UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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June 21, 1967

Dr. T. L. Shipman
H Division Leader
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Dear Dr. Shipman:

Enclosed are two copies of the report "Disposal of industrial effluents into Mortandad Canyon, Los Alamos County, New Mexico," by W. D. Purtymun, for your review and comments. We are considering the report for open-file release.

We will be glad to consider any questions or comments that you may have for the final version of the report.

Sincerely yours,

William E. Hale

W. E. Hale
District Chief, WRD

Encl: 2

4998

Los Alamos Environmental Restoration Facility
TA-3
ER Record I.D.# 001178

The disposal of industrial effluents in Mortandad Canyon, Los Alamos County, New Mexico

By

William D. Purtymun

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Santa Fe, New Mexico

The disposal of industrial effluents in Mortandad Canyon, Los Alamos County, New Mexico

By

William D. Purtymun

Prepared in cooperation with the U.S. Atomic Energy Commission and
Groups H-6 and H-7 of the Los Alamos Scientific
Laboratory, Los Alamos, New Mexico

June 1967

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The disposal of industrial effluents in Mortandad Canyon, Los Alamos County, New Mexico

By

William D. Purtymun

Abstract

The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commission and Groups H-6 and H-7 of the Los Alamos Scientific Laboratory made a study of the disposal area for low-level radioactive industrial effluents in Mortandad Canyon. The study was made to determine the movement of effluents in the disposal area and to evaluate the possibility of contamination of surface and ground water outside the disposal area.

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 because 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 area 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.

Introduction

Radioactive liquid wastes resulting from the many research and development projects associated with nuclear energy are produced at Los Alamos. These wastes were discharged untreated into deep canyons at Los Alamos prior to 1950. Waste treatment began in 1948 and a treatment plant was completed and put into operation during 1950. Since that time radioactive liquid wastes have been treated before being discharged into the environment (Christenson, 1959, p. 816). The plant construction in 1950 was within the city and effluents were discharged into an adjacent canyon. New technical areas were constructed and old technical areas were relocated on the Pajarito Plateau south of the city during the period 1958 to 1963. The new laboratories produced an increased volume of liquid wastes. A new centrally located treatment plant to process radioactive wastes was built at Technical Area TA-50 south of Los Alamos in 1962 and was put in operation in the latter part of June 1963. Liquid wastes are collected through an acid-sewer system for treatment at the plant. Treatment consists of chemical or ion exchange processing before effluents are discharged into the disposal area in Mortandad Canyon.

The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commission and Groups H-6 (Environmental Studies) and H-7 (Waste Treatment Section) of the Los Alamos Scientific Laboratory made a study of the geology and hydrology of the disposal area in Mortandad Canyon. The study was made to determine the movement of effluents in the disposal area, and to evaluate the possibility of contaminating surface and ground water in areas beyond the disposal area.

The cooperation of numerous personnel of the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory was appreciated. The support of W. R. Kennedy, H-6, LASL, and C. W. Christenson, H-7, LASL, who provided technical advise and supervised the laboratory's chemical and radiochemical analyses of alluvium and water is acknowledged.

Previous investigations

Early studies to locate a site suitable for the long term discharge of treated low-level radioactive effluent were made by C. W. Christenson and W. R. Kennedy of the Los Alamos Scientific Laboratory and J. H. Abrahams, Jr., of the U.S. Geological Survey. The results of the study indicated that the location of the plant near Technical area 35 would be centrally located and relatively isolated. A preliminary study of the geology and hydrology of Mortandad Canyon was summarized in an open file report for the period October 1960 to June 1961 (Baltz and others, 1963). An article in the U.S. Geological Survey Annual Review (Abrahams and others, 1962) describes the movement of water in the alluvium.

Geography

Mortandad Canyon is a narrow east-southeast-trending canyon, 9.5 miles long on the Pajarito Plateau in Los Alamos and Santa Fe Counties, New Mexico. The head of the canyon is three-fourths of a mile south of Los Alamos in the western part of the plateau. The mouth is in White Rock Canyon of the Rio Grande at the east side of the plateau (fig. 1). The Canyon floor slopes gently from an altitude of 7,300

Figure 1 (caption on next page) belongs near here.

feet near the head of the canyon to about one mile west of the Rio Grande where it drops from an altitude of 6,300 feet to 5,440 feet at the Rio Grande. The drainage area of the canyon and its tributaries above the confluence with Canada del Buey is about five square miles.

The area of investigation was the part of Mortandad Canyon west of the Los Alamos-Santa Fe County line (fig. 2). Near the Los Alamos-

Figure 2 (caption on next page) belongs near here.

Santa Fe County boundary, the canyon floor is relatively flat and is 600 to 700 feet wide. The canyon narrows to the west, and in the vicinity of well T-8 the floor of the canyon is only about 100 feet wide. West of well T-8 the canyon bottom is 30 to 80 feet wide and in many places is boulder strewn and irregular. The canyon walls are steep and in some places are near vertical.

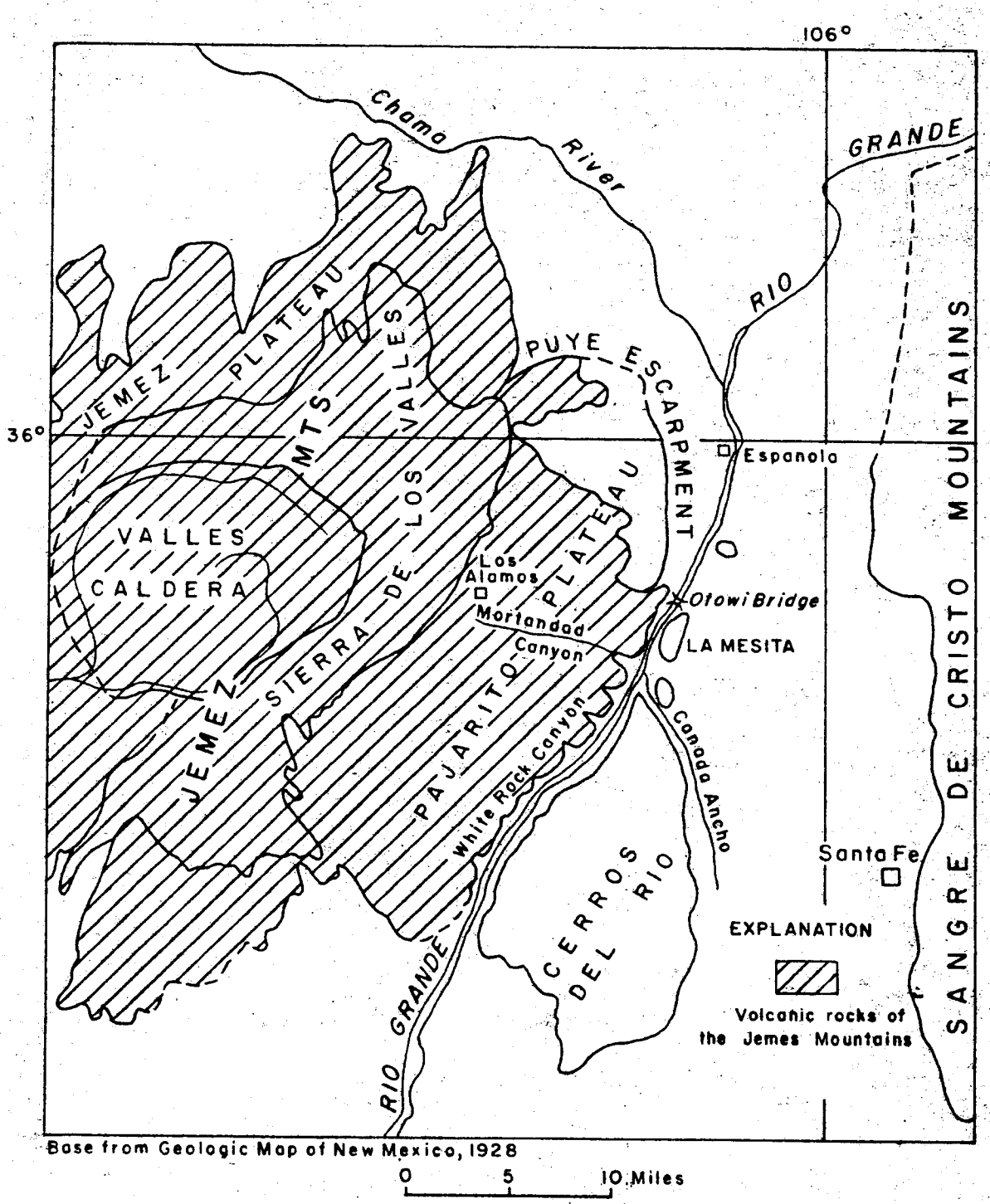


Figure 1.--Generalized map of north-central New Mexico showing location of Mortandad Canyon and related physiographic and hydrologic features.

