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The hydrology and the chemical and radiochemical quality of surface and ground water at Los Alamos, New Mexico, January 1956 through June 1957

By

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The hydrology and the chemical and radiochemical quality of surface and ground water at Los Alamos, New Mexico, January 1956 through June 1957

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Abstract

This is the third of a series of reports by the U.S. Geological Survey describing the hydrologic conditions in the Los Alamos area. Los Alamos, in north-central New Mexico, is on the Pajarito Plateau, which is formed by the Bandelier Tuff of Pleistocene age.

Several holes 11 to 73 feet deep were drilled in lines across the middle and lower reaches of Pueblo Canyon near where the canyon cuts the conglomerate underlying the tuff. Water perched in the alluvium and within the conglomerate was sampled.

Acid and Pueblo Canyons were the major disposal areas for radioactive waste effluents for the period of investigation. Most of the radioactivity in liquid wastes discharged into Acid Canyon were retained in deposits within one foot of the upper surface of the alluvium and did not reach Pueblo Canyon. The chemical quality of surface and ground water improved downgradient in Acid Canyon and Pueblo Canyons due to dilution by storm runoff and by treated sewage effluents.

Streamflow in Pueblo Canyon and changes in water levels in the wells that tap the alluvium in Pueblo Canyon are the result of precipitation and discharges from the waste and sewage treatment plants in Acid and Pueblo Canyons. Changes in water levels and the quality of water from the shallow test wells indicate hydraulic interconnection between the aquifers and surface water in Pueblo Canyon. The slight decline of water levels in the deep test wells may be due to a long-term trend.

The quality of water from the supply wells in Los Alamos and Guaje Canyons is good, and water levels are relatively stable. There are slight differences in the quality of water from different wells. The concentration of dissolved solids in samples of water from springs downgradient from the Acid-Pueblo Canyon disposal system was somewhat higher than in samples from other springs in the Los Alamos area.

Introduction

This report describes hydrologic conditions in the Los Alamos area during the period January 1956 through June 1957. It is the third of a series describing the effects of waste disposal at Los Alamos (Abrahams, 1962), and was prepared in cooperation with the Atomic Energy Commission and the University of California, Los Alamos Scientific Laboratory. Many of the data and conclusions herein are similar to those described for the period 1949 through December 1955 (Weir and others, 1962).

The general geology and hydrology of the Los Alamos area have been described by Griggs (1964). The physiographic features of the Los Alamos area are shown in figure 1, and the stratigraphic relations

Figure 1.--Generalized map of the physiographic features of the Jemez Mountain region, New Mexico, and sampling stations on the Rio Grande and Rio Chama.

of rocks in the Los Alamos area are shown in figure 2.

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

Observation wells in Pueblo Canyon were drilled by the Geological Survey. Samples of water from wells and from the Rio Grande and Rio Chama were collected by the Geological Survey and chemical and radiochemical analyses of water samples and the radiological analyses of samples of alluvium were made by the H-7 group of the Health Division of the Los Alamos Scientific Laboratory, under the direction of C. W. Christenson, Group Leader.

The chemical quality of water is expressed in parts per million (ppm), and the radiological quality is expressed in disintegrations per minute per liter (d/m/l). The chemical and radiochemical data are on file at the Los Alamos Scientific Laboratory at Los Alamos.

The major disposal area for liquid waste during the period was Acid and Pueblo Canyons. The floor of Acid Canyon below the waste treatment plant slopes at a rate of about 200 feet in half a mile and is cut into the Tshirege (upper) Member of the Bandelier Tuff of Pleistocene age. The alluvium beneath the stream channel in the canyon is 2 to 5 feet wide and generally about 1 to 3 feet thick. The alluvium in the upper one-third of the stream channel deposits is a pebbly sand, and in the lower two-thirds is a gravelly sand.

The floor of Pueblo Canyon below the Pueblo Sewage Plant (fig. 3)

Figure 3.--Map of Los Alamos area, showing locations of sampling stations.

slopes at an average rate of about 135 feet per mile for a distance of 6 miles. In the upper half of this reach the canyon is cut into the Otowi (middle) Member and the Guaje (lower) Member of the Bandelier Tuff and slopes at a rate of about 170 feet per mile. The alluvium beneath the streambed in this part of the canyon is generally about 2 to 8 feet thick, although in some places it may be 15 feet thick. The lower part of the canyon is cut into the Puye Conglomerate which underlies the Bandelier Tuff. The alluvium in the lower part of the canyon ranges from 1 to 20 feet in thickness.

Installation of wells

Drive points and dug wells were first installed in the Acid and Pueblo Canyons disposal area in 1954 (Weir and others, 1962). Changes in the types of wells were made during 1956. Better samples were collected, and some sandpoints destroyed in the spring of 1956 and others destroyed in a flash flood in August 1956 were replaced. Well PC-6, PC-7, and PC-9 were replaced with dug wells in July and August 1956.

Wells were drilled in Pueblo Canyon during the period April 10-18, 1956 in the reach that extends from a point about one-quarter of a mile upstream to a point about three-quarters of a mile downstream from Hamilton Bend, to improve the observation well network and better to define geologic and hydrologic conditions in the canyon. The wells were located along lines numbered 1 to 4 from east to west across Pueblo Canyon. Individual wells are designated by the letters "PO". The south well in each line is given only the line number. Letters A, B, C, etc., are added, in sequence from south to north, to the line number for other wells along the line. Holes PO-5 and PO-6 are not on lines. The locations of the wells are shown in figure 4, and a brief description of them is given in table 1.

Figure 4.--Map showing location of observation wells, and the geology of the lower part of Pueblo Canyon.

Results of investigations

Geologic interpretations

Formation samples collected at the time the holes were drilled near Hamilton Bend Spring showed that some penetrated the base of the Bandelier Tuff, but that most of them penetrated the Puye Conglomerate. The stream channel in Pueblo Canyon cuts through the Bandelier and into the Puye just west of Hamilton Bend.

Three general types of deposits that occur within the upper part of the Puye Conglomerate are traversed by the stream between the tuff exposure above Hamilton Bend and the basalt outcrop at the bridge in sec. 21, T. 19 N., R. 7 E. The southern edge of an alluvial fan is exposed in the southwestern part of section 17 and the northeastern part of section 18 (fig. 4). The fan is composed of fanglomerate which exhibits a chaotic distribution of angular blocks, boulders, and gravel in a matrix of sand. Some blocks are as much as 5 feet across. A deposit of a second type laps onto this fan from the west side. This deposit consists of a water-laid material containing lenses of boulders, gravel, and sand in a matrix of silt-sized reworked tuff. A deposit of a third type crops out at the head of Capture Canyon and between the fan and the confluence of Pueblo and Los Alamos Canyons. This third deposit is a water-laid silt or reworked tuff in which the rock and tuff particles are no more than half and inch in diameter. The finer material on the west, south, and east sides of the fan were apparently derived by erosion of the fan itself.

The deposit of silt or reworked tuff is covered by thin alluvium from a point upstream from Hamilton Bend to about 200 feet upstream from well PO-1A, where it appears to dip eastward beneath the alluvium. It is at a depth of about $17\frac{1}{2}$ feet at well PO-1A, and about 22 feet at well PO-1C. The top of this deposit is about 3 feet beneath the level of the alluvium in the streambed at well PO-2, which suggests that it has a southward dip at this site.

Water was found in all holes in lines 3 and 4 when the holes were drilled, but wells PO-3 and PO-3A became dry within several days and well PO-4 became dry within several months. Water that was perched on the layer of silt at wells PO-3 and PO-4 apparently entered the holes during drilling and subsequently drained out of the wells after the screens had been sealed off from the overlying saturated zone by the backfill around the casing. The water in well PO-4 had been perched within the Puye as a result of recharge from the stream. Water-yielding zones were not tapped by wells in lines 1 and 2, except for a thin lens perched in the layer of silt in the alluvium at well PO-2A.

Wells PO-3B, PO-4A, and PO-4B were finished within the Puye. The lenses of water-saturated deposits supplying wells PO-4A and PO-4B are probably recharged by the Pueblo stream. The source of water tapped by well PO-3B is not known, but the water level is about 20 feet beneath the level of Hamilton Bend Spring, located about 300 feet to the east. The silt layer which perches the water at Hamilton Bend Spring may also perch the water in the aquifer tapped by well PO-4B.

