoir	12-7-67	20	0	8	0	44	3	.2	3.5	79	50	66	7.3
"	4-23-69	6	2	6	0	26	2	.0	.4	86	21	56	7.3
"	5-7-71	10	9	7	0	44	0	0	.4	110	60	70	7.1
"	5-5-72	8	6	7	0	44	2	0	.4	95	44	78	7.0
S.W. at LAO-1	5-5-67	14	2	38	0	60	28	0	.9	179	43	208	7.5
"	8-11-69	16	4	79	0	96	26	.5	2.2	251	58	280	7.7
S.W. at LAO-4.5	12-5-67	28	10	70	0	114	35	.3	13.2	260	110	292	7.6
LAO-C	11-25-70	16	7	28	0	72	21	1	4.4	166	68	160	7.5
"	8-16-71	22	6	37	0	84	45	.1	.4	246	80	300	7.7
"	11-5-71	24	10	40	0	60	46	.2	.9	252	100	280	7.3
"	2-17-72	27	7	60	0	64	92	.03	.9	272	96	350	7.6
"	5-5-72	18	7	37	0	68	56	0	.4	186	72	300	7.1
"	7-31-72	19	5	50	0	100	42	.5	.4	226	68	284	7.4
"	11-2-72	30	10	64	0	84	106	.3	.9	328	116	440	7.2
LAO-1	12-5-67	28	12	125	0	94	35	.7	8.8	357	120	400	7.1
"	4-29-68	24	5	112	0	84	60	.8	3.9	220	80	440	7.4
"	6-19-68	14	0	70	0	78	14	3.0	1.3	258	36	268	7.7
"	10-4-68	14	3	65	0	110	24	15	.9	261	48	300	7.2
"	5-5-69	22	5	79	0	70	64	.1	1.8	309	74	400	7.3
"	8-5-69	18	5	86	0	80	29	.5	2.2	281	64	340	7.3
"	2-16-70	28	12	52	0	100	30	0	5.1	344	120	330	8.1
"	6-24-70	16	5	42	0	76	33	.7	.9	255	60	280	7.5
"	8-13-70	24	7	69	0	100	25	.8	2.6	358	90	400	7.8
"	11-17-70	20	12	52	0	86	14	2	4.4	774	100	320	7.6

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
LAO-1	2-12-71	35	12	64	0	92	25	1.4	7.9	404	138	410	7.3
"	5-7-71	35	11	70	0	92	25	.4	7.0	418	132	500	7.0
"	8-16-71	29	7	80	0	108	33	.3	6.6	430	100	500	7.4
"	11-5-71	24	9	82	0	108	22	.3	6.2	404	96	470	7.5
"	2-17-72	21	8	54	0	84	60	.4	6.1	356	84	420	7.5
"	5-5-72	21	7	68	0	80	70	.9	3.1	338	80	460	7.1
"	7-31-72	35	11	92	0	112	36	.3	7.9	498	132	560	7.6
"	11-2-72	24	8	86	0	124	34	1.0	5.3	394	92	460	7.2
LAO-1.2	5-5-69	17	4	66	0	72	42	0	.9	260	60	300	7.5
"	8-5-69	17	5	74	0	78	35	0	.4	239	64	300	7.4
"	8-13-70	16	6	53	0	90	30	0	2.2	234	65	300	7.1
LAO-1.8	5-5-69	18	4	42	0	58	33	0	.4	182	62	240	7.5
"	8-5-69	19	5	51	0	76	27	0	.4	223	70	252	7.4
LAO-2	12-5-67	24	12	180	0	204	73	7	74.8	594	110	760	7.3
"	4-29-68	12	5	127	0	100	45	14.7	7.0	366	50	430	7.8
"	6-19-68	16	2	41	0	68	25	7	.4	208	48	284	7.5
"	9-30-68	28	5	115	0	210	47	2.4	22	428	90	600	7.5
"	5-5-69	4	1	74	0	86	34	6.0	2.2	267	28	320	7.7
"	8-4-69	20	5	140	0	220	39	4.0	13.2	472	72	500	7.6
"	2-16-70	28	10	100	2	210	45	4	39.6	512	110	540	8.6
"	5-11-70	16	7	81	0	186	45	8	13.2	458	70	450	7.5
"	8-13-70	18	4	109	0	240	40	7	8.8	468	60	540	7.1
"	8-16-71	21	3	102	0	216	39	5.6	19.8	472	64	580	7.6
"	11-14-71	13	5	80	0	156	26	5.6	16.7	390	52	400	7.1

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
LAO-1	2-12-71	35	12	64	0	92	25	1.4	7.9	404	138	410	7.3
"	5-7-71	35	11	70	0	92	25	.4	7.0	418	132	500	7.0
"	8-16-71	29	7	80	0	108	33	.3	6.6	430	100	500	7.4
"	11-5-71	24	9	82	0	108	22	.3	6.2	404	96	470	7.5
"	2-17-72	21	8	54	0	84	60	.4	6.1	356	84	420	7.5
"	5-5-72	21	7	68	0	80	70	.9	3.1	338	80	460	7.1
"	7-31-72	35	11	92	0	112	36	.3	7.9	498	132	560	7.6
"	11-2-72	24	8	86	0	124	34	1.0	5.3	394	92	460	7.2
LAO-1.2	5-5-69	17	4	66	0	72	42	0	.9	260	60	300	7.5
"	8-5-69	17	5	74	0	78	35	0	.4	239	64	300	7.4
"	8-13-70	16	6	53	0	90	30	0	2.2	234	65	300	7.1
LAO-1.8	5-5-69	18	4	42	0	58	33	0	.4	182	62	240	7.5
"	8-5-69	19	5	51	0	76	27	0	.4	223	70	252	7.4
LAO-2	12-5-67	24	12	180	0	204	73	7	74.8	594	110	760	7.3
"	4-29-68	12	5	127	0	100	45	14.7	7.0	366	50	430	7.8
"	6-19-68	16	2	41	0	68	25	7	.4	208	48	284	7.5
"	9-30-68	28	5	115	0	210	47	2.4	22	428	90	600	7.5
"	5-5-69	9	1	74	0	86	34	6.0	2.2	267	28	320	7.7
"	8-4-69	20	5	140	0	220	39	4.0	13.2	472	72	500	7.6
"	2-16-70	28	10	100	2	210	45	4	39.6	512	110	540	8.6
"	5-11-70	16	7	81	0	186	48	8	13.2	458	70	450	7.5
"	8-13-70	18	4	109	0	240	40	7	8.8	468	60	540	7.1
"	8-16-71	21	3	102	0	216	39	5.6	19.8	472	64	580	7.6
"	11-14-71	13	5	80	0	156	26	5.6	16.7	390	52	400	7.1

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
LAO-2	2-17-72	26	4	87	0	180	82	3.9	41.8	520	90	640	7.6
"	7-31-72	19	7	111	0	232	48	4.7	21.6	486	76	600	7.6
"	11-2-72	16	5	92	0	200	36	4.6	15.4	412	60	480	7.4
LAO-3	12-5-67	40	7	152	0	190	53	8	26.0	474	130	540	7.2
"	4-29-67	24	10	127	0	136	60	7	22.4	422	100	560	7.7
"	6-20-68	17	3	82	0	102	30	10	4.0	335	56	380	7.6
"	9-30-68	18	2	85	0	150	30	7	4.4	388	54	430	7.7
"	5-5-69	26	4	127	0	160	70	5	22.0	430	84	580	7.8
"	8-4-69	17	4	102	0	150	37	5	8.8	357	60	420	7.5
"	2-16-70	28	17	80	10	190	35	5	22.0	468	140	460	7.7
"	6-24-70	16	7	81	0	186	48	8	13.2	458	70	520	7.6
"	9-13-70	16	6	100	0	210	35	7	8.8	414	65	540	7.2
"	11-17-70	16	6	74	0	170	52	8	8.8	440	65	430	7.3
"	5-7-71	21	7	86	0	168	50	5.5	22.0	430	80	520	7.3
"	8-16-71	21	4	82	0	180	41	4.7	15.4	427	68	520	7.7
"	11-4-71	19	5	77	0	180	30	5.6	14.1	432	68	460	7.2
"	2-16-72	24	6	114	0	152	78	4.7	28.8	482	84	580	7.6
"	5-5-72	26	9	97	0	196	82	4.1	28.2	508	100	700	7.2
"	7-31-72	26	7	130	0	126	76	4.8	39.2	510	92	680	7.7
"	11-2-72	18	6	92	0	204	38	5.8	13.2	434	68	500	7.4
LAO-4	12-5-67	36	10	117	0	150	45	.4	8.8	338	130	380	7.3
"	4-29-68	20	12	66	0	74	40	1.3	4.4	220	100	300	7.5
"	6-20-68	19	3	66	0	104	27	3	.9	366	60	300	7.5
"	10-4-68	18	6	67	0	130	27	.4	<.1	270	70	340	7.6

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
LAO-4	5-5-69	14	4	60	0	66	37	.6	.9	196	52	264	7.6
"	8-4-69	18	6	70	0	104	32	4.0	.4	238	70	300	7.4
"	8-13-70	22	7	57	0	180	40	2	1.8	284	85	370	7.1
LAO-4.5	5-5-69	16	0	57	0	78	32	0	.9	214	40	260	7.5
"	8-4-69	19	7	59	0	96	31	0	.4	339	76	280	7.3
"	2-16-70	24	10	39	0	100	30	0	1.8	208	100	240	8.2
"	5-11-70	20	7	33	0	88	25	.6	.9	279	80	260	7.6
"	6-24-70	20	7	30	0	80	28	.6	1.3	232	80	260	7.6
"	8-13-70	22	8	46	0	120	40	.2	1.8	242	90	320	7.0
"	11-17-70	24	6	43	0	272	38	1	1.3	362	85	284	8.4
"	2-12-71	22	9	37	0	88	40	.4	4.4	309	94	264	7.2
"	8-16-71	19	6	37	0	88	30	.1	3.1	236	72	270	7.7
"	11-4-71	14	10	35	0	88	20	.1	4.8	296	76	230	7.1
"	2-16-72	32	5	100	0	120	30	.2	.7	262	108	300	7.7
"	5-5-72	18	7	37	0	88	30	.2	.4	204	72	272	7.3
"	7-31-72	14	9	41	0	108	20	.5	.9	180	72	232	7.7
"	11-2-72	19	9	42	0	112	26	.8	.9	244	84	270	7.3
LAO-5	12-5-67	28	10	42	0	62	28	.4	2.6	209	110	240	7.2
"	6-20-68	18	5	45	0	64	24	.8	.4	212	64	240	7.2
"	10-4-68	16	5	44	0	90	26	.8	<.1	235	60	256	7.3
"	5-5-69	14	9	48	0	56	31	0	1.3	185	72	224	7.3
"	8-4-69	17	7	56	0	74	35	0	.4	220	70	260	7.4
LAO-6	10-4-68	18	5	49	0	200	26	.5	<.1	227	64	296	7.4
"	5-5-69	18	5	51	0	66	33	.1	.4	195	64	248	7.3