Figure 2.--Geologic map of the disposal area, a part of Mortandad Canyon, Los Alamos County, N. Mex. (in pocket)

Stands of large ponderosa pines interspersed with junipers and pinon pines grow on the floor of the canyon in the eastern part of the area. Westwardly, the junipers and pinons decrease in number and the canyon floor is chiefly a covered meadow of sparse grass and large ponderosa pines. The narrow part of the canyon contains relatively dense stands of spruce, fir, ponderosa pine, deciduous trees, shrubs, and grass.

Effluent and Ten Site Canyons are tributaries to Mortandad Canyon in the area of investigation. The middle part of Ten Site Canyon and the lower part of Effluent Canyon are narrow and steep walled and have irregular boulder strewn bottoms. The stream channel is precipitous in places. The upper part of these tributary canyons are relatively broad and contain only a few thin patches of alluvium and soil resting on bedrock. The vegetation is about the same as exhibited in the narrow part of Mortandad--fir, spruce, and ponderosa pine with some deciduous trees, shrubs, and grasses. The outfall from the waste treatment plant TA-50 is into Effluent Canyon.

Geology

An investigation of Mortandad Canyon as a site for disposal of treated low-level radioactive wastes was made prior to its use as a disposal area by Baltz, Abrahams, and Purtymun in 1963. This section on geology has been largely taken from that report.

Mortandad Canyon is on the Pajarito Plateau which is capped by the rhyolitic volcanic rocks of the Bandelier Tuff of the Pleistocene age, (Griggs, 1964, p. 46). The Bandelier Tuff rests unconformably on the Santa Fe Group of Middle(?) Miocene to Pleistocene(?) age. The lower part of the Santa Fe Group consists of silty sandstone, sandy siltstones with occasional siltstone and pebbly conglomerate called the Tesuque Formation by Spiegel and Baldwin (1963, p. 39). No wells have been drilled to the base of the Tesuque Formation on the Pajarito Plateau; thus, the nature of the rocks below the Santa Fe Group in this area is unknown.

The Tesuque Formation is overlain by the Puye Conglomerate of the Santa Fe Group (Griggs, 1964, p. 28). The Puye Conglomerate consists of the Totavi Lentil overlain by the fanglomerate member. The Totavi Lentil is a deposit of ancient river gravels composed of sand pebbles and boulders of quartzite, granite, and volcanic rocks. The Fanglomerate member is composed of silt, sand, and pebble to boulder breccia derived from volcanic rocks. The flows of the basaltic rocks of Chino Mesa are interbedded with the fanglomerate member beneath the plateau.

The surface rocks in the disposal area in Mortandad Canyon are the Tschirege Member of the Bandelier Tuff and Recent alluvium (fig. 2). The sub-surface rocks in well T-8, a test well drilled near the center of the disposal area, are the lower part of the Tshirege and the Otowi and Guaje Members of the Bandelier Tuff, the fanglomerate member of the Puye Conglomerate and the basaltic rocks of Chino Mesa (table 1). A description is given of these formations because of their hydrologic importance to the disposal of low-level radioactive effluents in Mortandad Canyon.

Puye Conglomerate

The fanglomerate member of the Puye Conglomerate of Pliocene(?) age is the oldest stratigraphic unit penetrated at well T-8 (table 1). The well is bottomed in sediments that are probably a short distance above the Totavi Lentil, which is the basal unit of the Puye Conglomerate. Most of the fanglomerate member consists of gravels, sand, silt, and clay, but the basaltic rocks of Chino Mesa occur between the depths of 580 and 725 feet and split the fanglomerate member into a main (lower) part and an upper part.

The main part of the fanglomerate consists of light-tan to light-gray tuff and tuffaceous, pebbly sand between the depths of 970 and 1,065 feet. Most of the sand is composed of fine to coarse quartz and angular quartz-crystal fragments with some pebble fragments consisting of pumice, basalt, rhyolite and latite. Water was found in well T-8 at the depth of 990 feet and rose in the hole to a depth of 962 feet below land surface. The fanglomerate member between the depths of 725 and 970 feet above the tuffaceous unit consists of sand, silt, and clay with an abundance of interbedded gravels composed of latite, basalt, rhyolite, and andesite fragments.

The upper part of the fanglomerate member, between the depths of 490 and 580 feet, is similar to the beds below the basalt. The fanglomerate between 490 and 500 feet is light-tan, slightly tuffaceous, and fine to coarse-grained sand containing rhyolite and latite fragments. No water was found in the upper part of the fanglomerate member; however, water introduced into the hole during drilling was perched at a depth of about 570 feet on a layer of silty, sandy clay resting on the basalt. A test indicated the absence of formational water in this interval.

Table 1.--Geologic section of well T-8

Location: NE¼NE¼SW¼, sec. 23, T. 19 W., R. 6 E.

Altitude: 6,872 feet above mean sea level datum.

Total depth: 1,065 feet.

Depth to water: 962.8 feet.

Geologic section:

Stratigraphic unit	Thickness (feet)	Depth (feet)
Recent alluvium:		
Silty sands and gravels ----------	40	40
Bandelier tuff:		
Tshirege Member:		
Unit 1 - Nonwelded pumiceous rhyolite tuff, some pumice fragments weathered to clay -	20	60
Otowi Member:		
Nonwelded pumiceous rhyolite tuff ---------	385	445
Guaje Member:		
Lump pumice ----------	45	490
Puye Conglomerate:		
Fanglomerate Member:		
Silt, sands, and gravels consisting of latite, basalt, andesite and rhyolite ----	90	580

Table 1.--Geologic section of well T-8 - Continued

Stratigraphic unit	Thickness (feet)	Depth (feet)
Basaltic rocks of Chino Mesa:		
Dense dark gray basalt, interformational tuffaceous gravels occur between the depths of 705 to 715 feet ----------	145	725
Puye Conglomerate:		
Fanglomerate Member:		
Silt, sands and gravels composed of latite, basalt, andesite and rhyolite from depths of 725 to 970 feet. Tuff and tuffaceous pebbly sands of quartz and fragments of basalt, pumice, rhyolite occur from 970 to 1,065 feet ----------	340	1,065

Basaltic rocks of Chino Mesa

Several flows of brown to dark-gray basalts are interbedded with the fanglomerate member between the depths of 580 and 725 feet. The drill cuttings are chiefly fragments of greenish-gray glass and feldspar crystals with a few large fragments of black basalt. Yellowish-tan tuffaceous sand, which seems to be a bed of interflow sediments, occurs near the base of the unit from 705 to 715 feet. Loss of water and drilling mud during the construction of well T-8 indicated open joints are numerous in the basalt.

Bandelier Tuff

The Bandelier Tuff of Pleistocene age is the surface formation in Mortandad Canyon and is present also in the sub-surface where it rests unconformably on the Puye Conglomerate. The Bandelier Tuff is rhyolitic and consists in ascending order: of the Guaje Member, a lump pumice; the Otowi Member, a nonwelded tuff; and the Tshirege Member, a series of nonwelded to welded tuff units. The Tshirege Member forms the outcrops in the disposal area (fig. 2).

Guaje Member

The Guaje Member was penetrated in well T-8 between the depths of 445 and 490 feet. It consists chiefly of rounded fragments of white, gray, and tan pumice in a matrix of glassy ash. Quartz, feldspar crystal fragments, and pink and red rock fragments also occur in the pumice.

Otowi Member

The Otowi Member overlies the Guaje Member and was penetrated in well T-8 between the depths of 60 and 445 feet. The Otowi Member consists of a light-gray to light-pinkish gray nonwelded rhyolitic tuff. It is made up of quartz and sanidine crystal and fragments of latite, rhyolite, and pumice in a matrix of fine ash shards. Several layers consist mainly of pumice fragments; some of which are as much as 1 inch across.

Tshirege Member

The Tshirege Member is exposed in the walls of Mortandad Canyon and forms the mesas to the north and south (fig. 2). The contact, an irregular erosion surface, between the Tshirege Member and the underlying Otowi Member can be observed in Sandia Canyon north of Mortandad Canyon. Although the contact is concealed in Mortandad Canyon, it is probably an erosional unconformity.

The Tshirege Member was divided into lithologic units in the disposal area and mapped accordingly (fig. 3). The three units, Unit 1, 2, and 3,

Figure 3 (caption on next page) belongs near here.

in ascending order, vary in degree of welding; this affects the rates of infiltration of water.

Unit 1: The lower part of the Tshirege Member consists of two ledge-forming layers of nonwelded to moderately-welded pumiceous tuff breccia that are generally similar in lithology, but are slightly different in color and weathering characteristics.