About 40 gallons of water were poured into well PO-3B on May 8, 1957 to study the hydraulic characteristics of the perched-water aquifer tapped by the well. A water-level rise of 4.65 feet was observed three minutes after injection stopped, and the pre-injection level of the water was reached about 9 hours later. This indicates that the transmissibility of the zone is very low, and the yield of the well would be small if it were pumped.

Water levels in wells

Ground-water levels and streamflow in Acid and Pueblo Canyons are affected by precipitation, discharge from the two sewage-treatment plants in Pueblo Canyon, and discharge from the waste-treatment plant in Acid Canyon. The precipitation (fig. 5) during 1956 was 11.53 inches, which was 6.80 inches below normal and near the record low. Discharge from the sewage-treatment plants (table 2) decreased substantially during spring and summer. The discharge from the waste-treatment plant in Acid Canyon was about 3 to 4 million gallons per month during the period of this study.

Streamflow from snowmelt in Pueblo Canyon was at a maximum rate during late May 1956, at which time it extended downstream to the Otowi Seep area. The eastern extent of this surface flow receded from east of well PO-1A by May 23, 1956 to near Hamilton Bend by May 24, and to a point between wells PC-4 and PC-5 by June 7.

In 1957 the streamflow was greater and more sustained than in 1956 due to increased precipitation, and bodies of perched water formed in the alluvium along line 4 and in the middle part of Pueblo Canyon. Only a small amount of flow reached the lower part of Pueblo Canyon. Streamflow measurements in March, April, and May 1957 (table 3) shows that some water was lost to the alluvium above the outfall from the sewage-treatment plant and near well PO-4A. The increase in streamflow between well PC-2 and well PC-3 probably reflects discharge from the plant in Acid Canyon. The increase in flow at well PC-5 reflects the discharge from the sewage-treatment plant. A crest or maximum water level at well PO-4A was reached in early April and at well PC-10 in June.

The depth to water in the observation wells PC-10 and the shallow test wells are shown in figure 5. The water levels as shown for well PO-4A

Figure 5.--Depth to water in observation wells, well PC-10, and the shallow test wells in Pueblo Canyon, and precipitation data, January 1956 through June 1957.

during 1956 and for well PO-1A during 1957 may represent water trapped in the casings rather than levels of water in the aquifer. The sharp decline of the water level in well PO-4 may reflect the decrease in discharge from the sewage-treatment plants in the Spring and the end of streamflow from snowmelt in the high country to the west. During an attempt to deepen well PO-4, the casing was broken off about 13 feet below land surface so the recovery of the water level in 1957 could not be determined. However, water levels in well PO-4A and PC-10 responded in 1957 to increased streamflow due to snowmelt, increased precipitation, and continued high discharge from the Central Sewage Plant.

The rate and direction of water movement from these perched water bodies is not known. The water in the perched zone along line 4 apparently does not recharge the water-bearing zone tapped by well PO-3B, as evidenced by the relatively stable water level in the well. The source of recharge to the water-bearing bed at well PO-3B, however, may be further west in the canyon. Some water probably moves eastward on a perching layer and is the source for Hamilton Bend Spring, a small seep near well PC-8 and Otowi Seep. Surface outlets for the body of water perched in the alluvium near PC-10 have not been found. Springs or seeps do not exist in Bayo or Capture Canyons to the northeast, and water flow in the lower part of Pueblo Canyon occurs only during spring runoff or during summer storms. However, the water may move through joints in the underlying basalt and recharge the perched zone supplying test well 1A.

Changes of water levels in test wells TW-1A and TW-2A (fig. 5) indicate that the wells are to some degree hydraulically connected to the Pueblo stream, however, water-level fluctuations caused by periodic pumping of these wells for water samples makes interpretation of the data difficult. The water level in well TW-2A continued to rise slowly from early 1953 through June 1957, even though the precipitation during the previous 10 years was substantially less than normal. This rise was probably due to the general increase of waste discharge into upper Pueblo Canyon during this same period. This constant flow of surface water infiltrated the upper reaches of Pueblo Canyon instead of moving downstream as did the high stream flows during spring runoff and floodflow. Since 1950, the water level in well TW-1A has declined slowly except for a short period in 1952 following heavier than normal precipitation. The water levels respond to recharge in about 4 to 6 months at well TW-2A and about 1 to 2 months at well TW-1A, although the data indicating such time logs are inconclusive.

The depth to water in deep test wells TW-1, TW-2, and TW-3 increased slightly during the period of this report (fig. 6). The water level in

Figure 6.--Depth to water in deep test wells 1, 2, and 3, Layne-Western well, and Stop Sign well, January 1956 through June 1957.

well TW-4 could not be measured because of obstructions in the well. This decline of water levels may be a long term trend; it could not be correlated with local streamflow data.

Chemical and radiochemical quality of water and radioactivity of streambed materials

Water samples from Acid Canyon usually were collected in early morning before discharge from the waste-treatment plant was started. Water was pumped from each well, for 5 to 10 minutes before a sample was collected so that the sample would be representative of water in the alluvium.

The pH of the waste water discharged into Acid Canyon generally was high, and the pH of water samples from Acid Canyon was commonly above 10. The range of the pH in the samples from Acid Canyon was 6.7 to 11.8, although the pH of about 90 percent were more than 9. On 8 of the 11 sampling dates the pH decreased downstream (table 4), so that the pH of water entering Pueblo Canyon from Acid Canyon was about 8.0 to 8.5.

The concentration of calcium was slightly less in samples from well AC-4 than in samples from well AC-3, possibly indicating some uptake of the calcium ions in the clays around well AC-4. A slight decrease in the concentration of the sodium in Pueblo Canyon was evident. The concentrations of calcium and sodium were less in Pueblo Canyon than in Acid Canyon, because of dilution in Pueblo Canyon.

The pH, the average concentration of anions, and the dissolved solids were less in Pueblo Canyon (table 4) than in Acid Canyon, primarily due to dilution in Pueblo Canyon. Water from well PC-2 contained higher concentrations of dissolved solids than water from well PC-1, less dissolved solids than water from Acid Canyon. The average concentrations decreased downstream from well PC-2. The concentration of flouride ranged from 4 to 9 ppm in about 60 percent of the samples from Acid Canyon, but decreased to 1.5 ppm in the lower part of Pueblo Canyon. The concentration of chloride ranged from 20 to 50 ppm in about 85 percent of the samples from Acid Canyon, and only slightly less in Pueblo Canyon. The concentration of nitrate was less than 60 ppm in about 90 percent of the samples from Acid Canyon and significantly lower in Pueblo Canyon. The relatively high concentration of nitrates in samples from well PC-4 persisted in most samples. The concentration of dissolved solids did not decrease significantly in Pueblo Canyon, and the concentration was slightly above the recommended limit for drinking water of 500 ppm at wells PC-9 and PC-10 in the lower part of Pueblo Canyon. The dissolved solids content of two samples collected in 1956 from Otowi Seep near well PC-9, average 2,730 ppm. The chemical quality of water in samples from Hamilton Bend Spring in Pueblo Canyon was similar to that from the Pueblo Canyon wells.

Changes in the amount of uranium, and gross alpha radioactivity in Acid Canyon (table 4A and 4B) was not significant. The amounts were appreciably larger through October 1956 than after that date. The larger amounts before October 1956 may have been due to adsorption of the materials on fine particles of clay, which were not filtered out before analysis. When samples were centrifuged and filtered, after October 1956, the average values decreased considerably.

The largest amounts of uranium and gross alpha and beta radiation, 614 d/m/l, 664 d/m/l, and 6,800 d/m/l, respectively, were found in samples collected on June 26, 1956 during discharge from the treatment plant. The sample containing the 6,800 d/m/l of gross beta activity was surface water at Pueblo 1 near PC-2; samples from several wells in Acid Canyon and PC-2 also had relatively high counts of gross beta on that date (table 4A).