Source DRAINAGE AREA 6 (SANDIA CANYON)	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
SCS-1	9-5-69	0	0	375	0	340	45	55	<.1	1738	0	1120	7.7
"	1-13-70	40	10	70	0	176	50	1.4	30.8	612	160	560	6.3
"	6-29-70	36	17	77	0	32	55	3	26.4	837	160	600	7.4
"	9-24-70	40	11	164	0	70	60	3	26.4	1028	145	900	7.2
"	3-8-71	38	14	78	0	32	55	2.6	21.1	700	152	660	6.7
"	6-1-71	30	12	90	0	60	40	1.6	22.0	732	124	640	7.0
"	9-14-71	58	34	575	--	—	45	2.6	26.4	4130	284	7000	2.1
"	12-6-71	30	15	81	0	36	54	1.4	17.6	696	136	560	6.7
"	3-3-72	54	15	170	0	144	66	1.8	4.4	754	196	840	7.5
"	6-9-72	4	8	156	0	148	34	179	18.0	1782	43	1300	—
"	8-31-72	32	14	97	0	140	64	19	29.5	760	136	620	7.3
"	11-6-72	22	11	42	0	88	28	9.7	35.2	354	100	380	7.1
SCS-2	9-5-69	40	12	140	0	100	50	6	11.9	680	150	720	7.9
"	1-12-70	40	14	135	0	80	95	1.3	26.4	1016	160	1000	7.1
"	9-24-70	36	7	109	0	100	50	2	17.6	610	120	640	7.6
"	12-21-70	59	15	166	0	80	80	1.9	30.8	930	208	880	7.1
"	3-15-71	39	16	144	0	80	75	3.2	24.2	802	160	840	7.1
"	6-1-71	37	11	173	0	72	65	2.1	17.6	856	138	1060	8.2
"	9-14-71	35	14	115	0	100	50	2.9	13.6	686	144	660	7.8
"	12-6-71	35	11	160	0	84	108	1.6	30.8	834	132	840	7.1
"	3-3-72	27	12	143	0	64	50	1.8	13.5	674	116	700	7.2
"	6-9-72	26	8	94	0	104	72	3.8	4.8	598	96	600	—
"	8-31-72	26	6	85	0	136	44	2.6	3.1	486	88	500	7.8
"	11-6-72	35	11	104	0	136	90	8.8	13.2	606	132	240	7.2
SCO-4	9-5-69	32	7	80	0	140	15	0	1.3	320	60	350	—

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
DRAINAGE AREA 7 (MORTANDAD CANYON)													
GS-1	12-6-67	44	0	127	132	170	5	2.0	8.8	291	110	600	11.2
"	4-30-68	32	2	50	6	102	10	.9	1.8	142	90	240	9.2
"	10-7-68	36	0	61	38	116	15	.7	.4	245	90	288	9.6
"	9-5-69	24	7	43	0	120	5	.0	2.2	244	90	220	9.0
"	6-22-70	44	5	185	44	148	13	1.4	382.8	896	130	860	9.4
"	7-21-70	6	1	430	180	270	21	.4	822.8	1735	20	2000	10.6
"	9-24-70	8	1	147	160	290	10	2	13.2	478	25	700	10.9
"	11-17-70	7	2	385	135	290	22	2	501.6	1358	25	1460	10.9
"	12-1-70	34	2	385	0	130	20	3	545.6	1558	93	1600	8.3
"	12-21-70	21	1	111	0	128	10	1.1	162.8	518	56	500	7.6
"	2-12-71	54	3	84	0	96	15	1.9	79.2	523	148	470	8.0
"	6-2-71	70	2	170	12	376	35	3.5	22.0	716	186	960	8.1
"	9-13-71	54	8	130	0	236	49	2.5	24.2	546	168	680	7.7
"	12-6-71	30	7	59	0	148	36	1.6	1.8	300	104	380	7.6
"	3-3-72	13	5	240	0	312	28	1.3	95.0	706	52	840	7.6
"	6-9-72	21	7	94	0	180	10	1.6	7.9	462	80	520	7.7
"	8-31-72	19	3	116	0	224	10	1.5	70.4	522	60	540	8.0
"	11-6-72	14	4	35	0	104	10	1.0	8.8	224	52	200	7.3
MCS-3.9	12-6-67	20	7	113	0	110	15	1.0	13.2	-	80	310	8.0
"	4-30-68	20	7	110	0	130	15	2.2	11.4	260	80	370	8.3
"	9-23-70	30	4	260	0	210	20	1.0	24.6	662	90	820	8.5
"	3-8-71	42	5	290	36	164	30	1.5	602.8	1308	124	1500	9.1
"	9-13-71	40	6	315	0	328	151	1.9	225.3	1134	124	1360	8.1

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
MCS- 3.9	12-6-71	35	7	235	0	260	132	1.1	79.2	828	116	1040	7.5
"	3-3-72	30	9	285	0	248	54	1.5	248.6	902	112	1080	7.8
"	6-9-72	21	9	200	32	304	48	1.1	435.6	1278	88	1520	7.8
"	8-31-72	34	6	315	0	464	28	1.5	277.2	1242	108	1340	8.2
"	11-6-72	26	3	240	0	356	26	2.0	233.2	970	76	1000	7.7
MCO-3	12-6-67	20	5	74	8	92	8	1.0	8.8	255	70	232	8.7
"	4-30-68	20	7	78	6	100	10	1.7	7.0	206	80	278	9.2
"	10-7-68	18	4	91	10	86	15	1.2	3.1	252	60	340	8.9
"	6-2-69	64	7	320	20	80	5	6	31	820	190	1000	9.1
"	9-5-69	18	6	154	0	160	5	0	10.6	314	70	320	8.5
"	1-12-70	20	7	78	0	100	15	1.1	17.6	320	60	400	8.3
"	6-22-70	28	7	180	52	166	15	1.4	294.8	805	100	860	9.2
"	9-24-70	16	2	260	30	210	25	1.0	171.6	612	50	700	9.3
"	12-21-70	35	2	320	0	168	25	1.3	576.4	1214	96	1200	7.5
"	3-15-71	21	4	340	160	248	20	1.5	629.2	1392	68	1640	10.5
"	6-3-71	24	1	250	36	300	20	5.2	237.6	890	64	1200	9.4
"	9-13-71	30	5	230	16	308	122	2.4	123.2	908	96	1140	8.8
"	12-6-71	30	5	205	0	236	114	1.4	405	666	96	880	7.7
"	3-10-72	18	5	170	12	184	26	2.2	134.6	652	64	600	8.5
"	6-9-72	50	7	310	0	324	38	1.2	426.8	1256	152	1500	7.9
"	8-31-72	51	6	285	0	340	28	1.1	422.4	1270	152	1400	8.0
"	11-2-72	22	5	173	0	296	20	1.7	162.8	730	76	800	8.3

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
MCO-4	12-6-67	24	7	101	0	108	18	.2	13.2	274	90	310	7.5
"	4-30-68	16	12	127	0	220	15	2.1	12.6	284	90	380	7.9
"	10-7-68	14	3	130	0	158	5	1.1	8.8	308	48	410	8.0
"	6-2-69	24	10	120	0	120	5	0	26.4	260	100	430	8.1
"	9-8-69	20	2	115	0	150	5	0	20.7	326	60	350	8.4
"	1-12-70	40	2	97	0	140	15	.8	35.2	406	110	540	7.8
"	5-14-70	28	7	84	0	130	18	.8	61.6	414	100	480	8.0
"	6-23-70	28	10	100	0	146	18	1.0	123.2	502	110	600	7.6
"	9-23-70	40	8	270	0	210	20	0	334.4	750	135	960	7.9
"	12-21-70	48	14	240	0	184	23	1.1	462.0	1050	176	1100	7.5
"	3-8-71	53	14	330	0	160	25	1.0	668.3	1330	188	1500	7.6
"	6-3-71	40	3	240	0	184	30	1.6	492.8	1110	114	1300	7.6
"	9-13-71	40	10	230	0	276	1	1.0	299.2	1106	140	1300	7.7
"	12-6-71	43	7	250	0	252	144	.6	110.0	888	136	1100	7.5
"	3-3-72	34	7	261	0	232	58	1.2	229.7	872	112	1020	7.6
"	6-9-72	37	12	250	0	280	46	1.3	338.8	1044	140	1300	7.5
"	8-31-72	40	6	245	0	340	34	1.7	334.4	1102	124	1260	7.7
"	11-6-72	30	8	240	0	388	32	1.5	286.0	1050	108	1120	7.7
MCO-5	12-6-67	12	7	164	0	162	13	1.0	.9	315	60	350	7.5
"	4-30-68	12	5	140	0	156	20	.5	8.8	300	50	390	7.5
"	10-7-68	7	1.4	115	0	122	10	.2	11.0	314	24	330	7.5
"	6-2-69	12	4	124	0	100	20	0	27.3	252	45	400	8.1
"	9-8-69	12	7	112	0	140	5	0	29.5	310	60	350	8.5