The lower layer is a massive orange-weathering pumiceous tuff breccia which forms a low ledge above the alluvium. It is composed of pink colored fragments of pumice ranging from 1/8 inch to 6 inches in the longest dimension and, quartz and sanidine crystals and obsidian and rhyolite fragments in a fine glassy ash matrix. The weathered outer 1 to 3 inches of tuff forms a hard rind that protects the soft inner rock from weathering. This basal layer is present across much of the Pajarito Plateau.

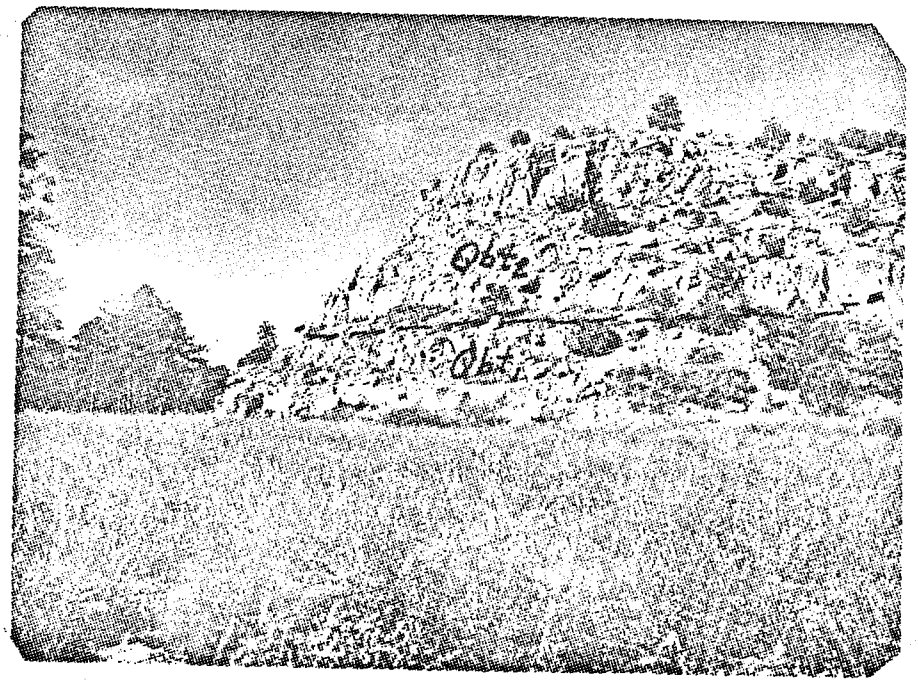


Figure 3.--View of the north wall of Mortandad Canyon northwest of well MCO-6.

The upper layer of unit 1 rests conformably on the lower layer and weathers to dull grayish-brown and light orange. It is a tuff breccia with a fine-grained, ash-shard matrix similar to the lower layer but with smaller pumice fragments and an increase in the amount of quartz crystals and dense volcanic rock fragments. It is slightly less resistant to erosion than the basal layer and forms a round ledge set back from the lower layer. West of well MCO-4 both layers form a vertical cliff along the north wall of the canyon. The layers can be distinguished here because a soft bed of pumice at the base of the upper layer weathers to a persistent notch in the cliff.

The thickness of the lower layer varies because it is deposited on the erosional surface at the top of the Otowi Member. Its thickness can be determined only at well T-8 where it is about 70 feet thick. The upper layer is fairly uniform in thickness ranging from 18 to 22 feet thick in the disposal area. Total thickness of Unit 1 is about 90 feet at well T-8.

Unit 2.--Unit 2 of the Tshirege Member rests conformably on Unit 1 and seems to be transitional into it. It is a light-gray moderately welded pumiceous tuff consisting of angular fragments of pumice, dense rhyolite, and latite fragments as large as 4 inches across. Also present are fragments of quartz and sanidine crystals. It weathers dull gray and grayish-brown with a hard rind several inches thick at the surface. A lower layer weathers to a rounded slope set back from Unit 1 along the eastern part of the disposal area. An upper layer in this area is resistant to erosion and forms ledges and benches above the rounded slopes of the lower layer. Westward from well MCO-4, Unit 2 forms the sheer cliff in the narrow part of Mortandad, Effluent, and Ten Site Canyons. The thickness of the unit ranges from 110 to 120 feet.

Unit 3.--Unit 3 of the Tshirege Member rests conformably on Unit 2 and grades downward into it. Unit 3 consists chiefly of a light-gray to light-tan nonwelded to moderately welded tuff. It is composed of lenses of large pumice fragments, quartz and sanidine crystals and fragments, and latite and rhyolite rock fragments in a fine ash-shard matrix. Most of Unit 3 is relatively soft and has been eroded to form round slopes. A hard rind several inches thick forms on the weathered surfaces. The upper 40 to 50 feet is moderately resistant to erosion and forms flat mesas and benches with steep sides north and south of Mortandad, Effluent, and Ten Site Canyons. Unit 3 is about 110 feet thick in the area west of MCO-2 and is the stratigraphically highest part of the Bandelier Tuff preserved in this part of the Pajarito Plateau.

Alluvium

Alluvium of Recent age rests unconformably on the Bandelier Tuff in Mortandad Canyon. The alluvium consists of detritus eroded from the Tshirege Member which forms the sides of the canyon. The alluvium between the outfall from TA-50 in Effluent Canyon and well MCO-2 in Mortandad Canyon (fig. 2) consists of boulders, cobbles, and pebbles of tuff intermixed with sand, silt, and clay. The sand consists of fine to course-grained crystal fragments of quartz and sanidine. The thickness ranges from zero to several feet in Effluent and upper Mortandad Canyons to 18 feet at well MCO-2.

The alluvium east of well MCO-2 is thicker and consists of two distinctive units. Samples from observation wells and access tubes constructed in the canyon show that the upper part of the alluvium is chiefly a coarse-grained, silty sand. This unit rests on brown, sandy silt, which constitutes a lower unit of alluvium.

The alluvium is about 40 feet thick at well MCO-3. The upper 28 feet consists mainly of silty sand, and the lower 12 feet consists of a tan, sandy silt resting on Unit 1 of the Tshirege Member. The alluvium is about 48 feet thick at well MCO-4. The upper 34 feet consists of coarse silty sand which laps onto Unit 1 of the Tshirege Member near the edges of the valley. The lower 14 feet consists mainly of brown sandy silt which rests on the Otowi Member. The alluvium is about 80 feet thick at well MCO-6. The upper 55 to 60 feet is silty sand. The lower 20-25 feet is brown sandy silt. The upper unit laps onto Unit 1 of the Tshirege Member near the edges of the valley and the lower silty unit rests on the Otowi Member.

The thickness of the alluvium in the canyon east of well MCO-6 is unknown. On the basis of extrapolation of gradients and comparison of the depth of Sandia Canyon to the north, the alluvium at the Los Alamos-Santa Fe County line (fig. 2) is probably 80 to 120 feet thick.

The alluvium in Mortandad Canyon has a complex history of deposition and erosion. The lower unit of alluvium contains much sandy silt which probably is the product of weathering in place of the Bandelier Tuff. The upper sand unit is chiefly the product of mechanical erosion. Alluviation is occurring at present, and small fans of coarse detritus are accumulating at the bottom of the steep slopes and at the mouths of some of the tributary canyons. The increase in the amount of surface water (waste water and effluents from the technical areas) has caused the alluvium to be eroded in the canyon west of well MCO-3 and to be redeposited a short distance to the east. This is generally the eastern limit of surface water flow during prolonged discharge of waste water.

Water was found in the alluvium during the construction of observation wells and access tubes from well MCO-1 to well MCO-7 (fig. 2). The water is perched on the Bandelier Tuff. The occurrence of water in the alluvium is discussed in a later section of this report.

Hydrology

The study of the hydrology of the disposal area was made to determine the movement of low-level radioactive effluents discharged from the waste treatment plant TA-50. Hydrologic data were collected from October 1960 to June 1965.

A net of shallow observation wells and access tubes were constructed in 1960 and 1961 to study the movement of water in the alluvium and underlying tuff. Twenty observation wells and thirty-one moisture access tubes were constructed; however, only observation wells and access tubes mentioned in the text are designated by letters and numbers. They are numbered consecutively down-gradient from west to east and are identified by the following letters:

Prefix MCO - Observation well.

Prefix MCM - Access tube.

Observation wells were completed in the alluvium and cased with 2, 3, or 4-inch diameter plastic pipe. Access tubes, used to determine distribution of moisture and density of adjacent material, were completed in the alluvium by casing 4-inch diameter holes with 2-inch plastic pipe. The annular space between the hole wall and the plastic pipe was filled with alluvium and compacted to near the density of the adjacent material.