The average concentrations of radioactive constituents in water samples collected at most stations in Acid and Pueblo Canyons were significantly higher through October 1956 than those collected after this date (tables 4A and 4B). The average gross beta radiation was abnormally high, due primarily to the samples collected on June 26, 1956. The concentration of the radioactive constituents tended to decrease downstream but without a regular pattern. Analyses for plutonium were made; however, method of analyses were not reliable so the results are not included in this report.

The radioactivity of alluvial samples from Acid and Pueblo Canyons is shown in tables 5 and 5A. Most of the activity in Acid Canyon was retained in the upper 24 inches of the alluvium. The gross alpha activity of samples collected near AC-2 and AC-3 were considerably less than that of samples collected to a depth of 18 inches on July 29, 1954 (Weir, and others, 1962). Radioactive materials adsorbed on fine particles of alluvium could have been replaced by ion exchange, or the fine particles could have been washed downstream by stormflow. The concentrations of most of the radioactive materials decreased downstream between stations near wells AC-3 and AC-5.

The concentrations of radioactive materials in Pueblo Canyon were significantly lower than those in Acid Canyon, indicating that most of the radioactive material was retained in Acid Canyon. However, the gross beta activity of samples collected at the station near well PC-1 was relatively high.

The concentration of most of the chemical constituents in samples of water from observation wells PO-1A, PO-3, and PO-4 (table 6) was about the same or slightly less than the concentration in samples of surface water.

The chemical quality of water from shallow test wells TW-2A and TW-1A is summarized in table 7. The quality of water from well TW-2A varied somewhat during the period of sampling, but trends were not apparent except for slight increases of calcium and magnesium after August 1956. The large range in concentrations of fluoride, uranium, and dissolved solids, as shown with examples below, probably reflect changes in their concentration in surface water and indicate a hydraulic connection with surface flow:

Date	Fluoride (parts per million)	Dissolved solids (parts per million)	Uranium (disintegrations per minute per liter)
January 25, 1956	3.0	236	0
February 20, 1956	.8	134	80

Significant trends or changes in the concentrations of the chemical constituents in water samples from TW-1A were not evident until May 11, 1956, at which time a spike of 200 pounds of sodium chloride was added to the well in an attempt to determine whether or not the chloride would appear at Basalt Spring. About 1,500 to 2,000 gallons of water were added to the well with the sodium chloride. During a prolonged dry period in 1956, the well was pumped dry once each month by pumping 3 gpm for 30 minutes. The concentrations of dissolved solids in water from the well decreased rapidly from June to September 1956. The decrease probably was caused by the addition of 1,000 gallons of water to the well in July and by water entering the lower part of Pueblo Canyon during flash floods in August.

The constituents in water from test well TW-1A that were affected by the spike and the degree to which they were affected are shown below:

Date	Calcium	Magnesium	Sodium	Chloride	Dissolved solids
	(parts per million)				
5-11-56	15	7	-	13	230
6- 5-56	148	37	-	9,026	15,309
6-26-56	383	118	-	-	18,318
9- 6-56	246	72	860	2,255	4,718
4-10-57	110	43	290	671	1,297
6-11-57	63	47	180	324	758

Table 7 shows that the concentrations of all chemical constituents in samples collected from well TW-1 were relatively low before well TW-1A was spiked with sodium chloride. The concentrations of calcium, magnesium, chloride, and dissolved solids in samples from well TW-1 rose to 158, 34, 710, and 1,450 ppm, respectively, during the 11 day period after well TW-1A was spiked on May 22, 1956. Some water probably moved from well TW-1A to TW-1 within a few days after the spike. This suggests that some of the water added to well TW-1A during the spike moved laterally about 25 feet up the piezometric gradient within the bed supplying water to well TW-1A and thendown the outside of the casing of well TW-1. A thousand gallons of water was added to well TW-1A in July to check for a leak, but at that time no evidence of leakage was found.

Increases in the concentration of calcium and magnesium in water from test well TW-3 may indicate some recharge from a surface source. The calcium increased from a relatively constant 20 ppm through September 1956 to 29 ppm in April 1957. The magnesium increased irregularly from 6 ppm to 19 ppm between June 1956 and March 1957, but the sample collected in April 1957 contained 64 ppm. Test well TW-2 was not sampled during the period of this report because the pump was inoperative.

The chemical quality of water from the supply wells in Guaje Canyon was relatively stable, and the range of the concentrations of the constituents was small. However, the concentration of calcium and magenesium decreased downgradient (eastward) (table 8) and the concentrations of calcium in wells G-2, G-3, and G-5 and magnesium in wells G-3, G-4, and G-5 increased with time. Significant trends of the radiochemical quality of the water were not noted.

The quality of water from wells in the Los Alamos Canyon field was similar to that from wells in the Guaje Canyon field. Contamination of the water was not evident. Variations in the quality of water in relation to the depths of the wells are shown in table 8. Wells LA-1, LA-2, and LA-3 are about 870 feet deep and wells LA-4, LA-5, and LA-6 are about 1,700 feet deep. The average concentration of fluoride and dissolved solids increased downgradient to the east in samples from both groups of wells, whereas the concentration of the calcium decreased downgradient. The chloride and dissolved solids (except LA-6) increased eastward from LA-4 to LA-1. Significant trends of the radiochemical quality of the water were not noted.

The highest concentrations and the greatest range in concentration of chemical constituents were in samples from well LA-6, near the middle of the Los Alamos Canyon well field. The ranges in concentrations were 20 to 163 ppm of sodium, 2.0 to 5.0 ppm of fluoride, 191 to 461 ppm of dissolved solids, in water from this well. The concentration of dissolved solids and the temperature correlated to some extent with the length of pumping time.

Chemical and radiochemical analyses of water samples from outside the Acid Canyon-Pueblo Canyon disposal system are shown in table 9. The water was relatively good except for a few isolated cases.

The water levels and the quality of water in the Layne-Western well probably reflect changes in the quality and amounts of water in the stream in Guaje Canyon. Water samples were not collected from the Stop Sign well, but the changes in the water level (fig. 6) apparently reflect pumpage from the supply wells in the lower part of Los Alamos Canyon.

The concentration of several of the chemical constituents in samples from Basalt, Los Alamos, and Indian Springs, all of which are down-gradient from the Acid and Pueblo Canyon disposal system, are slightly higher than samples from Ancho and Doe Springs, which are isolated from areas of liquid disposal. The relatively high gross beta count of 130 d/m/l in a sample of stormflow collected in Los Alamos Canyon on August 2, 1956 may have been related to a gross beta count of 150 d/m/l in a sample collected from Indian Spring on October 4, 1956.

The quality of the water in samples from the Rio Grande, collected weekly or monthly and composited, indicates that the water in the Rio Grande is not contaminated from the Los Alamos area.

Summary

Conclusions reached in this report are similar to those stated in the report by Weir and others (1962) which described investigations made in the Los Alamos area during the period 1949 through 1955.

Changes in the water levels and the quality of water in the shallow test wells indicate a possible hydraulic connection between the shallow water-bearing beds and the surface water in Pueblo Canyon. The water level changes in well TW-2A, in the upper part of Pueblo Canyon, appears to respond in 4 to 6 months to recharge from surface-water flow, whereas the water-level changes in well TW-1A appears to respond within about 2 months to changes in the amount of water in the stream.

The water levels in the deep test wells declined slightly during the period of investigation, possibly due to a long-term downward trend in precipitation. The quality of the water from the deep test wells was relatively constant, although the concentration of some ions in samples from well TW-3 increased slightly.

The concentrations of dissolved solids and radioactive materials in water samples from wells that tap the alluvium in Pueblo Canyon were significantly lower than those in samples from Acid Canyon, probably due to ion exchange and sediment uptake of radiochemical materials in Acid Canyon and to dilution by more surface flow in Pueblo Canyon. The concentrations generally decreased down the canyons.

Most of the radioactivity was retained or concentrated, within the upper 12 inches of the alluvium of Acid Canyon; only minor amounts were concentrated in the alluvium of Pueblo Canyon.

A spike of sodium chloride introduced into shallow test well TW-1A caused a temporary increase in the concentration of chemical constituents in samples from deep well TW-1, probably the result of leakage downward around the casing of well TW-1. Effects of the spike downgradient from well TW-1A were not found.