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents: Milligrams per liter										Specific conductance (micromhos at 25°C)	pH
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness		
MCO-5	9-23-70	32	10	131	0	150	10	0	198.0	546	120	660	7.5
"	3-8-71	58	20	250	0	152	25	.4	541.2	1116	228	1260	7.2
"	6-3-71	56	14	190	0	144	20	.2	506.0	1104	196	1320	7.2
"	9-13-71	37	13	185	0	160	50	.6	290.4	822	144	1000	7.5
"	12-6-71	30	8	210	0	172	88	.2	132.0	664	108	820	7.4
"	3-3-72	30	9	200	0	180	86	.1	128.5	634	112	820	7.6
"	6-9-72	34	10	144	0	188	58	.3	162.8	774	124	940	7.3
"	8-31-72	42	14	275	0	264	48	.8	286.0	986	160	1160	7.6
"	11-6-72	30	12	177	0	236	36	.8	277.2	836	124	880	7.4
MCO-6	12-6-67	16	5	141	0	154	3	.5	8.8	334	60	310	7.5
"	4-30-68	12	10	140	0	140	15	1.6	10.1	344	70	380	8.3
"	10-7-68	6	1	99	0	106	5	.2	9.7	281	22	290	7.9
"	6-2-69	12	1	137	0	90	15	0	26.4	296	35	400	7.8
"	9-8-69	24	7	105	0	140	5	0	22.0	328	90	340	8.5
"	1-12-70	20	10	80	0	150	15	.3	26.4	346	80	380	7.8
"	5-14-70	22	7	79	0	122	18	.8	39.6	399	85	460	7.5
"	6-23-70	20	7	77	0	120	15	.8	48.4	388	80	460	7.5
"	9-23-70	28	10	120	0	140	20	.9	171.6	524	110	660	7.1
"	12-22-70	48	10	152	0	156	20	.6	286.0	756	160	800	7.2
"	3-8-71	58	17	210	0	160	25	.6	475.2	1010	212	1180	8.0
"	6-3-71	54	14	230	0	124	25	2.0	576.4	1206	194	1500	7.1
"	9-13-71	37	14	205	0	168	35	.6	365.2	936	148	1080	7.4
"	12-6-71	40	11	260	0	192	96	0	220.0	848	144	1020	7.4

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
MCO-6	3-3-72	32	12	261	8	236	126	.7	134.6	814	128	1060	7.9
"	6-9-72	32	10	174	0	220	72	.5	215.6	886	120	1100	7.3
"	8-31-72	35	13	245	0	256	54	4.0	294.8	986	140	1160	7.6
"	11-6-72	37	12	240	0	276	40	4.0	334.4	976	140	1080	7.5
MCO-7	12-6-67	28	5	121	0	144	18	.3	8.8	323	90	320	7.4
"	4-30-68	20	10	132	0	144	20	.1	7.0	338	90	400	7.8
"	10-7-68	11	2	93	0	130	10	.2	6.2	289	34	320	7.4
"	6-24-69	20	2	128	0	130	20	0	13.2	330	60	400	7.9
"	9-8-69	16	5	115	0	140	10	0	17.6	340	60	350	8.5
"	1-12-70	20	7	67	0	150	10	0	17.6	304	80	320	7.5
"	6-23-70	20	8	103	0	126	15	.3	30.8	412	85	440	7.4
"	9-24-70	14	4	100	0	130	15	.2	57.2	354	60	460	7.3
"	3-8-71	40	15	144	0	132	20	.1	277.2	662	160	750	7.3
"	6-3-71	58	12	155	0	124	25	.6	466.4	950	194	1160	7.0
"	9-13-71	62	19	175	0	120	25	.03	431.2	1036	236	1100	7.2
"	12-6-71	46	16	190	0	136	42	0	325.6	870	186	940	7.2
"	3-3-72	40	11	200	0	172	86	.11	191.8	714	144	900	7.7
"	6-9-72	40	12	136	0	188	90	<.1	158.4	738	148	900	—
"	8-31-72	40	15	178	0	196	66	.5	281.6	788	160	960	7.5
"	11-6-72	42	10	165	0	212	54	.4	237.6	828	144	940	7.3
MCO-7.5	12-6-67	24	12	148	0	150	23	0	17.6	440	110	460	7.4
"	4-30-68	20	12	140	0	162	15	.8	6.6	342	100	420	8.1
"	10-7-68	18	0	106	0	150	5	0	.9	303	46	360	7.2

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
MCO-7.5	6-4-69	16	5	120	0	130	10	0	8.8	576	60	390	7.8
"	9-8-69	28	7	100	0	180	5	0	6.6	332	100	400	8.3
"	1-12-70	16	10	72	0	150	10	.2	17.6	234	80	340	7.4
"	9-23-70	18	5	100	0	140	5	0	48.4	372	65	460	7.3
"	6-3-71	40	11	140	0	140	20	1.3	299.2	834	146	920	7.2
"	9-13-71	56	17	160	0	124	25	.2	404.8	916	208	1000	7.0
"	12-6-71	59	14	200	0	120	25	0	435.6	916	204	1000	7.0
"	3-3-72	48	13	210	0	140	58	.2	315.9	846	172	980	7.6
"	6-9-72	45	9	136	0	172	94	<.1	176.0	742	148	920	—
"	8-31-72	42	14	170	0	184	84	.3	140.8	782	160	960	7.4
"	11-6-72	48	10	150	0	146	70	.3	237.6	800	160	900	7.3
MCO-8	12-6-67	40	12	93	0	134	18	1.0	22.0	339	150	360	7.3
"	4-30-68	32	14	78	0	130	20	.6	176	308	140	400	7.3
"	10-7-68	28	8	60	0	130	5	0	19.8	314	105	340	7.2
"	6-4-69	28	5	83	0	110	20	0	7.5	302	90	360	7.7
"	9-8-69	28	10	85	0	140	10	0	9.7	506	110	370	8.4
"	1-12-70	38	6	47	0	120	10	0	13.2	278	120	320	7.7
"	6-23-70	24	7	50	0	140	10	0	17.6	313	90	340	7.6
"	9-23-70	24	6	50	0	140	10	0	22.0	322	85	360	7.3
"	12-22-70	27	11	55	0	120	13	.5	26.4	328	112	360	7.7
"	6-9-72	61	16	94	0	128	46	<.1	250.8	770	216	820	—
"	8-31-72	54	18	116	0	144	60	.3	184.8	678	212	860	7.4
"	11-6-72	54	17	110	0	144	64	.4	215.6	706	204	780	7.4

APPENDIX E

(Continued)

Source	Date of Collection	Chemical Constituents: Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
DRAINAGE AREA 9 (CAÑADA DEL BUEY)													
TA-46	5-18-67	10	4	41	0	80	5	2.6	.9	183	42	164	8.0
"	5-7-71	16	8	24	0	80	5	.8	1.8	184	72	176	7.3
"	5-3-72	11	4	17	0	60	6	1.0	.4	162	44	136	7.3
DRAINAGE AREA 10 (PAJARITO CANYON)													
TA-18	5-9-67	19	5	44	0	120	10	.3	.4	214	70	232	7.4
"	5-7-71	26	10	16	0	76	20	0	.4	184	104	200	7.0
"	5-3-72	30	9	15	0	68	30	0	17.6	192	112	260	7.1
DRAINAGE AREA 11 (WATER CANYON)													
Amer. Spr.	12-7-67	16	10	8	0	60	3	0	1.8	112	80	100	7.4
"	4-23-69	10	4	10	0	54	3	0	.9	147	39	104	7.4
"	7-30-70	11	5	4	0	56	1	0	.4	—	48	120	7.2
Water Cany.	12-7-67	12	7	8	0	46	5	.1	.9	37	60	70	7.9
"	7-17-69	6	6	9	0	40	0	0	.4	112	40	72	7.5
"	7-30-70	8	2	4	0	42	0	0	7.5	86	30	86	6.9
"	7-29-71	8	6	6	0	76	2	.2	1.3	98	44	64	7.2
"	2-14-72	10	7	6	0	44	2	0	1.3	80	52	74	7.6
"	7-21-72	10	7	8	0	52	<1	.3	.9	38	52	80	7.9
"	12-21-72	8	8	7	0	52	<1	.2	.4	132	52	72	8.0
Near Beta Hole	4-15-70	12	5	19	0	100	8	.9	.9	255	50	280	7.8
"	5-10-71	11	8	25	0	84	5	.2	.9	160	60	150	7.3
"	5-3-72	11	8	27	0	80	14	.1	.4	162	60	192	7.0

Source	Date of Collection	Chemical Constituents: Milligrams per liter										Specific conductance (micromhos at 25°C)	pH
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness		
DRAINAGE AREA 13 (ANCHO CANYON)													
Ancho at RG	9-17-67	14	4	21	0	69	2	0.5	.4	156	50	272	8.4
11	9-25-71	16	5	12	8	76	2	<.1	.4	158	60	140	8.6
DRAINAGE AREA 15 (CHAQUEHUI CANYON)													
Doe Spring	9-17-69	12	4	22	0	64	3	0.2	<.1	153	46	180	8.4
	8-12-71	16	5	21	0	84	4	0.3	0.9	219	60	260	7.4

APPENDIX F

Radiochemical Analyses of Surface and Near Surface Ground Water in Drainage Areas, 1967 through 197