Access tubes MCM-1, 2, 3, 4, and 5 were constructed to study the distribution of moisture in the tuff. MCM-1 and 2 are in Effluent Canyon and upper Mortandad Canyon. The holes were drilled into the tuff at an angle of about 30 degrees from benches about 50 feet above the stream channel to positions of about 25 feet below the stream. The holes were cased with 2-inch plastic pipe and the annular space was filled and compacted with crushed tuff. Access tubes MCM-3, 4, and 5 were constructed by augering a 5-inch hole through the alluvium into the top of the tuff. A 4-inch steel casing was set into the top of the tuff to seal out the water from the alluvium. A 3-inch diameter hole was then augered into the tuff through the steel casing. A 2-inch plastic pipe was then set into the tuff and the annular space filled with crushed tuff which was compacted to near the density of the undisturbed tuff. The distribution of moisture in the alluvium and underlying tuff was determined in the access tubes by a neutron-scattering probe.

A deep test well (T-8) was drilled in 1960 to determine the geologic units beneath the canyon and the hydrologic characteristics of the main aquifer. Well T-8 is completed at a depth of 1,065 feet in the main aquifer. It is cased with 8-inch steel casing with the lower 110 feet slotted. It is near the center of sec. 23, T.19 N., R.6 E.

Two 6-inch modified Parshall flumes (GS-1, GS-2) were permanently installed in the stream channel in 1962 and were equipped with recorders to obtain a continuous record of surface water flow in the disposal area. Surface water and alluvium sampling stations are numbered downgradient from west to east and are identified by the following letters:

Prefix MCS - Surface water or alluvium sampling station.

The disposal area was divided into three parts, the upper canyon, middle canyon, and lower canyon (fig. 2), to facilitate the study of the relationship between the surface water and water in the alluvium. The upper canyon extends from the TA-50 outfall in Effluent Canyon to well MCO-2 in Mortandad Canyon. In this reach the canyon is relatively narrow and contains only thin alluvium (0-18 feet) and is underlain by Unit 2 of the Tshirege Member of the Bandelier Tuff. The middle canyon extends from well MCO-2 to MCO-4. In this reach the canyon begins to widen and the alluvium thickens from 18 feet at MCO-2, to 48 feet at MCO-4, and is underlain mainly by Unit 1 of the Tshirege Member, and near MCO-4 by the Otowi Member. The lower canyon extends from well MCO-4 to MCO-6. In this reach the canyon becomes progressively wider and the alluvium thickens from 48 feet at well MCO-4, to 80 feet at MCO-4, and is underlain by the Otowi Member.

Mortandad Canyon heads on the Pajarito Plateau. It has a relatively small drainage area consisting of about 0.5 square mile above gaging station 1 with an additional 0.8 square mile in the disposal area (upper, middle, and lower canyons). This includes about 0.4 square mile in Ten Site Canyon that is tributary to Mortandad in the lower canyon.

The stream channel in the upper and middle canyons is well defined, containing gravels and boulders from ashflows of the Tshirege Member of the Bandelier Tuff. In the lower canyon, east of well MCO-4 the stream channel is discontinuous, braiding out into the canyon floor. (fig.2).

Surface Water entering the disposal area consists of waste water, storm runoff, and industrial effluents. The volume of water entering the disposal area was determined by records from gaging station GS-1. The volume of water entering the middle canyon was determined from gaging station GS-2 near well MCO-2 (fig. 2). Very little surface water except storm runoff entered the lower canyon during the period of July 1963 to June 1965. As surface water moves eastward through the disposal area, losses occur by evapotranspiration and by infiltration into the alluvium. The surface water infiltrating into the alluvium recharges a small body of water perched on the underlying tuff because the tuff is less permeable than the alluvium. As the water moves eastward in the alluvium it is lost into the tuff.

The main aquifer of the Los Alamos area is at a depth of about 990 feet below the floor of the middle canyon. The source of recharge to the aquifer is unknown, but the slope of the potentiometric surface of the main aquifer suggests that the major recharge area are deep canyons cut into the western part of the Pajarito Plateau or in the Sierra de los Valles. The movement of water in the aquifer is eastward beneath the Pajarito Plateau toward the Rio Grande where part is discharged through a series of springs or directly into the river channel.

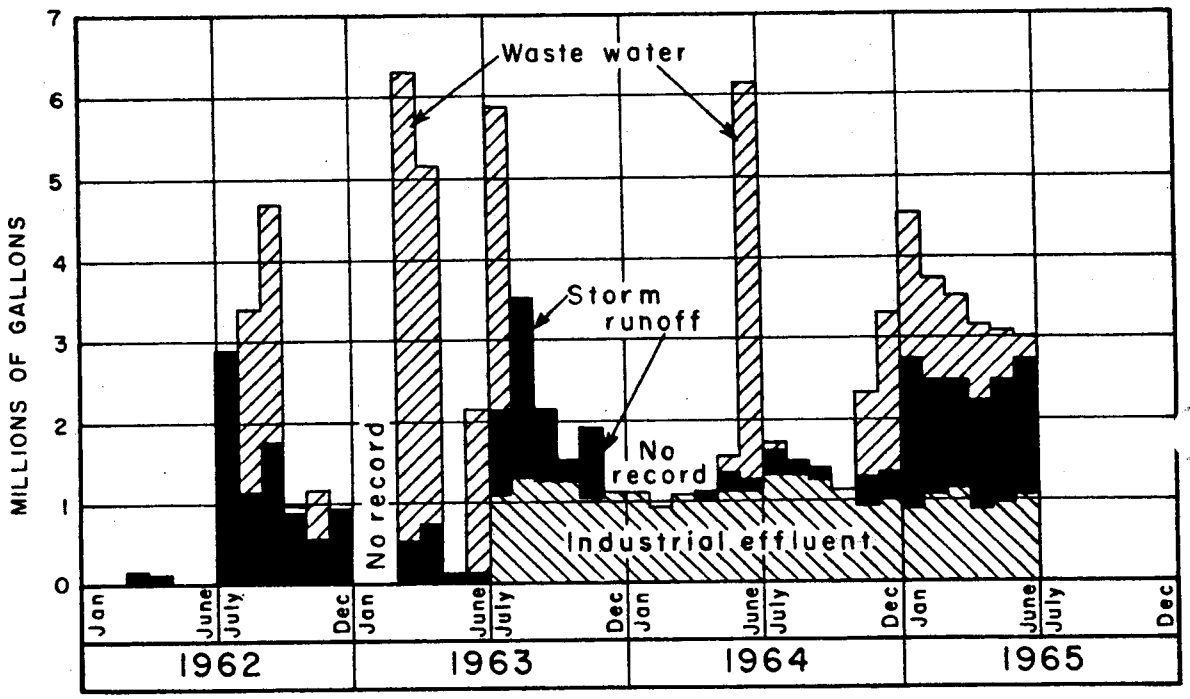
Surface water

Two surface water gaging stations (gaging stations 1 and 2) were established in February 1962. No records were obtained from gaging station 1 during the winters of 1962-63 and 1963-64 because the gage well was frozen. Continuous discharge of waste water from TA-48 in the winter of 1964-65 kept the gage well from freezing and records were obtained. No record of surface water discharge was obtained from gaging station 2 during the winters 1962-63, 1963-64, and 1964-65. The discharge at gaging station 2 during the winter of 1964-65 was estimated using the control maintained at gaging station 1 during this period.

Sources of surface water entering the disposal area from March 1962, when record began, to June 1963 consisted of waste water from TA-48 and New Sigma and storm runoff. Industrial effluents from TA-50 were added to the surface flow from July 1963 to June 1965.

Technical Area TA-48 is about one-half mile west of gaging station 1 and it discharges waste water from a cooling process into effluent Canyon. When discharge occurs the amount varies from 3 gpm (gallons per minute) to as much as 30 gpm at gaging station GS-1. New Sigma is about $1\frac{1}{4}$ miles west of gaging station 1 and discharges waste water from a cooling process into Mortandad Canyon. When discharge occurs the amounts range from 50 gpm to more than 300 gpm at gaging station GS-1. The recorded monthly amounts of waste water from TA-48 and New Sigma were as much as 5.8 million gallons (fig. 4).

Figure 4 (caption on next page) belongs near here.



1/ No record of waste water or storm runoff.

Figure 4.--Sources of surface water entering the disposal area in Mortandad Canyon.

The amounts of surface water resulting from storm runoff varies; however, the larger amounts generally are in July, August, or September when a large amount of precipitation occurs in a short interval of time. Runoff in the first 6 months of 1965 was maintained by the continuous discharge of waste water and above normal precipitation that occurred during these months.

Industrial effluents from TA-50 are discharged into the disposal area at rates of 250 gpm to 300 gpm in slugs of 20,000 gallons. The average monthly discharge from July 1963 to June 1965 was about one million gallons (fig.4).

Surface flow in the disposal area from industrial effluents extends from the TA-50 outfall to near gaging station 2 (fig. 2). Surface flow from waste water from TA-48 generally extends to near Station MCS-5; however, when industrial effluents are concurrently discharged the combined flow may extend to near Station MCS-7 for short intervals of time. Waste water from New Sigma discharging continuously at rates ranging from 200 gpm to 300 gpm at gaging station 1 causes surface flow to reach Station MCS-7 after 4 or 5 days depending on such factors as the amount of water in the alluvium of the upper canyon and the quantities of waste water from TA-48 and effluents from TA-50 being discharged concurrently.