The concentration of dissolved solids in samples from the supply wells in Guaje Canyon and Los Alamos Canyon well fields was low and relatively stable. The concentrations of calcium and magnesium decreased downgradient in the Guaje Canyon well field and increased slightly with time in some of the wells. The quality of the water from the three shallower (about 870 feet deep) wells and from the three deeper (about 1,700 feet deep) wells in Los Alamos Canyon well field changed slightly down the valley in each group. The quality of water from well LA-6, near the middle of the Los Alamos Canyon well field, varied slightly with pumping time.

The concentration of the ions in samples from springs downgradient from the Acid Canyon-Pueblo Canyon disposal system was somewhat higher than in samples from other springs in the Los Alamos area. Apparently no contamination was added to the Rio Grande from the discharge at Los Alamos, except possibly during summer floodflow.

References

Abrahams, J. H., Jr., 1963, Geologic and hydrologic environment of radioactive waste disposal sites at Los Alamos, New Mexico: 35 p., 3 figs., 4 tables.

Griggs, R. L., 1964, Geology and ground-water resources of the Los Alamos area, New Mexico: U.S. Geol. Survey Water-Supply Paper 1753, 107 p., 1 pl., 20 figs.

Weir, J. E., Jr., Abrahams, J. H., Jr., Waldon, J. F., and Purtymun, W. D., 1962, The hydrology and the chemical and radiochemical quality of surface and ground water at Los Alamos, New Mexico, 1949-55: U.S. Geol. Survey Admin. Rept., 40 p., 10 figs., 15 tables.

Table 3.--Streamflow in Pueblo Canyon, March, April, and May, 1957

(Measurements made with Pigmy current meter, in gallons per minute)

Station	March 13	April 11	May 9
Near well PC-2	380	280	270
Halfway between well PC-2 and well PC-3	-	240	-
Near well PC-3	-	260	440
One-quarter of the way between well PC-3 and well PC-4	410	200	420
Halfway between well PC-3 and well PC-4	540	210	560
Three-quarters of the way between well PC-3 and well PC-4	-	220	400
Near well PC-4	250 [a]	120	400
Above outfall of Central Sewage Plant near well PC-5	-	15	280
Below outfall of Central Sewage Plant near well PC-5	-	160	600
Halfway between well PC-5 below outfall of Central Sewage Plant and well PC-6	-	140	430
Near well PC-6	380	150	360
Halfway between well PC-6 and well PC-7	-	100	260
Three-quarters of the way between well PC-6 and well PC-7	-	20	-
Near well PC-7	-	-	240
Near well PO-4A	260	-	120

[a] Caught up with flow front.

Table 2.--Effluent from sewage treatment plants discharged into Pueblo Canyon.

(Flow, in gallons, as metered by the Zia Company)

Month	Pueblo Sewage Plant	Central Sewage Plant
January 1956	9,369,000	1,285,600
February 1956	9,279,700	1,240,840
March 1956	[illegible],644,000	1,113,721
April 1956	888,880 a/	672,231
May 1956	966,300 a/	19,992
June 1956	851,430 a/	27,489
July 1956	930,700 a/	460,649
August 1956	925,210 a/	1,586,032
September 1956	751,140 a/	1,791,217
October 1956	1,022,510 a/	1,920,065
November 1956	9,575,300	2,071,671
December 1956	9,219,500	2,856,357
January 1957	10,261,800	2,836,365
February 1957	9,307,600	3,034,575
March 1957	10,135,200	2,540,650
April 1957	1,004,820 a/	2,531,487

a/ About 90 percent of the total ~~flow~~ effluent pumped to the golf course for irrigation.

Table 1.--Records of observation wells - Continued

Well number	Elevation above sea level		Well depth (feet)	Depth to water below measuring point (feet)	Length and type of casing	Remarks
	Measuring point (feet)	Land surface (feet)				
PO-4A	6,530.31	6,524.3	43	18	21 feet of 5-inch pipe	Tuff or silt layer 5-10 feet interbedded clay and sand to 29 feet; hard drilling in consolidated material to 43 feet.
PO-4B	6,544.07	6,541.6	57	24	27 feet of 1½-inch pipe and sandpoint	Gravelly sand to 25 feet; interbedded gravel, clay, and sand to 42 feet; hard drilling in consolidated material to 57 feet. Alluvium wet 25-32 feet. Water began dropping after casing was installed.
PO-5	-	6,475(?)	22	dry	uncased	Sand, silt, and gravel to 18 feet; hard drilling in consolidated material at 22 feet.
PO-6	-	6,520(?)	18	dry	uncased	Tuff to 13 feet, gravelly sand to 18 feet.

Table 1.--Records of observation wells - Continued

Well number	Elevation above sea level		Well depth (feet)	Depth to water below measuring point (feet)	Length and type of casing	Remarks
	Measuring point (feet)	Land surface (feet)				
PO-3A	-	6,512.7	33	10 feet	22 feet of 1½-inch pipe and sandpoint	Gravelly sand to 11 feet; interbedded gravel, clay, and sand layers to 33 feet. Water gone several days after drillin
PO-3B	6,522.41	6,520.4	73	50½ feet	59 feet of 2-inch plastic pipe	Silty sand to 20 feet; gravel 20-21½ feet; moist to wet clay or silt 21½-26 feet; interbedded gravel, clay, and sand layers to 57 feet; hard drilling in consolidated silty material 57-73 feet.
PO-4	6,526.75	6,524.2	43	25.8	27 feet of 1½-inch pipe and sandpoint	Tuff or silt layer 5-10 feet interbedded gravel, clay, and sand layers to 40 feet hard drilling in consolidated material at bottom. Alluvium wet 18-25 feet. Water level began dropping after casing was installed

Table 1.--Records of observation wells - Continued

Well number	Elevation above sea level		Well depth (feet)	Depth to water below measuring point (feet)	Length and type of casing	Remarks
	Measuring point (feet)	Land surface (feet)				
PO-1D	-	6,450(?)	23	dry	uncased	Bottomed in dry sand and gravel at 23 feet.
PO-2	-	6,478.4	30	dry	uncased	Tuff to 13 feet; gravelly to 29 feet; hard drilling in consolidated material at 30 feet.
PO-2A	-	6,452.0	14½	2 feet	8 feet of 1¼-inch pipe and sandpoint	Silty from 2-12 feet, gravel 12-14; hard material at 14½ feet. Broke teeth on drill bit.
PO-2B	-	6,455.5	11	dry	uncased	Silty to 10 feet; hard material at 11 feet. Broke teeth on drill bit.
PO-3	-	6,498.9	27	1½ feet	12 feet of 1¼-inch pipe and sandpoint	Silt, sand, and gravel to 18 feet; interbedded gravel, clay, and sand layers to 27 feet. Water gone several days after drilling.

Table 1.--Records of observation wells drilled April 10 to 18, 1956, in Pueblo Canyon

Well number	Elevation above sea level		Well depth (feet)	Depth to water below measuring point (feet)	Length and type of casing	Remarks
	Measuring point (feet)	Land surface (feet)				
PO-1	-	-	16	dry	uncased	Dry silt, sand and gravel to 15 feet, boulders at 16 feet.
PO-1A	6,443.05	6,442.0	36	dry	18 feet of 5-inch pipe	Dry to moist clay, sand, and gravel to 17½ feet; gravelly silt to 36 feet. Augers dropped several tenths of a foot at 36 feet. Teeth on drill bit broken on hard material or boulders.
PO-1B	-	6,441.2	18	dry	uncased	Dry to moist clay, sand, and gravel to 15 feet; dry silt and gravel to 18 feet; hard drilling in consolidated silty material at 18 feet.
PO-1C	-	6,446.5	22	dry	uncased	Dry to moist clay, sand, and gravel to 15 feet; hard drilling in consolidated silty material at 22 feet.