Page 1 of 24

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
Drainage Area 4 (Acid-Pueblo Canyon)												
Acid Weir	4-16-70	<1	346	<0.05	0.07	—	—	—	—	—	3×10^3	<0.4
"	11-19-70	3	105	<.05	.48	—	—	—	—	—	3×10^3	.7
"	10-4-71	6	52	.18	7.98	—	—	—	<300	—	1.6×10^3	2.1
"	4-5-72	1	146	<.05	.11	—	—	—	<350	—	1.5×10^3	2.6
"	10-11-72	3	118	<.05	.72	—	—	—	<350	—	$<1 \times 10^3$	.8
Pueblo 1	4-16-70	<1	17	<.05	<.05	—	—	—	—	—	$<1 \times 10^3$	.5
"	11-19-70	<1	25	<.05	<.05	—	—	—	—	—	$<1 \times 10^3$	1.1
"	10-14-71	<1	7	.07	.08	—	—	—	<300	—	$<1 \times 10^3$	<.4
"	4-5-72	1	8	.16	.13	—	—	—	<350	—	$<1 \times 10^3$	2.6
"	10-11-72	<1	11	.05	<.05	—	—	—	<350	—	$<1 \times 10^3$	.2
Pueblo 2	4-16-70	<1	21	<.05	<.05	—	—	—	—	—	$<1 \times 10^3$	1.3
"	11-19-70	<1	19	<.05	.08	—	—	—	—	—	$<1 \times 10^3$	<.4
"	10-15-71	<1	9	.07	1.02	—	—	—	<300	—	$<1 \times 10^3$	.4
"	4-5-72	1	13	<.05	.09	—	—	—	<350	—	$<1 \times 10^3$	2.6
"	10-11-72	<1	14	<.05	.13	—	—	—	<350	—	$<1 \times 10^3$	<.2
Pueblo 3	4-16-70	<1	10	<.05	<.05	—	—	—	—	—	$<1 \times 10^3$	<.4
"	11-19-70	<1	12	<.05	<.05	—	—	—	—	—	$<1 \times 10^3$	1.0
"	10-14-71	<1	6	.06	<.05	—	—	—	<350	—	$<1 \times 10^3$	<.4
"	4-5-72	2	18	<.05	.11	—	—	—	<350	—	$<1 \times 10^3$	2.6
"	10-11-72	<1	23	.06	<.05	—	—	—	<350	—	$<1 \times 10^3$	.6

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
H.B.Spr.	4-17-70	<1	4	<0.05	<0.05	—	—	—	—	—	<1 X10³	<0.4
"	11-19-70	2	8	<.05	<.05	—	—	—	—	—	<1 X10³	.5
"	4-5-72	3	7	<.05	.09	—	—	—	<350	—	<1 X10³	3.3
"	10-11-72	<1	6	<.05	<.05	—	—	—	<350	—	1.8 X10³	.2
PO-3B	4-16-70	<1	7	<.05	<.05	—	—	—	—	—	15 X10³	<.4
"	11-19-70	<1	8	<.05	<.05	—	—	—	—	—	13 X10³	<.4
"	10-14-71	<1	6	.05	<.05	—	—	—	<300	—	1.4 X10³	<.4
"	4-5-72	2	6	<.05	.08	—	—	—	<350	—	14 X10³	2.0
"	10-11-72	<1	5	.22	.06	—	—	—	<350	—	22 X10³	<.2
PO-4A	4-16-70	<1	5	<.05	<.05	—	—	—	—	—	<1 X10³	1.5
"	4-5-72	2	7	<.05	.08	—	—	—	<350	—	<1 X10³	2.0
"	10-11-72	<1	7	<.05	.05	—	—	—	<350	—	1.3 X10³	<.2
PO-4B	4-16-70	4	10	<.05	<.05	—	—	—	—	—	<1 X10³	.5
Test Well TW-1A	5-1-68	1	10	<0.05	<.05	—	—	—	—	—	<1 X10³	1.7
"	6-10-68	1	14	<.05	<.05	—	—	—	—	—	<1 X10³	.4
"	2-25-69	2	7	<.05	<.05	—	—	—	—	—	<1 X10³	1.3
"	6-1-71	2	189	<.05	<.05	—	—	—	—	—	<1 X10³	.4
"	9-1-71	<1	<1	<.05	<.05	—	—	—	<350	—	<1 X10³	<.4
Basalt Spr.	12-16-67	1	4	<.05	[illegible]	—	—	—	—	—	—	.4
"	5-1-68	1	4	<.05	[illegible]	—	—	—	—	—	—	.4

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
Basalt Spr	5-12-68	<1	4	<0.05	<0.05	—	—	—	—	—	—	1.0
"	8-11-69	<1	3	<.05	<.05	—	—	—	—	—	—	2.3
"	10-20-70	<1	5	<.05	<.05	—	—	—	—	—	—	0.4
"	5-7-71	2	2	<.05	<.05	—	—	—	—	—	—	1.4
"	8-31-71	<1	<1	<.05	<.05	—	—	—	—	—	<1x10³	1.8
"	2-17-72	<1	3	<.05	<.05	—	—	—	<360	—	<1x10³	3.4
"	7-31-72	<1	4	<.05	<.05	—	—	—	<350	—	<1x10³	2.6

LASL-ERDA-OFFICIAL

APPENDIX F

(Continued)

Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
		PICOCURIES PER LITER										µg/l
Drainage Area 5 (DP Canyon)												
DPS-1	12-5-67	63	51,700	3.87	76.1	1.29	<0.15	32.1	34,000	28,600	542×10^3	—
"	4-30-68	7	32,000	1.53	6.57	1.97	<.15	10.1	33,000	23,000	$1,980 \times 10^3$	—
"	4-18-68	79	9,200	9.37	76.6	8.46	.21	104	5,200	11,200	287×10^3	—
"	10-4-68	16	1,720	1.85	3.3	3.13	<.15	54.8	2,000	880	3746×10^3	—
"	5-5-69	23	2,170	8.71	13.1	4.68	<.15	70.3	3,500	1,110	630×10^3	—
"	8-5-69	14	2,850	4.76	11.1	4.20	.32	18.6	5,700	860	500×10^3	—
"	11-4-69	4	1,160	3.25	3.1	1.85	—	9.0	1,270	430	160×10^3	—
"	6-24-70	5	1,240	1.19	2.88	1.18	—	9.2	900	580	490×10^3	—
"	8-14-70	.7	740	.72	1.68	.92	—	13.5	660	410	110×10^3	—
"	9-24-70	12	510	.72	2.31	1.37	<.15	15.1	250	210	62×10^3	—
"	11-17-70	2	1,110	.54	1.53	.85	—	10.1	350	610	750×10^3	—
"	12-1-70	11	2,410	.87	2.62	1.63	<.15	13.7	1,300	1,200	600×10^3	—
"	2-12-71	<1	980	.46	.65	.24	—	.92	1,600	310	190×10^3	—
"	5-7-71	62	2,875	1.45	3.79	1.22	—	—	1,700	—	123×10^3	—
"	8-16-71	16	615	2.75	3.47	.72	<.15	25.6	1,050	837	655×10^3	—
"	11-4-71	9	1,100	.05	.38	.21	<.15	10.4	460	1,002	454×10^3	2.3
"	2-17-72	2	843	<.05	.53	—	—	—	<370	—	$1,120 \times 10^3$	10.1
"	7-31-72	17	3,960	.29	16.2	.55	—	—	<350	—	57×10^3	6.7
"	11-2-72	19	2,604	.63	.31	.11	—	—	<350	—	11.5×10^3	4.4
DPS-2	12-5-67	4	6,690	.38	2.70	.63	<.15	4.40	2,740	5810	660×10^3	—

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
DPS-2	4-30-68	5	6,090	0.36	1.39	0.44	<0.15	9.70	4,220	3,380	536 x10³	–
"	6-18-68	8	3,300	.24	2.80	1.20	<.15	13.7	2,116	1,860	287 x10³	–
"	5-5-69	20	1,360	3.68	4.97	2.19	<.15	33.1	2,260	350	798 x10³	–
"	8-5-69	44	750	.89	2.31	1.21	<.15	81.5	–	–	542 x10³	–
"	2-16-70	12	1,390	2.04	2.33	.97	<.15	42.0	740	620	511 x10³	–
"	8-14-70	4	590	.23	.33	.19	–	10.9	<220	447	250 x10³	–
"	1-20-71	5	640	5.64	.72	.25	–	2.11	523	376	195 x10³	–
DPS-3	12-5-67	5	2,920	.21	.77	<.05	<.15	9.30	310	2,26	427 x10³	–
"	4-30-68	6	130	.24	1.77	1.65	.21	13.9	1,560	3,470	686 x10³	–
"	6-18-68	6	2,920	.61	3.48	1.19	<.15	18.5	1,330	2,890	412 x 10³	–
"	5-5-69	10	840	5.31	5.99	2.81	.19	34.4	1,120	530	876 x10³	–
"	8-5-69	27	1,040	.79	2.46	1.00	<.15	54.1	530	506	140 x10³	–
"	2-16-70	45	1,140	2.60	1.94	1.08	<.15	167	330	530	732 x10³	–
"	8-14-70	3	750	.20	.24	.16	–	10.2	460	376	185 x10³	–
DPS-4	12-5-67	<2	1800	.13	.14	<.05	.35	2.05	<240	632	410 x10³	–
"	4-30-68	<2	730	.07	.05	<.05	<.15	3.56	<240	517	679 x10³	–
"	9-31-68	9	520	.11	.11	.11	.19	3.13	<240	352	273 x10³	–
"	2-5-69	<1	520	<.05	.08	.14	<.15	2.46	<240	271	258 x10³	–
"	5-5-69	3	430	.11	.16	.16	–	4.25	<240	589	702 x10³	–
"	8-5-69	2	510	.19	.83	.37	–	2.12	<240	–	372 x10³	–

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
DPS-4	10-22-69	3	210	1.41	0.99	0.72	–	2.05	<240	–	53X10³	–
	2-16-70	<1	480	<.05	.14	.19	–	2.41	–	–	318X10³	–
	6-24-70	<2	420	.10	.54	.37	–	1.23	<250	–	117X10³	–
	8-14-70	<1	440	.14	.09	.12	–	1.30	<220	200	99X10³	–
	11-17-70	<1	480	.24	.05	.10	–	1.16	<230	270	115X10³	–
	2-12-71	<1	480	.07	<.05	<.05	–	2.80	<230	–	101X10³	–
	5-12-71	9	700	.09	<.05	.10	–	–	–	–	108X10³	–
	8-16-71	<1	4	.13	.16	.07	–	1.15	<340	360	78X10³	–
	11-4-71	3	300	.15	.28	.08	–	1.20	<340	269	126X10³	0.6
	2-16-72	<1	482	<.05	.07	–	–	–	<360	–	308X10³	4.6
	7-31-72	2	598	.08	.46	.26	–	–	<360	–	136X10³	3.6
	11-2-72	5	798	.09	.27	<.05	–	–	<350	–	735X10³	1.8
DPE-STP	12-5-67	3	14	<.05	<.05	–	–	–	–	–	<50X10³	.9
	5-5-69	3	20	<.05	<.05	–	–	–	–	–	<50X10³	.9
	8-5-69	<2	13	<.05	<.05	.07	–	–	–	–	<50X10³	1.3
	2-16-70	3	14	.16	.14	.08	–	–	–	–	8X10³	.6