The leading edge of surface flow continues to advance toward Station MCS-8 as storage builds up in the alluvium by continuing discharge or runoff. Periodic discharge of effluents during time of high storage extends the leading edge of the surface flow further eastward for short periods of time. Storm runoff during the period of investigation extended east of the MCS-9, however, all surface flow was contained within the disposal area.

Surface water losses

Surface water losses in the disposal area are by evapotranspiration and infiltration into the alluvium. Evapotranspiration is the return of water to the atmosphere by evaporation and by transpiration of plants. U.S. Weather Bureau pan evaporation data (1953-61) at Santa Fe extrapolated to Los Alamos indicated evaporation at about 55 inches annually, or, if applied to the upper canyon a loss of about 5 million gallons. A method described by Hantush (1959, p. 8) used the monthly mean temperature to compute the potential evapotranspiration. The estimated evapotranspiration can be assumed if the soil moisture is at near field capacity, a condition existing in a part of the upper canyon. The annual evapotranspiration loss in the upper canyon for the four year period was estimated to be 23 inches over an area of 143,000 square feet or approximately 2 million gallons a year. As the area of soil moisture in the upper canyon varies during the year, loss to evapotranspiration probably ranges from 2 to 5 million gallons annually with the largest losses occurring in June, July, and August when the monthly mean temperatures are at a maximum, which also corresponds to a period of high plant consumption.

Surface water loss by infiltration into the alluvium occurs in the upper and middle canyon but the amount of surface water entering the lower canyon is negligible. The area of greatest loss of surface water (upper or middle canyon) is dependent on the amount, rate, and time duration of surface flow entering the disposal area at gaging station GS-1, and the amount of storage in the alluvium of the upper canyon.

Records available for 14 months in the period March 1962 to June 1963 prior to the operation of the waste treatment plant show that the loss by seepage and evapotranspiration was about 45 percent (12.2 million gallons) in the upper canyon and about 55 percent (14.7 million gallons) in the middle canyon. Two periods of discharge of waste water from New Sigma during August-September 1962 (6.2 million gallons) and March-April 1963 (10.3 million gallons) caused complete saturation of the alluvium in the upper canyon, so that in effect surface water was perched on the water in the alluvium and flow extended into the middle canyon.

Records available for 20 months in the period July 1963 to June 1965 during operation of the waste treatment plant show that the losses were about 73 percent (40.9 million gallons) in the upper canyon and about 27 percent (14.9 million gallons) in the middle canyon. The increased percentage of loss in the upper canyon (73 percent) for the period July 1963 to June 1965, a period when more water entered the disposal area, was due to a lower, more uniform rate of surface flow entering the disposal area and only partial saturation of the alluvium in the upper canyon.

Quality of surface water

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 floculator 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.

Careful control is maintained throughout the entire treatment operation by frequent collection and analyses 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.

The wastes vary in chemical and radiochemical constituents when they arrive at the treatment plant; however, the resulting effluent reflects the chemical treatment (fig. 5). Concentrations of sodium, calcium,

Figure 5 (caption on next page) belongs near here.

carbonate, bicarbonate, and chloride are higher than that in the native water and, if acidized for the ion exchange columns, high nitrate as well as as pH and conductivity are characteristic of the effluent (table 2).

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. The chemical quality of the waste water discharged into the disposal area did not change significantly during the study (table 2). Beta-gamma emitters in waste water from New Sigma for March 1963 were above background. The cause of the contamination is unknown. Other radioactivity was background.

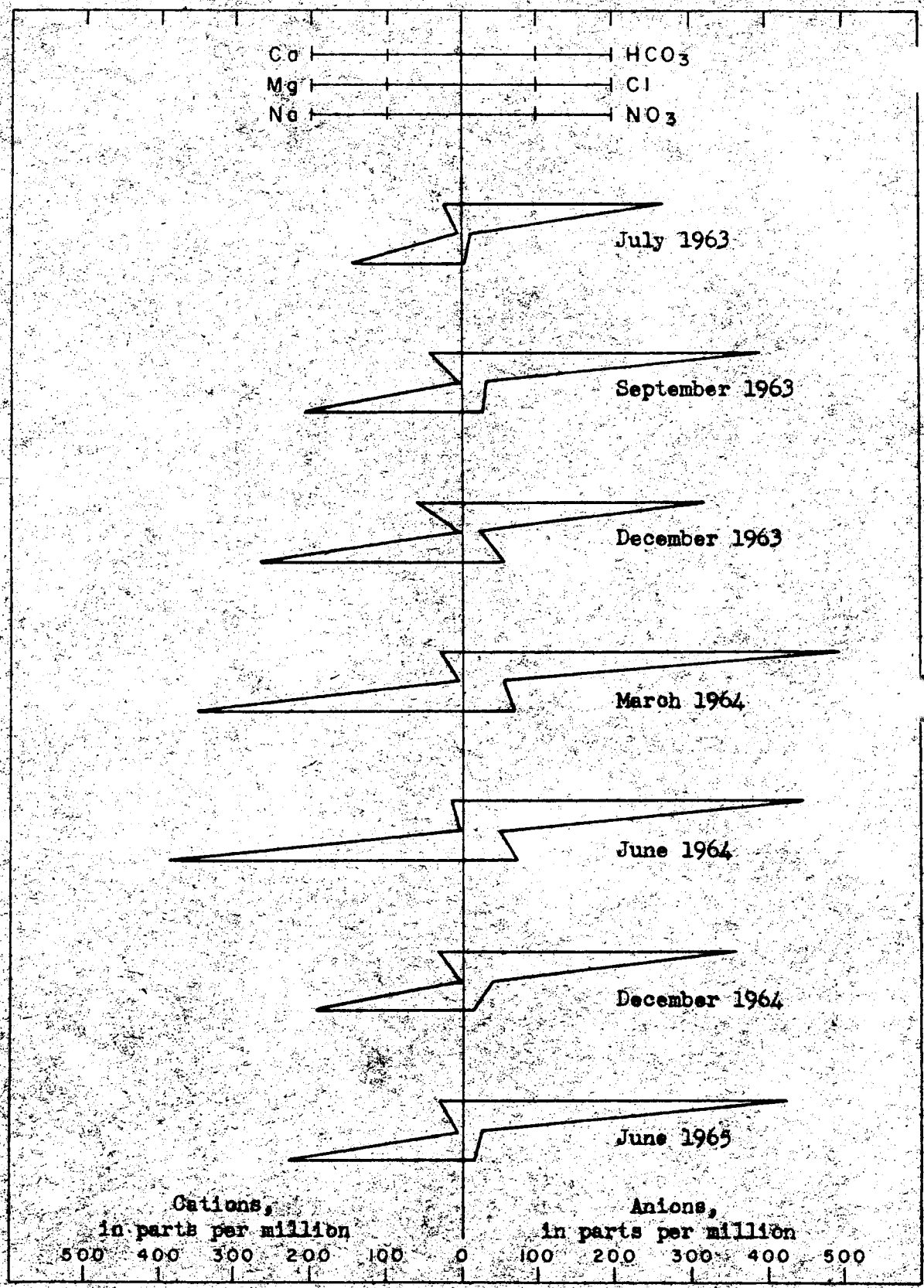


Figure 5.--Graphic comparison of the chemical quality of effluent discharged in to Mortandad Canyon from TA-50.

The chemical quality of surface water in the disposal area (after July, 1963) varied due to slight changes in chemical quality of the effluents, the amount of dilution of the effluents by waste water or storm runoff, and to ion and base exchange processes between the relatively unstable chemical combinations in the industrial effluents and the alluvial materials. Chemical constituents generally decrease downgradient in surface water consisting of industrial effluents and waste water while that of base flow (drainage from bank storage) shows no apparent trend of chemical changes (table 2).

Radiochemical analyses of surface water in the disposal area shows varying amounts of radioactive contamination. Plutonium was reported from most of the samples as was beta-gama emitters. There was a general decrease in the amount of radioactive contamination in the surface water downgradient in the disposal area.

Table 2.--Selected chemic

(Analyses by the Los Alam

Source	Date of collection	Chem					
		Parts per million					
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Chloride (Cl)
							Ir
TA-50	July 1963	25	1	145	175	269	11
Do.	June 1964	17	1	382	315	448	46
Do.	June 1965	30	1	237	329	429	24
TA-48	12- 4-62	10	3	36	0	80	6
Do.	5- 7-65	7	2	44	6	118	2
New Sigma	3-21-63	12	2	34	0	85	4
Do.	5- 7-65	7	2	32	6	88	2
							Bas
MCS-1	3-24-64	13	1	145	36	221	20
MCS-4	3-24-64	18	12	218	10	164	32
MCS-5	3-24-64	19	10	112	0	154	30
							Industr
MCS-1	7-16-63	15	1	87	52	192	10
MCS-7	7-16-63	11	3	50	6	134	7

a/ Average monthly chemical and radiochemical quality of effluents from
b/ Counts per minute per liter, showing relative values.