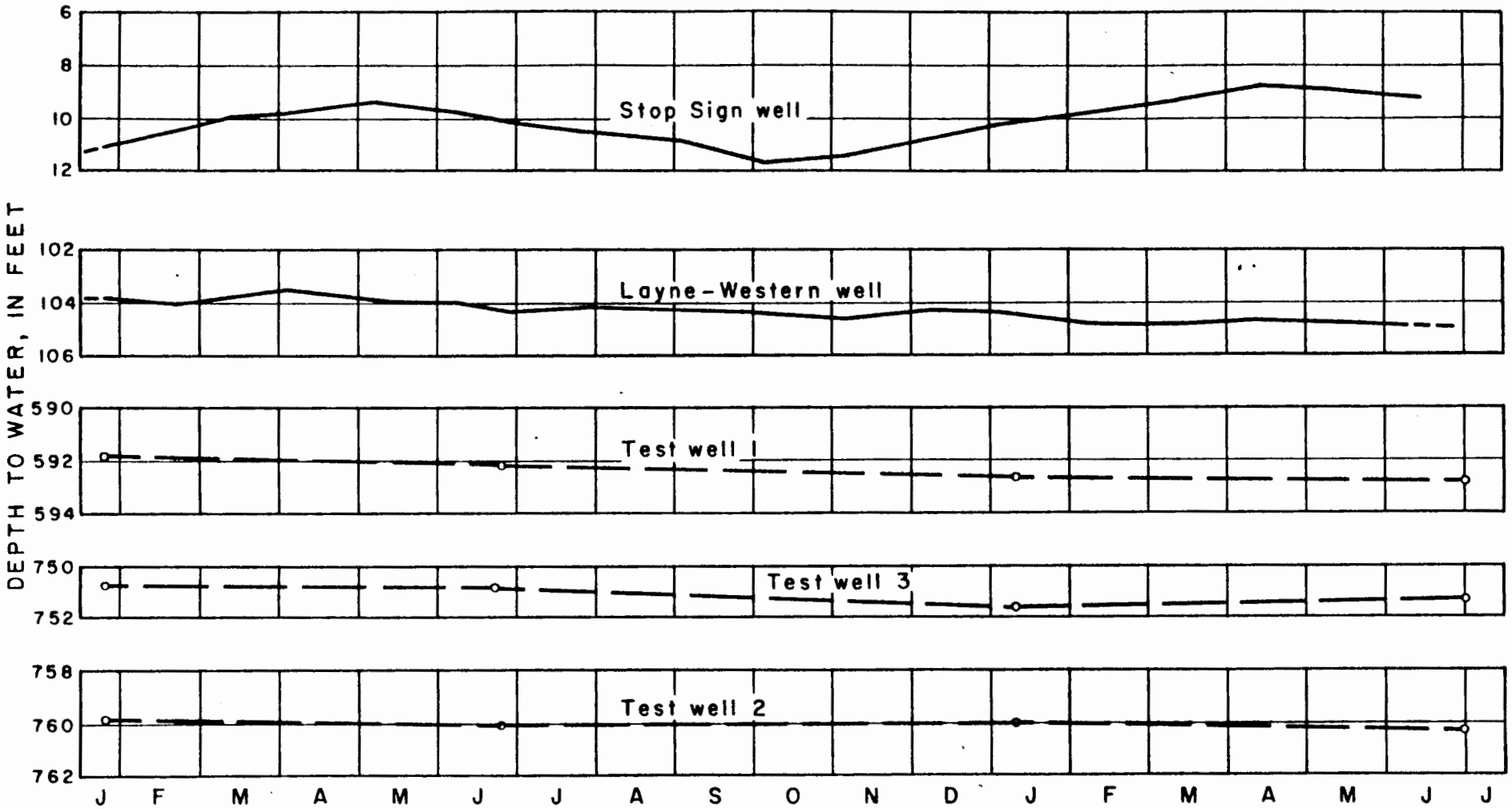

Figure 6.--Depth to water in deep test wells 1, 2, and 3, Layne-Western well, and Stop Sign well, January 1956 through June 1957

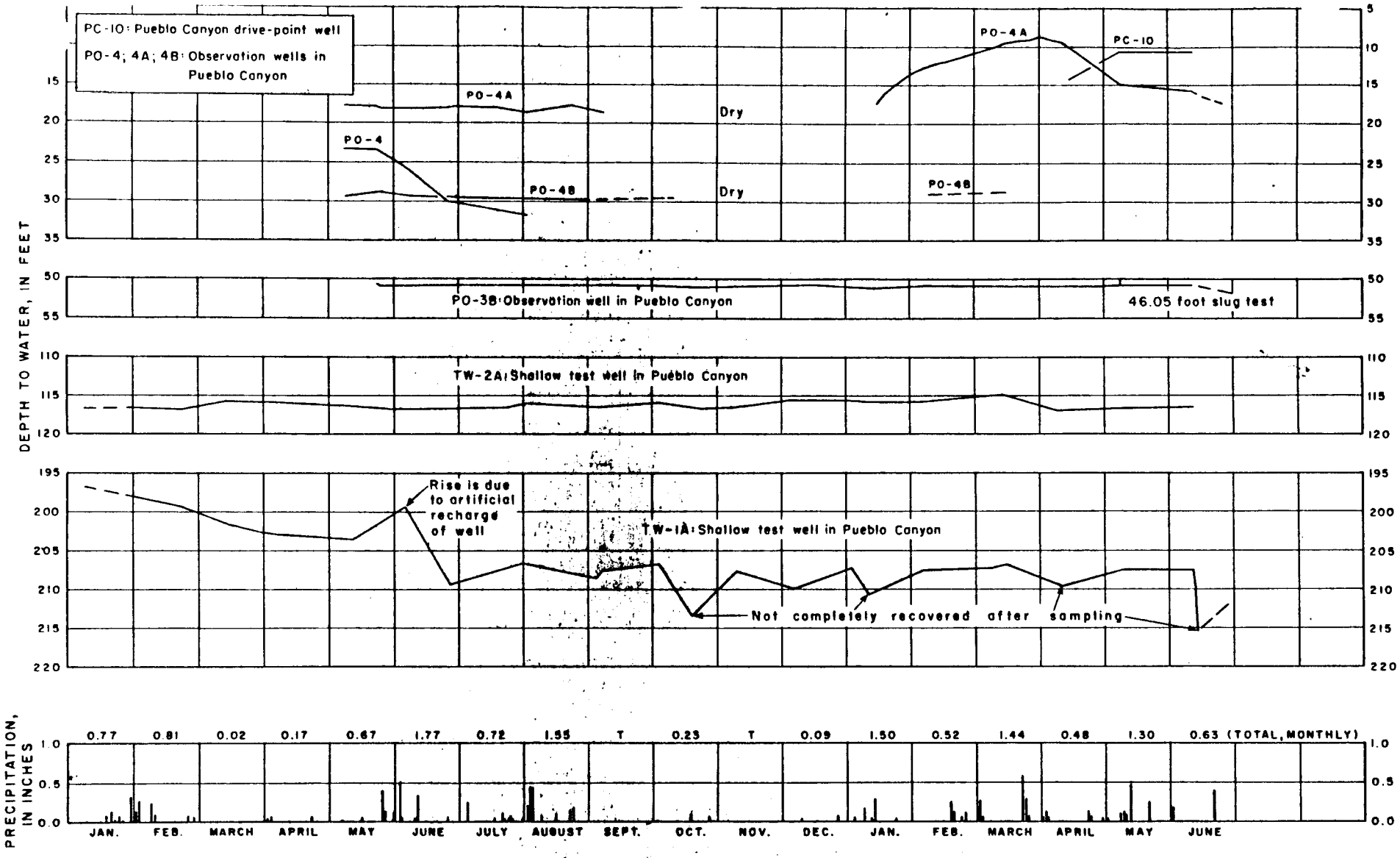

Figure 5.--Depth to water in observation wells, well PO-10, and the shallow test wells in Pueblo Canyon, and precipitation data, January 1956 through June 1957