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
Drainage Area 5 (Los Alamos Canyon)												
Reservoir	12-7-67	<1	6	<0.05	<0.05	—	<0.15	—	—	—	<50X10^3	0.8
"	4-23-69	<1	2	<.05	<.05	—	—	—	—	—	<50X10^3	.6
"	5-7-71	2	2	<.05	<.05	—	—	—	—	—	<50X10^3	.4
"	5-3-72	<1	<1	<.05	<.05	—	—	—	—	—	<1X10^3	1.5
SW at LAO-1	2-5-69	<1	20	<.05	<.05	—	—	—	—	—	—	<.4
"	5-5-69	<1	17	<.05	<.05	—	—	—	—	—	<1X10^3	<.4
"	8-11-69	<1	13	<.05	.06	—	—	—	—	—	—	1.5
SW at LAO-1.5	4-11-69	<1	4	<.05	.05	—	—	—	—	—	<50X10^3	1.5
SW at LAO-1.5	12-5-67	<1	18	<.05	<.05	—	<.15	—	—	—	160X10^3	1.1
LAO-C	11-25-70	<1	4	<.05	<.05	—	—	—	<340	—	<1X10^3	1.2
"	8-16-71	<1	<1	<.05	<.05	—	—	—	<350	—	<1X10^3	<.4
"	11-5-71	<1	<1	<.05	<.05	—	—	—	—	—	<1X10^3	<.4
"	2-17-72	<1	6	<.05	.14	—	—	—	<360	—	<1X10^3	2.3
"	5-5-72	<1	2	.09	<.05	—	—	—	<350	—	<1X10^3	<.4
"	7-31-72	<1	4	<.05	<.05	0.06	—	—	<350	—	<1X10^3	1.8
"	11-2-72	<1	9	<.05	<.05	.19	—	—	<350	—	1.9X10^3	<.4
LAO-1	12-5-67	<1	50	<.05	<.05	—	.19	—	—	—	<50X10^3	1.3
"	4-29-68	3	52	<.05	<.05	—	.19	—	—	—	<50X10^3	<.4
"	6-19-68	<1	20	<.05	<.05	—	<.15	—	—	—	<50X10^3	<.4
"	10-4-68	4	40	<.05	.13	<.05	<.15	.32	<240	—	<50X10^3	—

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LAO-1	5-5-69	<1	26	<0.05	<0.05	–	–	–	–	–	<50x10³	<0.4
"	8-5-69	<1	40	<.05	<.05	–	–	–	–	–	<50x10³	<.4
"	11-4-69	<1	42	<.05	.07	–	–	–	–	–	<50x10³	1.5
"	2-16-70	<1	88	<.05	.05	–	–	–	–	–	4x10³	<.4
"	2-24-70	<1	36	<.05	.05	–	–	–	–	–	6x10³	.9
"	8-13-70	<1	71	<.05	<.05	–	–	–	–	–	11x10³	<.4
"	11-17-70	<1	107	.09	.06	–	–	–	–	–	41x10³	<.4
"	2-12-71	<1	148	<.05	<.05	–	–	–	–	–	24x10³	.8
"	5-7-71	<2	78	.06	.09	–	–	–	–	–	76x10³	1.6
"	8-16-71	<1	93	.05	<.05	–	–	–	<340	–	33x10³	<.4
"	11-4-71	<1	55	.05	.90	–	–	–	<350	–	8.5x10³	<.4
"	2-17-72	<1	76	<.05	.07	–	–	–	<360	–	26x10³	1.3
"	5-5-72	<1	53	.46	<.05	–	–	–	<350	–	11.7x10³	<.2
"	7-13-72	2	222	<.05	.06	<0.05	–	–	<350	–	14.9x10³	1.0
"	11-2-72	2	157	.10	.55	<0.05	–	–	<350	–	25.7x10³	<.2
LAO-1.2	5-5-69	<1	4	<.05	<.05	–	–	–	–	–	<50x10³	.7
"	8-5-69	2	6	<.05	<.05	–	–	–	–	–	19x10³	<.4
"	8-13-70	<1	3	<.05	<.05	–	–	–	–	–	6x10³	<.4
LAO-1.8	5-5-69	<1	4	<.05	<.05	–	–	–	–	–	<50x10³	.9
	8-5-69	2	5	<.05	.05	–	–	–	–	–	<50x10³	1.1

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LAO-2	12-5-67	<1	91	<0.05	0.05	–	0.30	–	–	–	390x10³	2.6
"	4-29-68	3	57	<.05	<.05	–	<.15	–	–	–	115x10³	2.0
"	6-19-68	<1	44	<.05	.06	–	<.15	–	–	–	27x10³	<.4
"	9-31-68	4	77	<.05	.08	<0.05	<.15	–	<250	–	180x10³	2.4
"	8-4-69	2	86	<.05	.43	–	–	–	–	–	210x10³	2.2
"	11-5-69	<1	68	.15	.78	–	–	–	–	–	–	1.0
"	2-16-70	<1	80	<.05	.10	–	–	–	–	–	280x10³	.6
"	5-11-70	<1	73	<.05	.20	–	–	–	<250	–	–	<.4
"	8-13-70	<1	87	<.05	.14	–	–	–	–	–	86x10³	.7
"	8-16-71	<1	106	<.05	.16	–	–	–	<340	–	59x10³	1.0
"	11-4-71	2	95	.25	.51	–	–	–	<340	–	45x10³	.8
"	2-16-72	<1	162	<.05	<.05	–	–	–	<360	–	245x10³	3.6
"	7-31-72	2	239	.12	.05	.12	–	–	<350	–	145x10³	4.2
"	11-2-72	3	163	.11	.46	.12	–	–	<350	–	71x10³	<.2
LAO-3	12-5-67	<1	45	<.05	.05	–	.19	–	–	–	215x10³	4.9
"	4-29-68	2	103	<.05	<.05	–	.28	2.00	<240	–	220x10³	–
"	6-20-68	<1	34	<.05	<.05	–	<.15	–	–	–	70x10³	.7
"	9-30-68	3	45	.11	.15	<.05	.30	–	<240	–	35x10³	.9
"	5-5-69	2	45	<.05	<.05	–	–	–	–	–	505x10³	1.7
"	8-4-69	2	53	<.05	.08	–	–	–	–	–	192x10³	1.0

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LAO-3	2-16-70	3	9	<0.05	<0.05	—	—	—	—	—	46 X 10³	<0.4
"	6-24-70	<1	65	<.05	.07	—	—	—	—	—	97 X 10³	1.6
"	8-13-70	3	75	<.05	.07	—	—	—	—	—	90 X 10³	1.3
"	11-17-70	<1	74	<.05	.12	—	—	—	<230	—	59 X 10³	<.4
"	5-7-71	<1	190	.10	<.05	—	—	—	<350	—	21 X 10³	.4
"	8-16-71	<1	49	.05	.12	—	—	—	<340	—	58 X 10³	1.8
"	11-4-71	4	45	<.05	.08	—	—	—	410	—	34 X 10³	1.4
"	2-16-72	<1	62	<.05	.05	—	—	—	<370	—	191 X 10³	3.6
"	5-5-72	2	69	<.05	<.05	—	—	—	<350	—	226 X 10³	2.8
"	7-31-72	4	109	.25	.41	<0.05	—	—	<350	—	259 X 10³	5.5
"	11-2-72	5	127	<.05	.10	<0.05	—	—	<350	—	71 X 10³	.2
LAO-4	12-5-67	<1	9	<.05	.06	—	—	—	—	—	222 X 10³	.8
"	4-29-68	3	17	<.05	<.05	—	<0.15	—	—	—	71 X 10³	.4
"	6-20-68	<1	10	<.05	.05	—	<.15	—	—	—	59 X 10³	.4
"	10-4-68	11	20	.06	<.05	<.05	<.15	—	<240	—	53 X 10³	1.8
"	5-5-69	<1	9	<.05	<.05	—	—	—	—	—	55 X 10³	<.4
"	8-4-69	<1	10	<.05	<.05	—	—	—	—	—	56 X 10³	.4
"	8-13-70	<1	10	<.05	<.05	—	—	—	—	—	66 X 10³	<.4
LAO-4.5	5-5-69	<1	3	<.05	<.05	—	—	—	—	—	56 X 10³	.9
"	8-4-69	<1	8	<.05	<.05	—	—	—	—	—	41 X 10³	.8

APPENDIX

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LA0-4.5	11-4-69	1	4	<0.05	<0.05	—	—	—	—	—	32 X10³	<0.1
"	2-16-70	2	71	<.05	.19	—	—	—	—	—	173 X10³	.1
"	5-11-70	<1	8	<.05	<.05	—	—	—	—	—	—	<.1
"	6-24-70	<1	6	.11	<.05	—	—	—	—	—	44 X10³	<.1
"	8-13-70	<1	4	<.05	<.05	—	—	—	—	—	54 X10³	<.4
"	11-17-70	2	42	<.05	<.05	—	—	—	—	—	40 X10³	<.4
"	2-12-71	<1	7	<.05	<.05	—	—	—	—	—	34 X10³	1.2
"	8-16-71	<1	1	.09	.11	—	—	—	<340	—	26 X10³	<.4
"	11-4-71	2	6	.06	.18	—	—	—	<350	—	12 X10³	<.4
"	2-16-72	<1	6	<.05	<.05	—	—	—	<360	—	34 X10³	2.6
"	5-5-72	<1	3	.20	.06	—	—	—	<350	—	28 X10³	<.2
"	7-31-72	<1	8	<.05	.08	0.06	—	—	<350	—	18.2 X10³	2.1
"	11-2-72	3	12	<.05	<.05	<.05	—	—	<350	—	32.5 X10³	<.2
LA0-5	12-5-67	<1	4	<.05	<.05	—	—	—	—	—	126 X10³	<.1
"	6-20-68	<1	10	<.05	<.05	—	—	—	—	—	76 X10³	1.8
"	10-4-68	<1	7	<.05	<.05	<.05	<0.15	—	<240	—	76 X10³	.6
"	5-5-69	<1	3	<.05	<.05	—	—	—	—	—	61 X10³	.9
"	8-4-69	<1	7	<.05	<.05	—	—	—	—	—	50 X10³	.6
LA0-6	10-4-68	2	18	.17	.25	—	<.15	—	<240	—	75 X10³	.4
"	5-5-69	<1	7	<.05	<.05	—	—	—	<240	—	51 X10³	<.4