Water in the alluvium

Surface water infiltrates into the alluvium to recharge a body of water perched on the underlying tuff. The movement of water in the alluvium is downgradient toward the east. As the water moves, part is lost to evapotranspiration and part is lost by infiltration into the tuff. The monthly water level measurements in observation wells and the volume of alluvium compiled from data obtained during construction of observation wells and access tubes were used to compute the volume of saturated alluvium in the disposal area. The storage of water in the alluvium was calculated from the volume of saturated alluvium by using a 25 percent porosity. The amount of water in transit storage varies because of variations in the amount of surface water entering the disposal area (fig. 6). Surface water recharge at present is sufficient

Figure 6 (caption on next page) belongs near here.

to maintain water in the alluvium as far downgradient as well MCO-7 (fig. 2).

The distribution of moisture in the alluvium was determined by a scaler and a neutron-scattering moisture probe lowered into access tubes completed in the alluvium. The moisture content of the alluvium on the floor of the upper canyon is as much as 40 percent by volume during complete saturation. In the capillary fringe (above the zone of saturation) the moisture content ranged from 20 to 30 percent by volume. Above the capillary fringe the moisture content ranged from 10 to 20 percent.

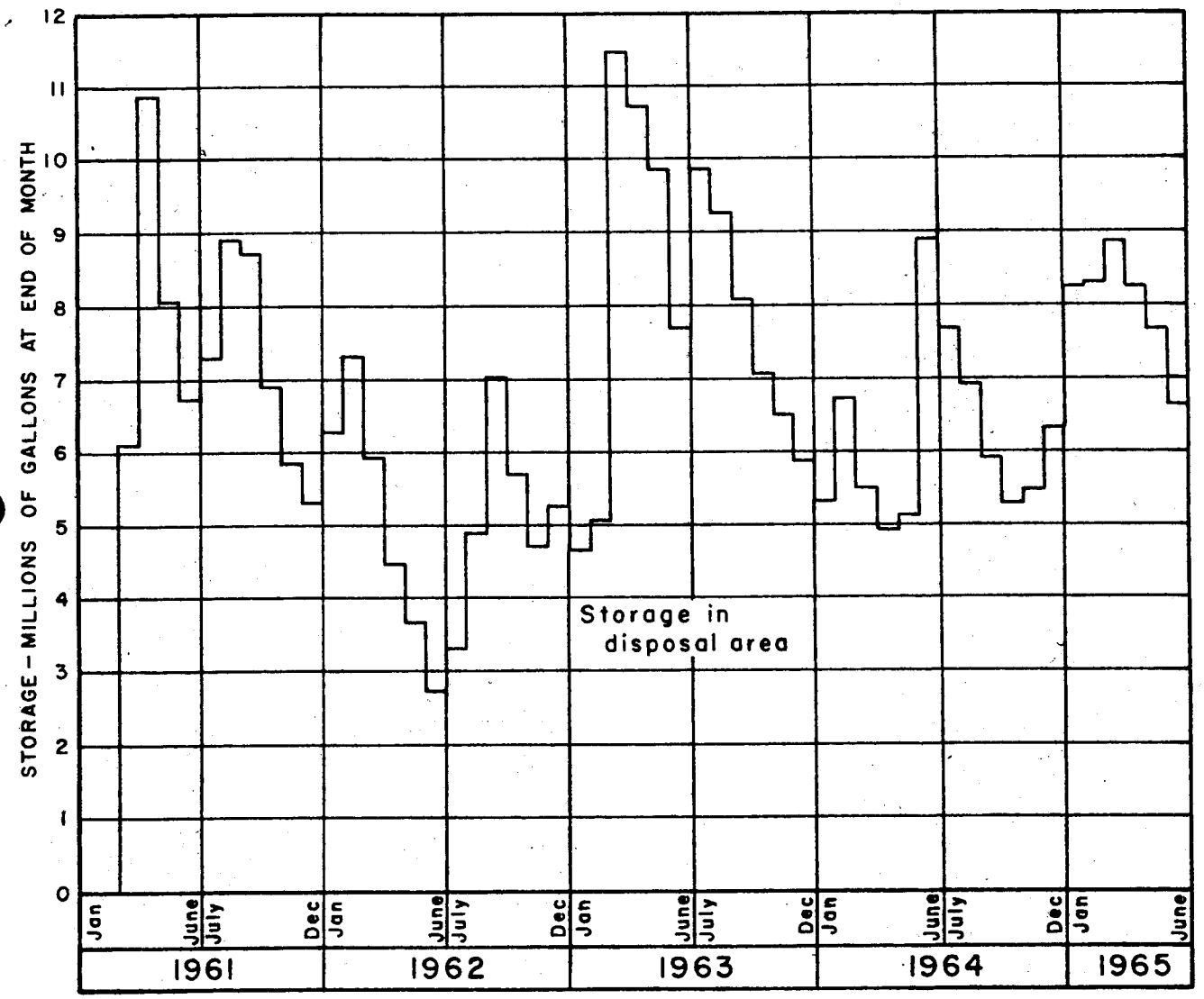


Figure 6.--Estimated storage in the alluvium of the disposal area,

The alluvium in the middle and lower canyons contains three distinct zones of moisture. The moisture content of the alluvium in the capillary fringe ranged from 20 to 30 percent by volume and rose 4 to 6 feet above the zone of saturation. Above the capillary fringe the moisture content of the alluvium ranged from 4 to 8 percent to a depth of about 8 feet then varied from 10 to 38 percent by volume from 8 feet to the surface depending upon prevailing weather conditions.

A moisture gradient in the upper 8 feet of alluvium occurs after measureable precipitation. The gradient ranges from 30 to 38 percent at a depth of 1 foot to less than 10 percent at a depth of 8 feet. The measurements made after the precipitation show a decrease in the moisture contents of the alluvium in the upper 8 feet with no change occurring in the zone below (range 4 to 8 percent). Thus, the precipitation on the floor of the canyon outside the stream channel infiltrates to a depth of 8 feet and then is returned to the atmosphere by evapotranspiration.

Movement of water

The observation wells were used to determine the rate of movement of water through the alluvium. The rate of movement of water in the alluvium changes due to the amount of water in transit storage. The changes in the amount of water in transit storage either increases or decreases the water table gradient which is the major factor in determining rate of movement.

The hydrologic characteristics of the alluvium were determined by two aquifer tests of MCO-2. The field coefficient of permeability from these tests ranged from 6,000 gpd per sq. ft. (gallons per day per square foot) to 6,500 gpd per sq. ft. The well is completed in a silty sand. The coefficient of permeability was used to determine the rate of movement and the amount of water entering the middle and lower canyons by percolation through the alluvium.

The rate of movement of water in the middle and lower canyon was computed from coefficient of permeability of 6,000 gpd per sq. ft., an average gradient of 140 feet per mile and a porosity of the alluvium of 25 percent by volume. The movement of water in the alluvium in the middle and lower canyon is about 85 feet per day.

The alluvium in the upper canyon is able to store and to transmit water into the tuff if the surface flow at gaging station GS-1 is less than 30 to 35 gpm. When the surface discharge exceeds this rate over a period of time the alluvium will become saturated as the tuff is unable to receive the excess.

The surface flow infiltrates into the alluvium near the leading edge of the stream but will continue along the entire stream due to the slow eastward movement of the water in the alluvium and continuing loss into the tuff. The front of the saturation zone is represented by a mound, which moves downgradient in the stream. When the amount of surface flow becomes less than the amount of water lost by moving downgradient in the alluvium and into the underlying tuff, the front of the surface flow will adjust to the point where infiltration is equal to the amount lost into the alluvium and tuff (Abrahams and others, 1962, p. B-93).

The phenomenon of building a groundwater mound in the alluvium occurs on a small scale 8 to 25 times a week with the discharge of industrial effluents in the upper canyon. It occurs on a larger scale when the discharge of waste water and storm runoff is combined with industrial effluent and may extend into the middle canyon. It results in differential rates of movement of the effluents and confuses the interpretation of chemical and radiochemical quality of water from individual discharges of effluent.

Water losses into the tuff

Water losses from the alluvium into the tuff were estimated for the upper, middle, and lower canyons of the disposal area (fig. 7).

Figure 7 (caption on next page) belongs near here.

The losses were determined by a comparison of the amount of surface water entering the upper and middle canyons, the average monthly amounts of water moving through the alluvium in various sections of the canyon and monthly changes in storage in various sections of the canyon (table 3). Th losses estimated by evapotranspiration (Hantush method) in the upper canyon are also shown on figure 7.