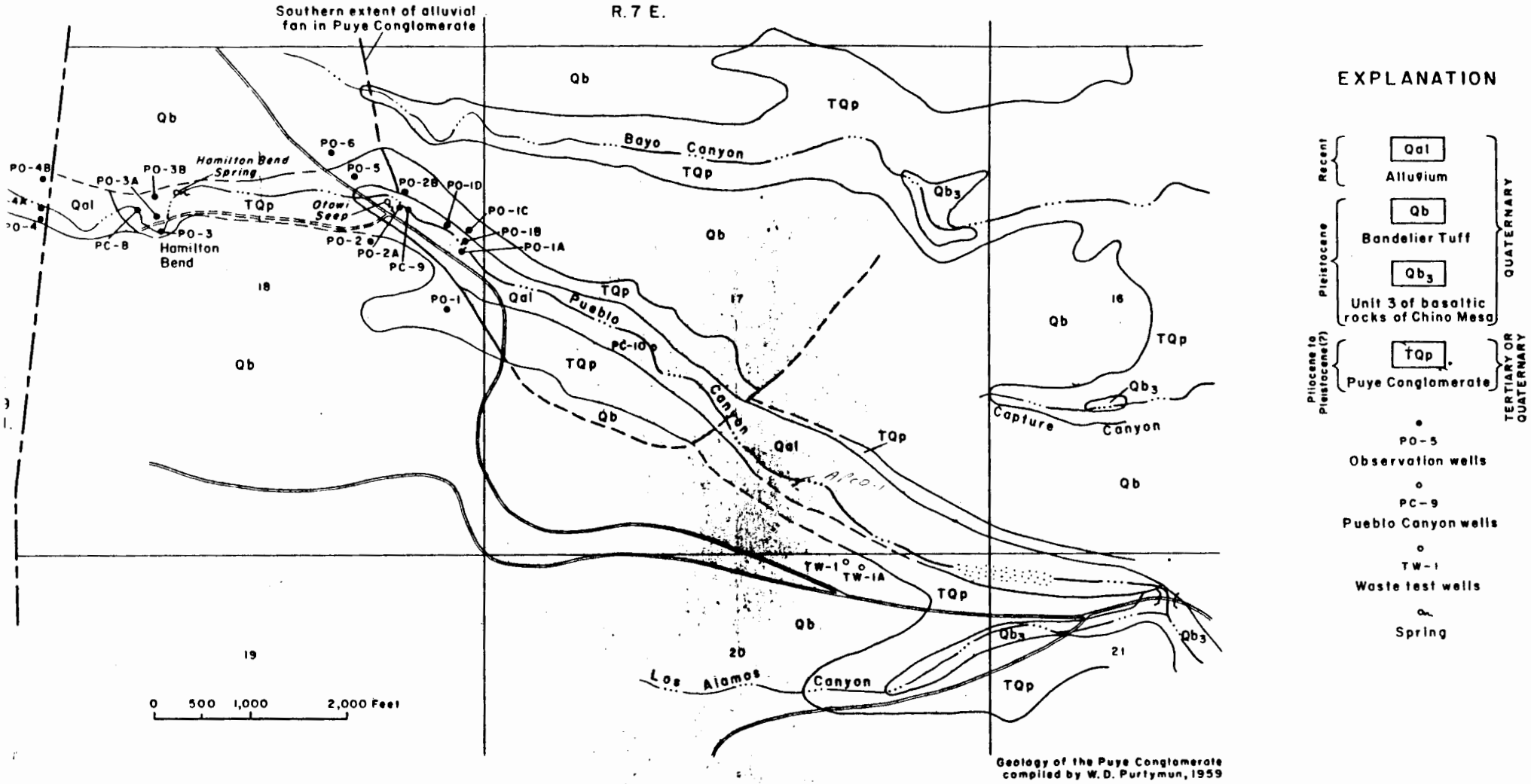

Figure 4.--Map showing location of observation wells and the geology of the lower part of Pueblo Canyon

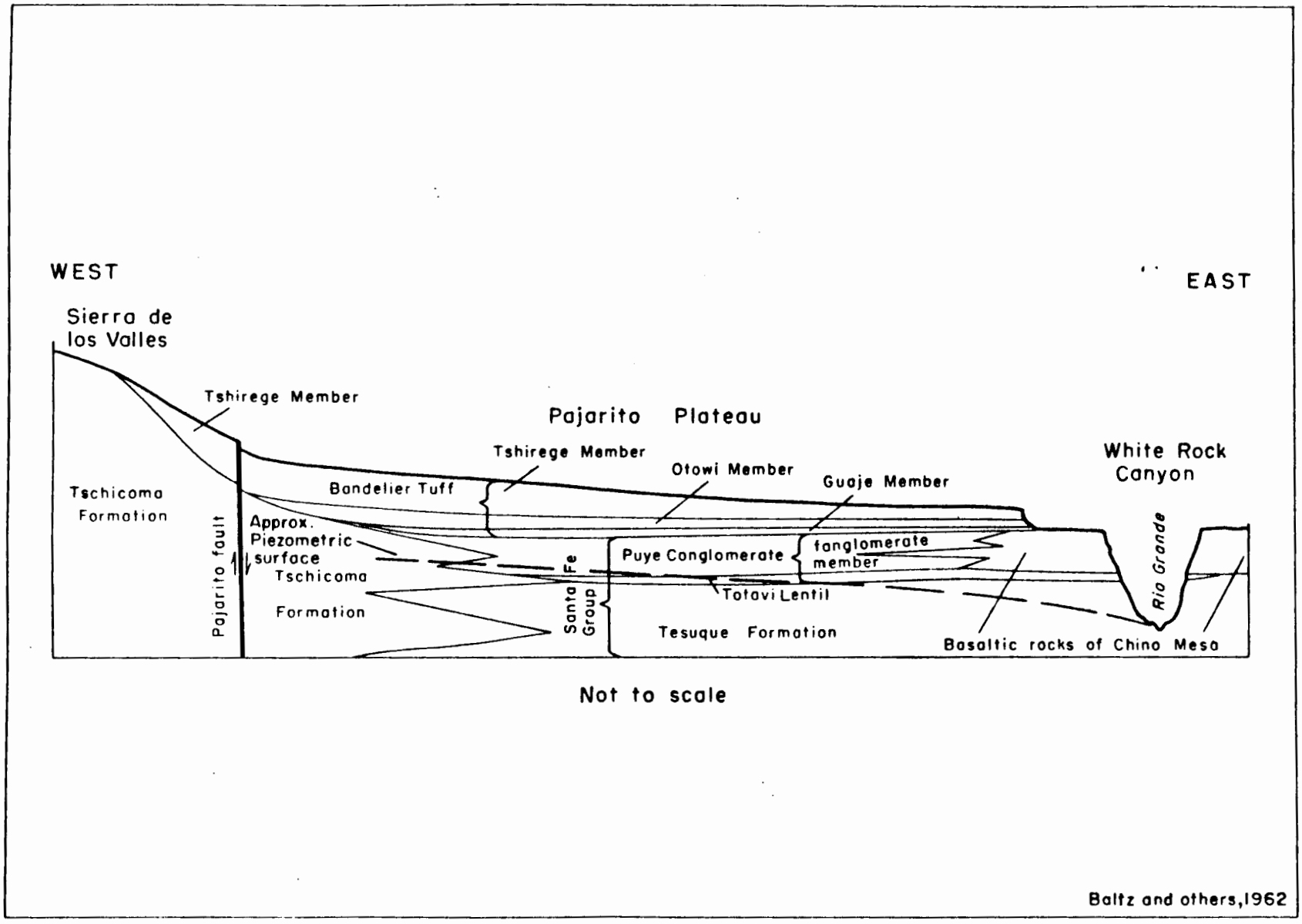

Figure 2.-- Diagrammatic cross section showing generalized stratigraphic relations of the Bandelier Tuff to older rocks in the Los Alamos area