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
LAS-1	7-31-68	1	21	0.05	<0.05	—	—	1.11	<240	—	—	—
"	8-5-68	<1	12	.06	.05	—	—	2.06	<240	—	—	—
"	8-18-68	<1	8	.17	.27	—	—	.74	<240	—	—	—
"	9-22-68	<1	7	<.05	.05	—	—	.94	<240	—	—	—
"	7-23-71	<1	9	<.05	<.05	—	—	—	<300	—	$<1\times10^3$	<0.4
"	7-29-71	<1	3	.12	<.05	—	—	—	<300	—	$<1\times10^3$	.5
"	8-29-71	<1	6	.06	.05	—	—	—	<310	—	$<1\times10^3$	<0.4
LAS-2	8-18-68	<1	220	<.05	.19	—	—	—	<240	—	—	.5
"	7-29-71	<1	131	<.05	<.05	—	—	—	<300	—	4.5×10^3	<.4
"	8-29-71	<1	111	<.05	.07	—	—	—	<300	—	6.8×10^3	.4
LAS-3	7-31-68	2	470	<.05	<.05	—	—	—	<240	—	—	.7
"	8-5-68	<1	320	<.05	.09	—	—	—	<240	—	—	1.1
"	8-18-68	<1	220	<.05	.17	—	—	—	<240	—	—	.7
"	9-22-68	<1	140	<.05	.08	—	—	—	<240	—	—	.09
"	7-23-71	<1	236	<.05	<.05	—	—	—	<300	58.5	11×10^3	<.4
"	7-29-71	<1	116	.07	.09	—	—	—	<308	—	3.2×10^3	<.4
"	8-29-71	<1	224	.08	<.05	—	—	—	<310	<6.0	17.5×10^3	<.4
LAS-4	7-31-68	1	830	.12	.17	—	—	—	<240	—	—	.8

Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
		PICOCURIES PER LITER										µg/l
Drainage Area 6 (Sandia Canyon)												
SCS-1	2-6-69	2	14	<0.05	<0.05	—	—	—	—	—	—	<0.4
"	9-5-69	<1	8	<.05	<.05	—	—	—	—	—	8.7×10^3	3.1
"	1-13-70	<1	12	<.05	.05	—	—	—	—	—	17×10^3	<.4
"	3-19-70	<1	16	<.05	<.05	—	—	—	—	—	127×10^3	<.4
"	6-29-70	<1	17	<.05	<.05	—	—	—	—	—	10×10^3	<.4
"	9-24-70	<1	13	<.05	<.05	—	—	—	—	—	8×10^3	<.4
"	12-22-70	<1	11	<.05	.05	—	—	—	—	—	$<1 \times 10^3$	<.4
"	3-8-71	<1	15	<.05	<.05	—	—	—	—	—	5×10^3	<.4
"	6-1-71	<1	22	<.12	.12	—	—	—	—	—	7×10^3	<.4
"	9-14-71	<1	14	.10	.08	—	—	—	<330	—	2.7×10^3	2.9
"	12-6-71	3	12	<.05	<.05	—	—	—	<140	—	4×10^3	<.4
"	3-3-72	<1	9	<.05	.06	—	—	—	280	—	3×10^3	<.2
"	6-9-72	<1	19	.16	<.05	—	—	—	<160	—	1×10^3	.5
"	8-31-72	<1	22	.13	.09	—	—	—	<105	—	3.9×10^3	3.8
"	11-6-72	3	19	.09	<.05	—	—	—	<50	—	5.5×10^3	<.2
SCS-2	2-6-69	<1	11	<.05	<.05	—	—	—	—	—	—	<.4
"	9-5-69	<1	10	<.05	<.05	—	—	—	—	—	7.1×10^3	.4
"	1-12-70	<1	12	<.05	<.05	—	—	—	—	—	22×10^3	<.4
"	3-19-70	<1	12	<.05	<.05	—	—	—	—	—	26×10^3	<.4
"	9-24-70	<1	8	<.05	<.05	—	—	—	—	—	7×10^3	<.4

APPENDIX F
(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
SCS-2	12-21-70	<1	12	<0.05	<0.05	—	—	—	—	—	23×10^3	<0.4
"	3-15-71	<1	21	<.05	<.05	—	—	—	—	—	10×10^3	<.4
"	6-1-71	<1	17	<.05	<.05	—	—	—	—	—	10×10^3	<.4
"	9-14-71	<1	6	<.05	<.05	—	—	—	<340	—	5.8×10^3	<.4
"	12-6-71	<1	10	<.05	<.05	—	—	—	<140	—	6×10^3	<.4
"	3-3-72	<1	11	<.05	.08	—	—	—	1,960	—	4×10^3	<.2
"	6-9-72	<1	14	.09	.05	—	—	—	<356	—	3.4×10^3	1.8
"	8-31-72	<1	15	.14	.06	.08	—	—	<356	—	4.7×10^3	2.0
"	11-6-72	3	22	<.05	<.05	.05	—	—	<356	—	5.1×10^3	1.1
SCO-4	9-5-69	<1	2	<.05	<.05	—	—	—	—	—	$<4 \times 10^3$	.4

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
Drainage Area 7 (Mortandad Canyon)												
GS-1	12-6-67	<1	343	<0.05	<0.05	—	0.38	0.40	<240	—	<50x10³	—
"	4-30-68	<1	364	.32	.41	—	<.15	.88	<240	—	<50x10³	—
"	10-7-68	<1	219	.59	.47	<0.05	<.15	—	270	—	<50x10³	0.5
"	6-2-69	12	2,206	12.5	13.2	—	<.15	1.18	5,806	169	53x10³	—
"	9-5-69	7	148	.42	.08	—	<.15	—	<240	—	428x10³	.7
"	1-12-70	2	1,560	1.50	.13	.27	—	.95	690	326	304x10³	—
"	3-17-70	14	1,280	7.14	3.63	17.6	<.15	.86	7,740	794	65x10³	—
"	6-22-70	2	1,520	.34	.19	.09	—	5.17	2,780	375	35x10³	—
"	7-21-70	29	904	28.0	18.5	.89	<.15	.58	2,030	32	24x10³	—
"	9-24-70	5	924	3.92	1.78	.38	—	.23	1,420	91	44x10³	—
"	11-17-70	11	1,240	14.0	5.44	2.56	.15	.73	2,380	67	41x10³	—
"	12-1-70	74	19,300	50.7	11.1	2.64	.15	4.56	32,300	1,260	171x10³	—
"	12-21-70	12	811	12.8	3.99	.08	.15	2.96	1,350	134	10x10³	—
"	2-12-71	12	2,340	14.7	2.20	.19	.15	1.80	4,320	489	54x10³	—
"	3-15-71	27	879	32.5	4.21	1.78	.15	3.72	1,670	116	8x10³	—
"	6-3-71	363	2,120	266.0	16.9	18.8	.15	—	8,120	—	17x10³	—
"	9-13-71	15	2,246	11.5	1.77	1.24	.15	9.20	3,410	126	20x10³	—
"	12-6-71	4	434	2.03	.23	.55	—	2.01	260	201	55x10³	—
"	3-3-72	3	714	5.6	.54	—	—	—	—	—	14x10³	3.3
"	6-9-72	18	562	13.3	1.18	—	—	—	1,330	—	45.6x10³	4.4

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
GS-1	8-31-72	12	6.12	12.2	1.73	0.99	—	—	475	—	29.4x10³	5.1
"	11-6-72	15	192	3.6	.43	—	—	—	350	—	4.9x10³	<.2
MCS-3.9	12-6-67	<1	97	<.05	<.05	—	<0.15	—			82x10³	.8
"	4-30-68	<1	230	.18	.29	—	<.15	2.95	<240		<50x10³	—
"	10-7-68	2	156	.05	.15	<.05	<.15	—	<240		—	3.1
"	9-8-69	<1	142	.22	.17	—	—	—	—		6x10³	1.2
"	3-17-70	3	265	.31	.27	—	—	—	—	72	718x10³	1.2
"	9-23-70	<1	353	.39	.29	—	—	—	—	101	63x10³	1.7
"	3-8-71	3	483	1.76	.23	—	—	—	280	—	49x10³	7.5
"	6-3-71	22	1,776	6.64	.59	—	—	—	490	—	31x10³	10.1
"	9-13-71	9	659	2.17	.43	—	<.15	—	380	1	45x10³	5.5
"	12-6-71	7	354	2.05	.09	—	—	—	<140	154	55x10³	9.1
"	3-3-72	2	279	.95	.24	—	—	—	—	—	—	8.3
"	6-9-72	.8	550	1.14	.07	—	—	—	<350	—	69x10³	8.2
"	8-31-72	15	610	16.0	2.67	1.53	—	—	<350	—	95.6x10³	10.8
"	8-6-72	24	651	5.8	.61	.19	—	—	<350	—	44.3x10³	6.4
GS-2	1-18-71	95	312	1.05	5.00	3.02	<0.15	2.03	390	89	28x10³	—
MCO-3	12-6-67	<1	116	<.05	.14	—	<.15	—	<240	—	<50x10³	1.3
"	4-30-68	2	214	.13	.13	—	<.15	2.77	<270	—	<50x10³	—
"	10-7-68	<1	117	.41	.31	<.05	<.15	—	—	—	<50x10³	.7