Surface water recharge to the zone of saturation in the alluvium in the upper canyon is rapid because the alluvium is highly permeable and is relatively thin. The upper canyon was able to absorb almost all of the streamflow that occurred in the canyon over a two year period except during discharge of waste water from New Sigma. The waste water discharged from New Sigma July 1963 and June 1964 caused near saturation of the alluvium in the upper canyon as did the waste water from TA-48 and storm runoff from November 1964 to June 1965. These periods of recharge are reflected by the increase of water in transit storage in the middle and upper canyons. The increase of water in transit storage in each section of the canyon is accompanied by increased losses into the tuff.

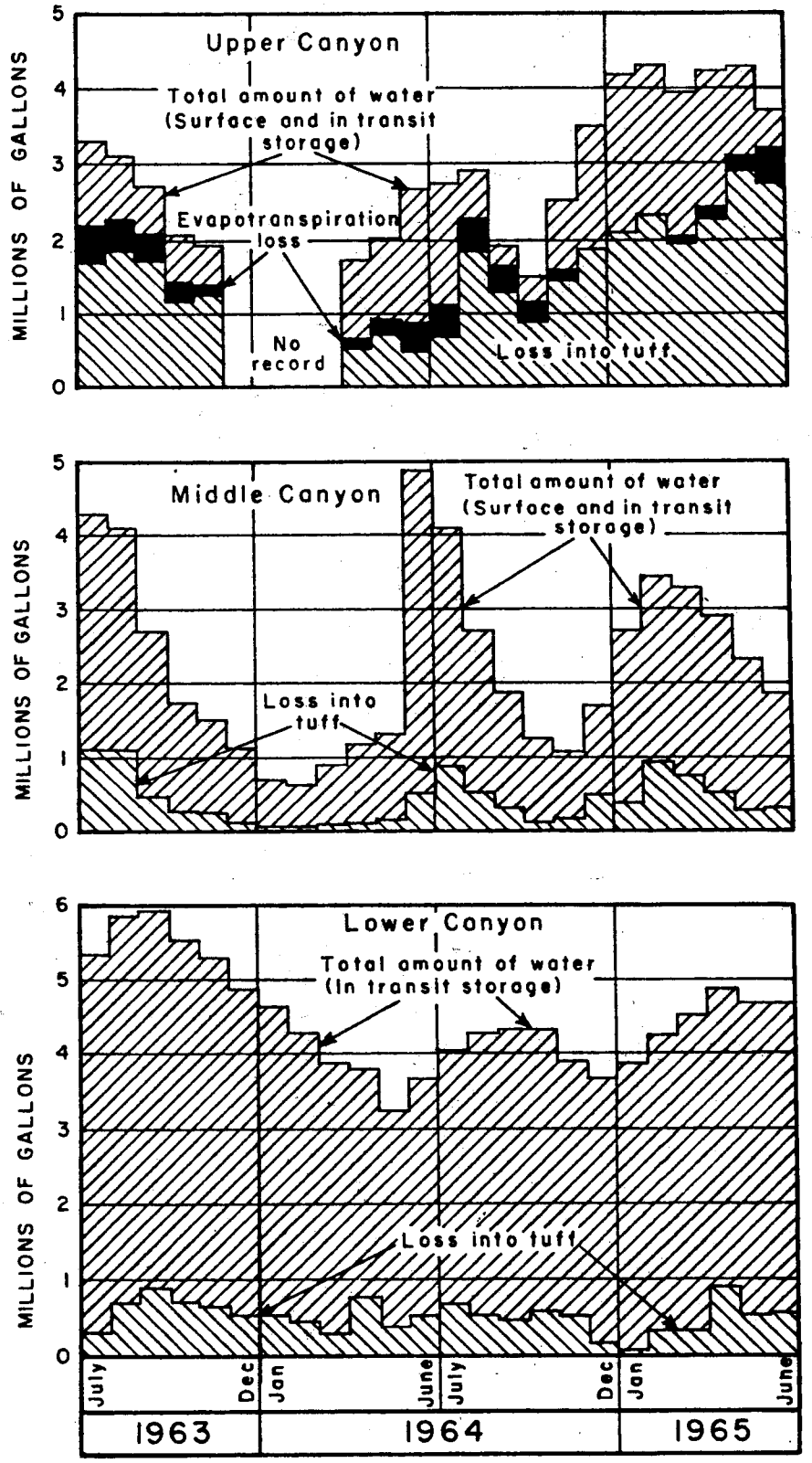


Figure 7.--Water in transit storage and loss into the tuff in the upper, middle, and lower canyons of the disposal area.

Larger amounts of water were lost into the tuff in the upper canyon than in the middle and lower canyons. The weathering of the tuff to silt and clays has progressed more rapidly in the middle and lower canyons than in the upper canyon thus decreasing the permeability. This is shown by the average loss per square foot into the tuff in the various sections of the canyon from July 1963 to July 1965.

	Average loss (gpd per sq ft)
Upper Canyon	0.4
Middle Canyon	.1
Lower Canyon	.04

Periodic moisture measurements are made in the tuff underlying the alluvium in the upper canyon (MCM-1 and 2), middle canyon (MCM-3), and lower canyon (MCM-4 and 5) to determine moisture distribution. The moisture content of the tuff in the upper canyon ranged to a maximum of 28 percent by volume. Over a three month period the moisture content of the tuff beneath the stream varied as much as 6 percent at given depths. The tuff in the middle canyon (MCM-3) ranged to a maximum of about 36 percent by volume. The moisture content varied as much as 4 percent by volume at given depths showing some movement of water into the tuff. In the lower canyon the moisture content of the tuff (MCM-4 and 5) ranged to a maximum of 48 percent by volume. There is very little or no change of the moisture content at given depths. Gamma-radiation logs indicate the tuff underlying the alluvium in the lower-canyon contains a fine material (weathered tuff composed of a large amount of clay) that is of low permeability, thus restricting the amount of water moving downward from the alluvium.

Quality of water

Industrial effluents discharged into the disposal area are diluted by waste water and storm runoff. The amount of dilution varies and is reflected in the chemical and radiochemical quality of the water in the alluvium. The dilution occurs largely in the upper canyon as the water moves through the alluvium (fig. 8). It was observed that the

Figure 8 (caption on next page) belongs near here.

chemical contamination decreased downgradient; however, individual chemical constituents varied due to slight changes of the chemical quality of the industrial effluent as well as the amount of dilution of the effluents with waste water and storm runoff (table 4).

The sodium ions may move at a faster rate than chloride ions indicating that some chemical constituents move at differential rates. Some of these ions lag behind as a result of physical and chemical affinity of the ions in solution to the ions of the clay minerals.

The sodium concentrations began to increase in well MCO-1 in August 1963, well MCO-2 in September 1963, well MCO-3, MCO-4, and MCO-5 in October 1963, with no significant change in sodium concentrations in well MCO-6 until July 1964. Chloride ions began to increase in well MCO-1 in September 1963, well MCO-2 in December 1963 and not until February 1964 in wells MCO-3, MCO-4, and MCO-5. Chlorides have not changed significantly in well MCO-6 to June 1965.