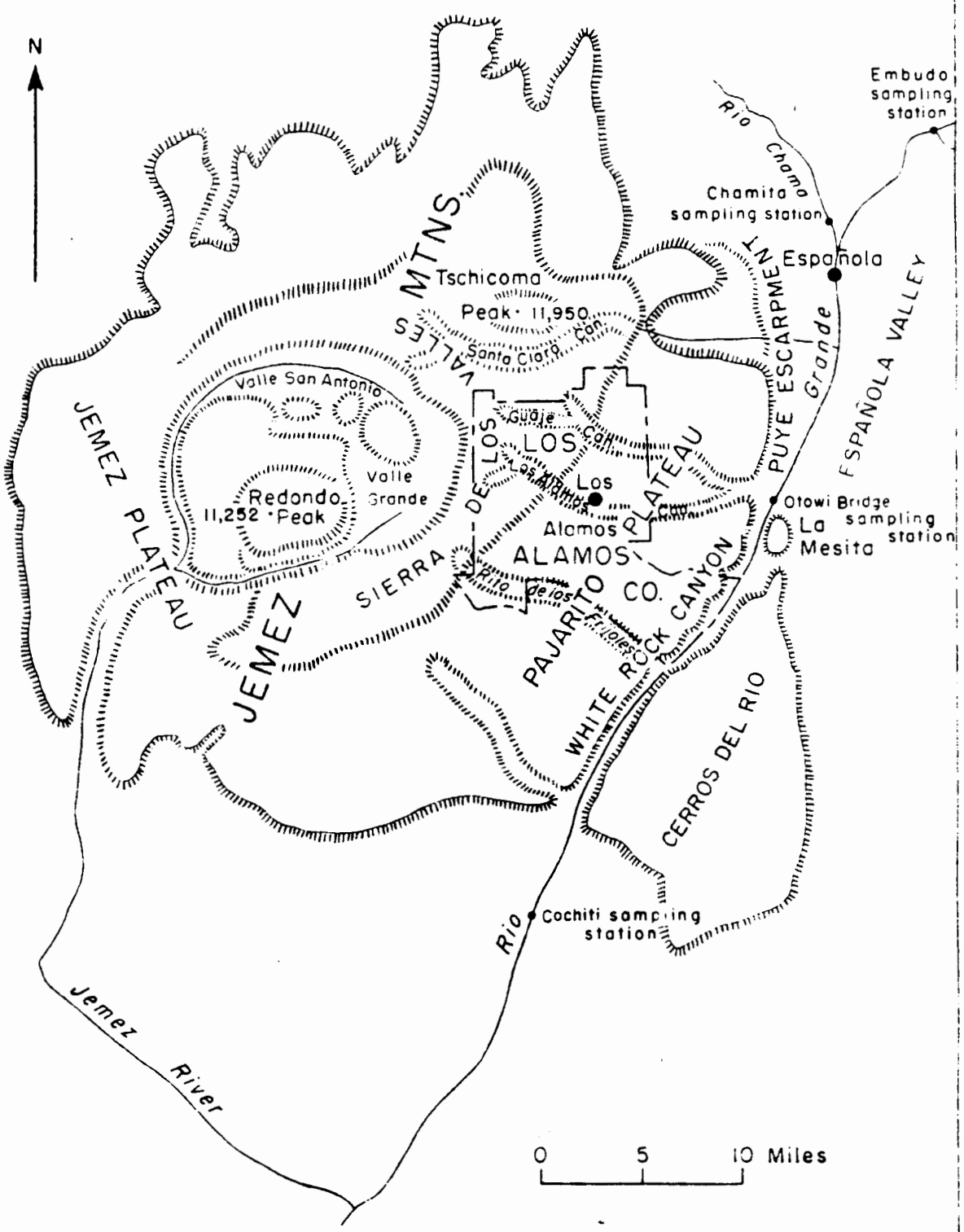

Figure 1.--Generalized map of the physiographic features of the Jemez Mountain region, New Mexico, and sampling stations on the Rio Grande and Rio Chama.

Table 9.--Summary of the quality of water (averages) from sampling stations outside the Acid-Pueblo Canyon disposal system.

Sampling point	Parts per million							pH	Disintegrations per minute per liter			Number of Samples
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Fluoride (F)	Nitrates (NO_3N)	Dissolved solids		Uranium (U)	Gross alpha	Gross beta	
Layne-Western well	35	13	70	5	0.7	1.4	165	8.0	10	20	-	2
Basalt Spring	31	22	34	17	.6	3.5	212	8.0	21	43	30	18
Los Alamos Spring	38	20	21	23	1.0	2.6	243	7.9	25	26	38	9
Indian Spring	33	6	25	3	.6	.5	197	8.3	27	19	210	3
Ancho Spring	14	6	12	3	.4	.5	148	7.9	48	18	0	4
Doe Spring	12	4	15	2	.4	.5	166	7.9	34	20	0	2
Los Alamos Canyon	16	0	16	11	2.0	3.0	162	7.3	0	6	260	1
Fence Canyon	18	0	12	0	1.0	1.2	266	7.6	0	13	0	1
Rio Grande at Embudo	37	11	24	6	.7	1.2	209	8.0	33	33	4	5
Rio Chama at Chamita	48	26	44	14	.4	.5	415	8.0	55	41	94	5
Rio Grande at Otowi	36	16	29	8	.6	.3	270	8.0	17	13	32	5
Rio Grande at Cochiti	36	17	27	8	.5	.4	260	8.0	21	16	6	5
Frijoles	10	6	12	2	.3	.5	133	7.8	18	37	0	5

Table 8.--Summary of quality of water (averages) from supply wells in Guaje and Los Alamos Canyons

Well No.	Temperature	Parts per million							pH	Disintegrations per minute per liter			Number of Samples
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Fluoride (F)	Nitrates (NO_3-N)	Dissolved solids		Uranium (U)	Gross alpha	Gross beta	
						Guaje Canyon							
G-1	80	15	2	22	6	0.7	1.8	180	8.2	20	27	260	5
G-1A	81	16	3	21	4	.4	2.3	182	8.3	37	35	60	4
G-2	81	16	6	27	2	.7	.8	215	8.2	22	14	0	3
G-3	83	16	8	20	2	.3	.5	167	8.4	14	15	0	3
G-4	75	21	14	44	3	.6	.9	134	8.2	38	53	36	3
G-5	77	22	11	12	4	.3	.6	154	8.3	17	21	50	3
						Los Alamos Canyon							
LA-1	70	8	0	8	16	2.0	1.7	244	8.4	23	34	6	6
LA-2	74	9	0	59(?)	12	1.9	2.0	220	8.5	37	23	20	3
LA-3	69	14	0	37	6	.7	1.6	162	8.4	16	32	0	3
LA-6	83	5	0	93	6	2.4	4.8	313	8.7	35	46	20	30[a]
LA-5	75	10	1	27	3	1.2	1.3	173	8.5	79	117	0	3
LA-4	80	13	0	21	3	.4	1.3	94	8.6	31	41	24	3

a/ Chem. only, Radiochemical-13 samples.

Table 7.--Summary of quality of water (averages) from test wells 1, 1A, 2A, and 3

Well No.	Parts per million							pH	Disintegration per minute per liter		
	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Fluoride (F)	Nitrates (NO_3-N)	Dissolved solids		Uranium (U)	Gross alpha	Gross beta
TW-1A	12 a/	5.6 a/	-	13 a/	0.6	1.8	279 a/	7.8	22	25	-
No. of samples	5	5	-	5	19	19	5	19	17	13	-
TW-2A	8 b/	2.5 c/	11.6	7	.5	1.9	144	7.6	31	39	44
No of samples	8	8	9	17	17	17	17	17	17	13	12
TW-1	21 d/	2 a/	20.5	5 e/	1.6	4.1	161 d/	8.0	4	4	6
No. of samples	19	19	10	10	21	21	12	21	21	20	10
TW-3	22	11 f/	13	6	.5	1.3	205	7.9	19	32	-
No. of samples	11	10	8	11	11	11	11	11	11	11	-

a/ Collected before spike on May 11, 1956.

b/ Average after August 1956 for 9 samples, 12.6 ppm.

c/ After August 1956 for 9 samples; average 10 ppm, range 0-30 ppm.

d/ Does not include samples collected May 22, 1956.

e/ Does not include samples collected for about 3 months after spike.

f/ April 11, 1957: 64 ppm.