APPENDIX

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-3	9-8-69	7	9.3	0.27	0.35	—	—	—	—	—	17×10^3	0.9
"	1-12-70	13	150	1.76	.42	—	<0.15	—	<240	—	2910×10^3	1.2
"	3-17-70	2	294	.79	.60	—	—	—	—	32	272×10^3	<.4
"	6-22-70	5	975	.97	.51	—	—	—	—	191	64×10^3	2.3
"	9-24-70	6	345	1.29	.68	0.20	—	—	—	54	16×10^3	2.1
"	12-21-70	3	760	.33	.13	—	—	—	450	—	49×10^3	3.5
"	3-15-71	23	2,170	29.0	3.88	—	<0.15	—	7,010	—	25×10^3	—
"	6-3-71	37	2,630	21.9	1.65	—	—	—	750	—	20×10^3	13.7
"	9-13-71	14	616	5.04	.64	—	<0.15	—	446	412	46×10^3	8.4
"	12-6-71	8	466	1.31	.24	—	—	—	160	215	41×10^3	4.9
"	3-10-72	3	213	6.93	.48	—	—	—	—	—	49×10^3	5.2
"	6-9-72	8	729	1.94	.20	—	—	—	445	—	35.6×10^3	12.4
"	8-31-72	8	875	2.28	.34	.27	—	—	<356	—	54.1×10^3	9.1
"	11-6-72	26	629	4.6	.37	.72	—	—	<350	—	49.7×10^3	3.6
MCO-4	12-6-67	<1	83	<.05	.06	—	<.15	—	—	—	69×10^3	<.4
"	4-30-68	2	137	.21	.56	—	<.15	1.48	<240	—	$<50 \times 10^3$	—
"	10-7-68	<1	28	<.05	.30	<.05	<.15		<240	—	$<50 \times 10^3$	1.2
"	6-2-69	2	122	<.05	<.05	—	—	—	—	—	18×10^3	1.1
"	9-8-69	<1	77	<.05	.17	—	—	—	—	—	18×10^3	<.4
"	11-6-69	7	188	.33	.14	—	—	—	—	—	17×10^3	3.6

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-4	1-12-70	10	76	0.34	0.12	—	<0.15	—	<230	—	2180X10³	1.0
"	3-17-70	4	109	<.05	.10	—	—	—	<230	—	1060X10³	.4
"	5-14-70	<1	114	<.05	.08	—	—	—	—	—	522X10³	1.3
"	6-23-70	<1	125	<.05	<.05	—	—	—	—	—	242X10³	.9
"	9-23-70	2	174	<.05	<.05	—	—	—	—	—	102X10³	1.8
"	12-21-70	<1	248	.12	<.05	—	—	—	<230	—	58X10³	3.5
"	3-8-71	<1	422	.12	.05	—	—	—	<230	—	60X10³	3.7
"	6-3-71	3	512	.15	.05	—	—	—	<350	—	41X10³	3.8
"	9-13-71	2	437	.35	.10	—	—	—	<340	211	41X10³	3.1
"	12-6-71	5	306	.29	.07	—	—	—	<140	147	58X10³	4.0
"	3-3-72	2	219	.89	.26	—		—	—	—	96X10³	12.0
"	6-9-72	9	313	.53	.07	—	—	—	<350	—	45X10³	6.9
"	8-31-72	5	331	.93	.15	<0.05	—	—	<350	—	53X10³	3.1
"	11-6-72	20	509	1.38	.17	.15	—	—	<350	—	63X10³	2.0
MCO-5	12-6-67	2	9	<.05	<.05	—	<.15	—	—	—	222X10³	<.4
"	4-30-68	1	68	.12	.05	—	<.15	—	—	—	83X10³	.6
"	10-7-68	<1	21	.09	1.20	3.81	<.15	—	<240	—	57X10³	<.4
"	6-2-69	<1	29	<.05	.07	—	—	—	—	—	17X10³	.6
"	9-8-69	<1	28	.06	.10	—	—	—	—	—	22X10³	.7
"	3-17-70	7	19	.05	<.05	—	—	—	—	—	141X10³	.4

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-5	9-23-76	<1	30	0.06	<0.05	–	–	–	–	–	303 X 10³	0.6
"	3-8-71	<1	216	<.05	<.05	–	–	–	<220	–	82 X 10³	1.5
"	6-3-71	<1	178	.20	<.05	–	–	–	<356	–	86 X 10³	1.4
"	9-13-71	2	278	<.05	<.05	–	–	–	<346	175	69 X 10³	1.3
"	12-6-71	<1	71	.07	<.05	–	–	–	<146	–	59 X 10³	1.3
"	3-3-72	<1	63	<.05	.08	–	–	–	–	–	79 X 10³	2.1
"	6-9-72	1	52	.24	<.05	–	–	–	<350	–	64 X 10³	3.6
"	8-31-72	2	127	<.05	.08	.08	–	–	<350	–	109 X 10³	3.1
"	11-6-72	6	204	.20	.08	.30	–	–	<350	–	61 X 10³	2.0
MCO-6	12-6-67	2	7	<.05	.09	–	–	–	–	–	144 X 10³	4.6
"	4-30-68	10	31	<.05	.32	–	.54	–	–	–	77 X 10³	1.9
"	10-7-68	1	22	.10	1.26	<.05	.19	–	<246	–	61 X 10³	<.4
"	6-2-69	<1	10	<.05	.05	–	–	–	–	–	18 X 10³	<.4
"	9-8-69	7	26	<.05	.07	–	<.15	–	–	–	17 X 10³	.6
"	1-12-70	11	20	<.05	.05	–	<.15	–	<230	–	27 X 10³	<.4
"	3-17-70	10	21	<.05	<.05	–	<.15	–	–	–	132 X 10³	<.4
"	5-14-70	<1	27	<.05	<.05	–	–	–	–	–	1120 X 10³	2.6
"	6-23-70	<1	40	<.05	<.05	–	–	–	–	–	642 X 10³	1.3
"	9-23-70	1	32	<.05	<.05	–	–	–	–	–	343 X 10³	<.4
"	12-22-70	<1	45	<.05	<.05	–	–	–	–	–	148 X 10³	.7

APPENDIX

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-6	3-8-71	<1	224	<0.05	<0.05	–	–	–	–	–	79 X10³	1.3
"	6-3-71	<1	172	.06	<.05	–	–	–	–	–	61 X10³	.9
"	9-13-71	<1	152	<.05	<.05	–	–	–	<340	–	56 X10³	1.3
"	12-6-71	3	125	<.05	<.05	–	–	–	<140	–	47 X10³	2.4
"	3-3-72	<1	93	<.05	<.05	–	–	–	–	–	51 X10³	3.9
"	6-9-72	1	53	.14	<.05	–	–	–	<350	–	65 X10³	3.1
"	8-31-72	1	160	.06	<.05	0.19	–	–	<350	–	62 X10³	3.9
"	11-6-72	6	222	.09	<.05	.25	–	–	<350	–	61 X10³	3.1
MCO-7	12-6-67	2	2	<.05	.05	–	–	–	–	–	143 X10³	1.5
"	4-30-68	2	8	<.05	.05	–	<0.15	–	–	–	154 X10³	1.2
"	10-7-68	<1	12	<.05	.16	<.05	<.15	–	<240	–	67 X10³	<.4
"	6-24-69	1	11	<.05	.06	–	–	–	–	–	29 X10³	.9
"	9-8-69	8	6	<.05	<.05	–	.19	–	–	–	27 X10³	.4
"	1-12-70	3	20	<.05	<.05	–	–	–	<230	–	22 X10³	.4
"	3-17-70	3	10	<.05	.07	–	–	–	–	–	45 X10³	<.4
"	6-23-70	<1	14	<.05	<.05	–	–	–	–	–	899 X10³	<.4
"	9-23-70	2	23	<.05	<.05	–	–	–	–	–	639 X10³	<.4
"	3-8-71	<1	44	<.05	<.05	–	–	–	<230	–	212 X10³	.8
"	6-3-71	<1	168	<.05	<.05	–	–	–	<350	–	126 X10³	1.2
"	9-13-71	<1	134	.19	<.05	–	–	–	<340	–	89 X10³	<.4

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-7	12-6-71	<1	72	<0.05	<0.05	—	—	—	<140	—	79 X10³	<0.4
"	3-3-72	<1	70	<.05	.07	—	—	—	—	—	66 X10³	1.3
"	6-9-72	<1	45	.19	<.05	—	—	—	<350	—	56 X10³	3.1
"	8-31-72	<1	57	.07	<.05	0.11	—	—	<350	—	51 X10³	2.0
"	11-6-72	3	119	.17	<.05	<.05	—	—	<350	—	72 X10³	.8
MCO-7.5	12-6-67	3	11	<.05	.06	—	<.15	—	—	—	230 X10³	3.6
	4-30-68	4	13	.12	<.05	—	.56	—	—	—	196 X10³	1.2
	10-7-68	<1	5	.09	.59	.10	—	—	<240	—	118 X10³	<.4
	6-4-69	2	9	<.05	<.05	—	—	—	—	—	48 X10³	1.1
	9-8-69	<1	69	.15	.24	—	—	—	—	—	33 X10³	.4
	1-12-70	7	35	.25	.27	—	—	—	<240	—	24 X10³	.4
	3-17-70	8	36	.49	.70	—	—	—	—	—	40 X10³	<.4
	9-23-70	6	26	.22	.14	—	—	—	—	—	177 X10³	<.4
	6-3-71	2	95	.26	<.05	—	—	—	<350	—	183 X10³	1.1
	9-13-71	<1	56	.05	<.05	—	—	—	<340	—	146 X10³	<.4
	12-6-71	<1	54	<.05	<.05	—	—	—	<140	—	104 X10³	.6
	3-3-72	<1	74	<.05	.30	—	—	—	—	—	183 X10³	1.5
	6-9-72	1	52	.08	.06	—	—	—	<350	—	58 X10³	2.9
	8-31-72	<1	56	.09	.05	.37	—	—	<350	—	77 X10³	1.8
	11-6-72	2	99	.08	<.05	1.78	—	—	<350	—	88 X10³	1.1

APPENDIX F

(Continued)