Table 6.--Summary of quality of water (averages) from observation wells in Pueblo Canyon

Well number	Parts per million				pH	Disintegrations per minute per liter			Number of samples
	Chloride Cl	Fluoride F	Nitrates NO_3-N	Dissolved solids		Uranium U	Gross alpha	Gross beta	
PO-1A (1957)	29	1.2	17.5	318	7.5	13	31	-	3
PO-3 (1957)	28	1.1	11.0	307	7.5	28	30	-	1
PO-3B (1956-57)	19	.6	1.5	323	7.7	24	31	38	14
PO-4 (5/12/56)	35	1.0	10.1	534	7.1	70	196	-	

Table 5a.--Summary of radiochemical analyses (averages of several samples) of streambed alluvium in Pueblo Canyon, September 6, 1956.

Depth	Gross alpha Counts per minute per gram (dry weight)			Gross beta Counts per minute per gram (dry weight)			Gross gamma Counts per minute per gram (dry weight)		
	Sampling stations			Sampling stations			Sampling stations		
	PC-1	PC-2	PC-3	PC-1	PC-2	PC-3	PC-1	PC-2	PC-3
Surface	-	5	5	-	0	17	-	0	0
6 inches	0	4	8	0	5	10	0	3	8
12 inches	0	8	5	7	13	10	6	1	3
24 inches	0	-	8	76	-	13	4	-	0

Table 5.--Summary of radiochemical analyses of streambed alluvium in Acid and Pueblo Canyons

h ies)	Year	Gross alpha Counts per minute per gram (dry weight)					Gross beta Counts per minute per gram (dry weight)					Gross gamma Counts per minute per gram (dry weight)					Uranium Counts per minute per gram (dry weight)		
		Sampling stations					Sampling stations					Sampling stations					Sampling stations		
		Near well AC-1	Near well AC-2	Near well AC-3	Near well AC-4	Near well AC-5	Near well AC-1	Near well AC-2	Near well AC-3	Near well AC-4	Near well AC-5	Near well AC-1	Near well AC-2	Near well AC-3	Near well AC-4	Near well AC-5	Near well AC-2	Near well AC-3	Near well AC-4
L	1956	6	40	106	224	172	3[a]	26	100	104	58	5	3	4	24	17	-	-	38[a]
	1957	-	-	584	238	94	-	-	420	110	60	-	-	63	8	5	-	-	-
5	1956	4	58	228	128	46	1[a]	57	120	54	26	4	2	13	30	6	-	32	49
	1957	-	-	250	222	54	-	-	212	83	40	-	-	24	10	3	-	-	-
2	1956	0	80	126	130	68	0[a]	30[a]	42	70	30	0	16	20	26	7	22	13	17
	1957	-	-	264	82	30	-	-	112	48	40	-	-	17	3	1	-	-	-
8	1956	-	-	52	0	24	-	-	24	9[a]	29[a]	-	-	7	6[a]	0[a]	-	-	-
	1957	-	-	158	98	54	-	-	90	60	20	-	-	8	4	2	-	-	-
4	1956	-	-	-	94	-	-	-	-	93	-	-	-	-	6[a]	-	-	-	0[a]
	1957	-	-	100	32	-	-	-	40[a]	30	-	-	-	0[a]	2	2	-	-	-
0	1956	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1957	-	-	-	6	44	-	-	-	0	4[a]	-	-	-	4[a]	3[a]	-	-	-
6	1956	-	-	-	0	-	-	-	-	-0	-	-	-	-	1[a]	-	-	-	-
	1957	-	-	-	-	6	-	-	-	0	20[a]	-	-	-	2[a]	0[a]	-	-	-

[a] One sample only

Table 4B.--Summary of radiochemical quality of water from shallow wells and surface flow in Acid and Pueblo Canyons, November 1956 through June 1957.

Sampling stations	Disintegrations per minute per liter				Number of samples	Disintegrations per minute per liter
	Uranium		Gross alpha			
	Average	Range	Average	Range		Gross beta
Well AC-3	9	0-26	24	4-54	5	340
Well AC-4	29	6-74	63	26-80	5	276
Well AC-5	-	20-22	-	20-34	2	180
Acid weir	33	0-54	55	34-90	4	320
Well PC-1	9	0-18	27	0-70	4	90
Well PC-2	18	0-56	41	8-78	4	56
Well PC-3	24	6-56	30	22-50	4	316
Well PC-4	22	0-40	26	14-46	4	166
Well PC-6	16	0-28	32	16-64	4	134
Well PC-7	42	12-70	40	0-86	4	320
Well PC-9	29	0-90	36	0-96	5	36
Pueblo 1	35	0-70	40	0-70	4	90
Pueblo 2	20	8-48	38	6-94	4	306

Table 4A.--Summary of radiochemical quality of water from shallow wells and surface flow in Acid and Pueblo Canyons, January 1956 through October 1956

Sampling stations	Disintegrations per minute per liter				Number of samples	Disintegrations per minute per liter		Number of samples
	Uranium		Gross alpha			Gross beta		
	Average	Range	Average	Range		Average	Range	
Well AC-3	169	0-614[a]	376	4 -664[a]	6	1,488	500-3,080[a]	3
Well AC-4	207	104-548[a]	399	210 -566	6	590	180-1,260[a]	3
Well AC-5	-	0-286	-	40 -332	2	1,312	290- 240[a]	3
Acid weir	143	32-426[a]	182	60 -388[a]	6	-	180-3,140[a]	2
Well PC-1	57	6- 80	80	26 -174	5	240	-	1
Well PC-2	58	0-238[a]	63	16 -294	10	848	40-3,800[a]	5
Well PC-3	41	16-110	77	70 -160	4	150	-	1
Well PC-4	-	0- 50	-	-	2	-	-	-
Well PC-6	24	2- 36	39	24 - 60	3	-	0- 60	2
Well PC-7	-	0- 14	-	8.2- 10	2	-	140- 156	2
Well PC-9	-	8- 14	26	12 - 40	2	-	50- 228	2
Pueblo 1	-	24-164[a]	-	32 -180[a]	2	6,800[a]	-	1
Pueblo 2	2	0- 64	63	8.6- 84	5	120	20- 190	3

a/ June 26, 1956.

Table 4.--Summary of chemical quality of water from shallow wells and surface flow in Acid and Pueblo Canyons, January 1956 through June 1957

Sampling stations	Parts per million								pH		Number of Samples
	Chloride (Cl)		Fluoride (F)		Nitrate (N)		Dissolved solids				
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	
Well AC-3	30	5-114	6.1	2 -12	43	4 -184	686	291-1,276	10.7	9.5-11.5	11
Well AC-4	38	22- 81	6.4	4 -10	30	1.5- 52	582	349- 801	9.6	8.8-10.5	11
Well AC-5	33	29- 42	4	1 - 6	16	2 - 41	553	409- 360	9.8	8.6-10.8	4
Acid Weir	32	4- 47	5.7	2 - 8	50	10 -172	583	364- 805	8.6	6.7-10.3	10
Well PC-1	27	5- 38	1.7	1 - 2.4	10	3 - 14	731	394-2,960	7.9	6.8- 8.2	9
Well PC-2	38	27- 56	2.3	1 - 4	11	1 - 16	542	345-1,250	7.7	6.9- 8.2	14
Well PC-3	32	21- 57	2.3	1 - 3.6	10	5.5- 16	445	388- 543	7.6	6.5- 8.0	8
Well PC-4	34	29- 38	1.9	1 - 3.2	17	11 - 20	450	413- 495	7.6	7.4- 7.8	6
Well PC-6	32	25- 34	1.7	1 - 2	5	1.6- 10	394	300- 462	7.6	7.2- 8.6	7
Well PC-7	29	12- 34	1.7	1 - 3	11	2 - 18	338	105- 455	7.6	7.3- 7.9	6
Well PC-9	17	6- 29	1.7	1 - 3.6	11	3 - 21	654	318- 954	7.5	6.9- 8.2	7
[a] Well PC-10	23	-	1.0	-	8.0	-	549	-	7.8	-	1
Pueblo 1	35	31- 38	2.5	1 - 4.4	14	10 - 21	445	378- 581	8.0	7.3- 8.8	8
Pueblo 2	34	29- 43	2.4	1.6- 5	6	1 - 13.3	444	337- 452	8.2	7.7- 8.8	9

[a] May 17, 1957