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
MCO-8	12-6-67	<1	10	<0.05	<0.05	—	<0.15	—	—	—	510 X10³	<0.1
	4-30-68	1	11	.05	<.05	—	<.15	—	—	—	360 X10³	2.7
	10-7-68	<1	8	.05	.16	<0.05	—	—	<240	—	238 X10³	.6
	6-4-69	<1	8	<.05	<.05	—	—	—	—	—	136 X10³	1.3
	9-8-69	2	36	<.05	<.05	—	—	—	—	—	134 X10³	<.4
	1-12-70	<1	6	<.05	<.05	—	—	—	<230	—	78 X10³	.4
	3-17-70	<1	15	<.05	<.05	—	—	—	—	—	84 X10³	<.4
	6-23-70	<1	8	<.05	<.05	—	—	—	—	—	49 X10³	1.3
	9-23-70	1	9	.07	<.05	—	—	—	—	—	208 X10³	.4
	12-22-70	<1	8	.06	<.05	—	—	—	<230	—	348 X10³	.4
	6-9-72	1	32	.19	<.05	—	—	—	<350	—	122 X10³	1.5
	8-31-72	<1	48	.06	1.46	0.32	—	—	<350	—	126 X10³	1.1
	11-6-72	1	58	<.05	<.05	.30	—	—	<350	—	141 X10³	<.2

APPENDIX F

(Continued)

Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
		PICOCURIES PER LITER										µg/l
Drainage Area 9 (Canada del Buey)												
Nr. TA-46	3-19-70	1	5	<0.05	<0.05	—	—	—	—	—	41 X10³	0.4
"	5-7-71	2	3	<.05	<.05	—	—	—	—	—	20X10³	.4
"	5-3-72	<1	2	.20	<.05	—	—	—	<350	—	1X10³	1.8
Drainage Area 10 (Pajarito Canyon)												
Nr. TA-18	5-7-71	2	2	<0.05	<0.05	—	—	—	—	—	11X10³	0.4
	5-2-71	<1	3	.10	.06	—	—	—	<350	—	3X10³	3.1
Drainage Area 11 (Water Canyon)												
Am. Spr.	12-7-67	2	7	<0.05	<0.05	—	—	—	—	—	1.7X10³	0.4
"	4-23-69	<1	3	<.05	<.05	—	—	—	—	—	1.5X10³	.5
"	7-30-70	<1	10	<.05	<.05	—	—	—	—	—	<1X10³	.4
Water Canyon	12-7-67	2	6	<.05	<.05	—	—	—	—	—	<1X10³	1.3
"	7-17-69	4	6	<.05	<.05	—	—	—	—	—	<1X10³	2.5
"	7-30-70	2	5	<.05	<.05	—	—	—	—	—	<1X10³	.4
"	7-29-71	<1	<1	<.05	<.05	—	—	—	—	—	<1X10³	<.4
"	2-14-72	<1	3	<.05	<.05	—	—	—	<290	—	<1X10³	.2
"	7-8-72	<1	11	<.05	<.05	—	—	—	<350	—	<1X10³	2.9
"	12-20-72	—	—	<.05	<.05	—	—	—	<358	—	<1X10³	—

APPENDIX
(Continued)

Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
		PICOCURIES PER LITER										µg/l
Drainage Area 11 (Cont.) (Water Canyon)												
Valle Canyon	12-7-67	<1	6	<0.05	<0.05	–	–	–	–	–	–	<0.4
"	4-23-69	<1	2	<.05	<.05	–	–	–	–	–	–	.6
Nr. Bet. Hole	4-15-70	1	2	<.05	<.05	–	–	–	–	–	<1X10³	2.1
"	5-10-71	2	2	<.05	<.05	–	–	–	–	–	<1X10³	.7
"	5-2-72	<1	3	.11	.06	–	–	–	<350	–	<1X10³	1.3
Drainage Area 13 (Ancho Canyon)												
Ancho at RG	9-17-69	<1	2	<0.05	<0.05	–	–	–	–	–	<1X10³	0.7
"	8-25-71	<1	<1	<.05	<.05	–	–	–	<350	–	<1X10³	<.4
Drainage Area 15 (Chaquehui Canyon)												
Doe Spr	9-17-69	<1	1	<0.05	<0.05	–	–	–	–	–	–	0.4
	8-25-71	<1	<1	<0.05	<0.05	–	–	–	–	–	<1X10³	0.6

APPENDIX G

Chemical Analyses of Water from the Main Aquifer

1 of 2 Pages

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
TW-1	2-25-69	30	2	33	0	114	8	<0.1	0.4	188	84	205	7.5
"	5-1-70	32	7	11	0	118	8	.5	<.4	161	110	240	7.5
TW-2	6-10-68	14	3	19	0	62	4	1.0	1.3	—	50	130	7.9
"	2-25-69	8	3	17	0	48	3	<.1	<.4	90	32	160	8.3
"	9-24-70	14	5	11	0	70	5	.5	1.7	198	55	240	7.8
"	6-1-71	13	3	10	0	52	5	.8	<.4	86	44	140	8.3
"	10-11-72	10	2	10	0	40	6	.5	.4	46	32	140	8.5
TW-3	11-13-67	28	31	24	0	82	10	0.8	<0.4	171	200	175	7.5
"	11-17-67	28	10	25	0	100	5	0.4	2.6	191	110	170	7.5
"	6-10-68	19	6	24	0	86	4	0.4	1.3	201	72	180	8.0
"	2-25-69	17	5	22	0	88	5	<.1	.4	124	64	145	8.0
"	9-23-70	20	5	15	0	100	5	<.1	1.7	180	73	160	7.6
"	6-3-71	18	5	15	0	84	5	.6	.4	106	64	160	7.8
"	10-12-72	19	5	19	0	92	6	.5	<.4	94	68	140	7.6
TW-4	10-19-64	10	6	13	0	71	<1	0.4	0.9	163	49	160	8.0
"	6-8-65	10	5	20	0	70	2	<.1	.4	163	45	150	7.9
DT-54	2-15-67	9	3	13	0	58	4	0.9	<0.4	121	36	180	
"	2-15-67	8	3	14	0	60	4	.1	<.4	130	34	180	
"	2-24-69	8	2	19	0	52	3	<.1	.4	120	28	180	
"	9-24-70	12	5	11	0	54	5	.4	.4	101	50	150	

APPENDIX C

(Continued)

2 of 2 Pages

Source	Date of Collection	Chemical Constituents, Milligrams per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness	Specific conductance (micromhos at 25°C)	pH
TW-8	2-14-67	10	4	13	0	64	<1	<0.1	<0.4	141	44	220	7.7
"	1-19-69	11	3	23	0	66	3	<.1	1.7	146	40	220	7.8
DT-9	2-20-69	10	4	19	0	56	3	<0.1	1.3	160	40	180	7.3
"	4-28-70	12	5	10	0	53	5	<.1	<.4	170	50	150	7.8
"	11-5-71	11	5	14	0	72	4	<.1	.9	160	48	200	7.2
DT-10	2-24-69	10	5	19	0	60	3	<.1	0.9	155	44	200	7.7
"	9-30-70	20	7	10	0	62	3	.4	<.4	118	60	150	7.9
RWP-2	12-7-67	32	5	47	0	114	8	0.1	0.9	170	100	200	8.1
RWP-5	12-7-67	28	7	79	0	158	10	0.2	3.1	253	100	270	7.6
Buckman W-1	8-25-64	4	<1	48	14	113	4	0.4	5.3	247	12	240	8.9

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APPENDIX H

Radiochemical Analyses of Water from the Main Aquifer

1 of 2 Pages

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
TW-1	2-29-69	1	<0.05	<0.05	<0.05	–	–	–	–	–	<1X10³	<0.4
"	5-1-70	<1	<.05	<.05	<0.5	–	–	–	–	–	<1X10³	<0.4
TW-2	6-10-68	<1	2	<0.05	<0.05	–	–	–	–	–	–	1.1
"	2-25-69	1	1	<.05	<.05	–	–	–	–	–	–	.4
"	4-7-70	<1	1	<.05	<.05	–	–	–	–	–	<1X10³	.4
"	9-24-70	<1	1	<.05	<.05	–	–	–	–	–	<1X10³	1.0
"	6-1-71	2	2	<.05	<.05	–	–	–	–	–	<1X10³	.4
"	10-12-72	<1	<1	<.05	<.05	–	–	–	<350	–	<1X10³	<.2
TW-3	11-13-67	<1	8	<0.05	<0.05	–	–	–	–	–	–	0.5
"	11-17-67	<1	3	<.05	<.05	–	–	–	–	–	–	2.2
"	6-10-68	<1	3	<.05	<.05	–	–	–	–	–	–	2.4
"	2-25-69	<1	2	<.05	<.05	–	–	–	–	–	–	1.0
"	11-5-69	<1	2	<.05	<.05	–	–	–	–	–	–	.4
"	4-7-70	4	4	<.05	<.05	–	–	–	–	–	<1X10³	.4
"	9-23-70	<1	1	<.05	<.05	–	–	–	–	–	<1X10³	2.0
"	6-3-71	2	4	<.05	<.05	–	–	–	–	–	<1X10³	.4
"	10-12-71	<1	2	<.05	<.05	–	–	–	<350	–	<1X10³	<.4
"												

APPENDIX
(Continued)

2 of 3 pages

		PICOCURIES PER LITER										µg/l
Source	Date Collected	Gross Alpha	Gross Beta	^{238}Pu	^{239}Pu	^{241}Am	^{226}Ra	^{234}U	^{137}Cs	^{90}Sr	^{3}H	^{238}U
DT-5A	2-24-69	<1	3	<0.05	<0.05	–	–	–	–	–	–	0.4
"	4-24-70	3	2	<.05	<.05	–	–	–	–	–	<1X10^{-3}	0.4
TW-8	1-10-69	<1	2	<0.05	<0.05	–	–	–	–	–	–	0.5
"	1-14-69	2	3	<.05	<.05	–	–	–	–	–	–	.4
"	2-14-69	<1	1	<.05	<.05	–	–	–	–	–	–	.4
"	11-6-69	<1	3	<.05	<.05	–	–	–	–	–	–	.4
DT-9	2-20-69	<1	1	<0.05	<0.05	–	–	–	–	–	–	0.8
"	4-28-70	<1	2	<.05	<.05	–	–	–	–	–	<1X10^{3}	.9
DT-10	2-24-69	<1	1	<0.05	<0.05	–	–	–	–	–	–	1.2
"	4-30-70	<1	2	<.05	<.05	–	–	–	–	–	<1X10^{3}	.4
RWP-2	12-7-67	4	10	<0.05	<0.05	–	–	–	–	–	–	1.8
RWP-5	12-7-67	2	14	<0.05	<0.05	–	–	–	–	–	–	2.3