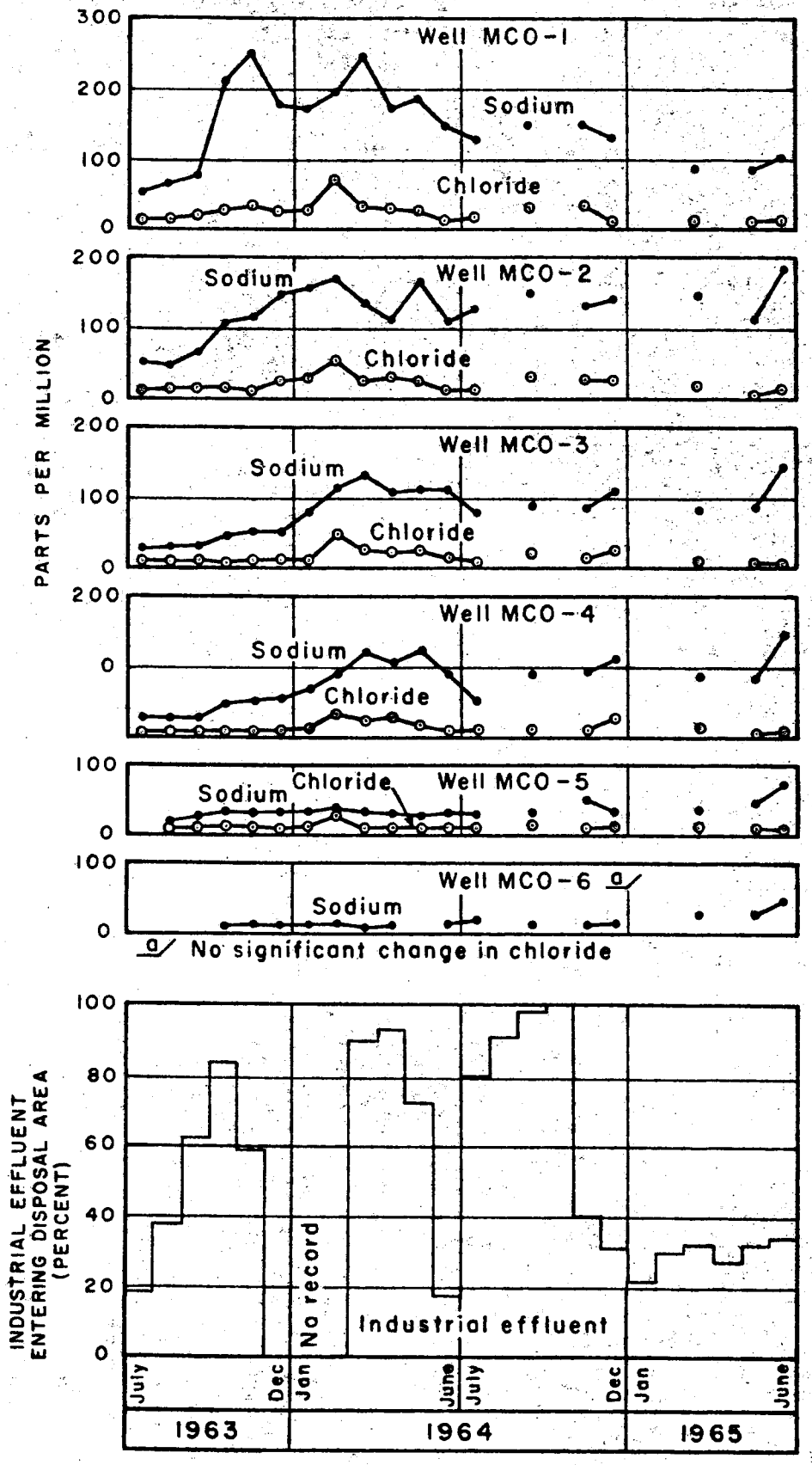


Figure 8.--Dilution of effluents with waste water and storm runoff and effects on sodium and chloride in observation wells.

Table 4.--Selected chemical

(Analyes by the

Source	Date of collection	Parts per (gamma)				
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)
Well MCO-1	5-22-63	.95 19	.41 5	33	0	110
Do.	6-23-64	.20 4	.04 .5	144	8	207
Do.	6- 8-65	.20 4	.02 .2	100	8	186
Well MCO-2	5-21-63	.50 10	.33 4	32	0	110
Do.	6-24-64	.80 16	.25 3	108	0	189
Do.	6- 8-65	.40 8	.33 4	181	6	198
Well MCO-3	5-21-63	.40 8	1.40 17	23	0	77
Do.	6-24-64	1.00 20	.49 6	108	0	109
Do.	6- 8-65	0.65 13	.33 4	142	0	158
Well MCO-4	5-21-63	0.55 11	.58 7	20	0	72
Do.	6-24-64	1.00 20	.49 6	88	0	85
Do.	6- 8-65	0.65 13	.25 3	142	0	154
Well MCO-5	5-21-63	.75 15	1.40 17	24	0	65
Do.	6-24-64	.70 14	.33 4	31	0	72
Do.	6- 8-65	.80 16	.08 1	68	0	110
Well MCO-6	5-21-63	.80 16	.66 8	11	0	55
Do.	6-24-64	1.00 20	.49 6	17	0	64
Do.	6- 8-65	1.15 23	.74 9	42	0	92
Well T-8	11-30-61	.55 11	.25 3	15	4	58
Do.	11-15-63	.40 8	.66 8	16	0	62
Do.	9-24-65	.50 10	.25 3	10	0	58

The various chemical constituents generally varied with time in individual wells; however, the larger amount of change occurred in well MCO-1 in the upper canyon (fig. 9). The chemical constituents from well MCO-2

Figure 9 (caption on next page) belongs near here.

and MCO-4 have increased steadily during the period of July 1963 to June 1965 (figs. 10 and 11). Slight variations in individual constituents

Figure 10 (caption on next page) belongs near here.

Figure 11 (caption on next page) belongs near here.

in these wells are due to dilution and differential movement of water owing to "slug" type discharge with waste water. Water from well MCO-6 had changed very little until June 1964. Since that time there has been only a slight increase in most chemical constituents (fig. 12).

Figure 12 (caption on next page) belongs near here.

The degree of change of the chemical constituents in the water decreased downgradient in the disposal area. This is due in part to the relative unstable chemical combination in the effluent adjusting to the environment and in part to dilution of the industrial effluents with waste water and storm runoff which infiltrate at a greater distance from the point of effluent discharge. The slower movement and the longer time in transit storage allows chemical changes to occur before the water reaches the eastern-most part of the disposal area.

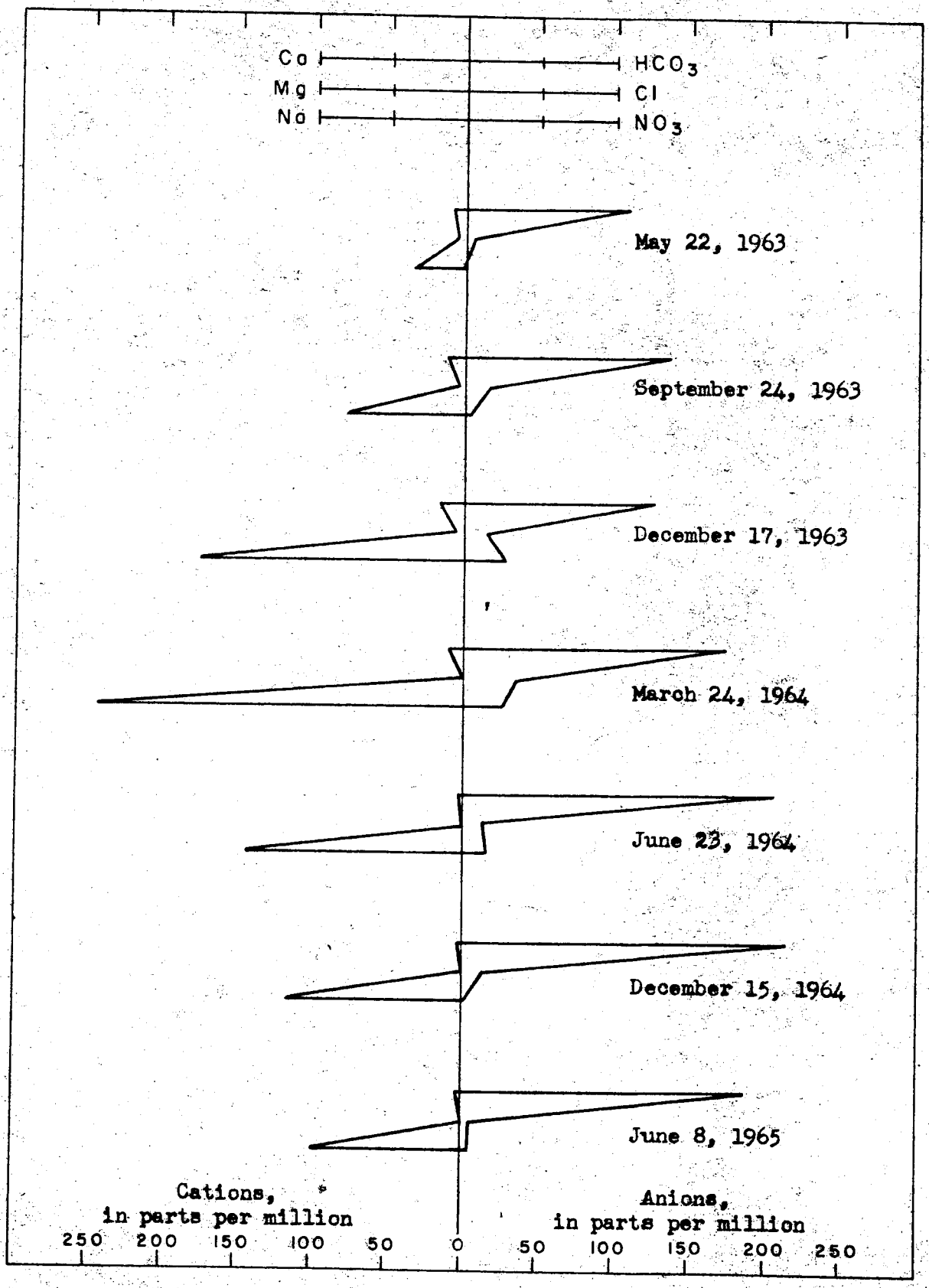


Figure 9.--Graphic comparison of the chemical quality of water from well MCO-1.

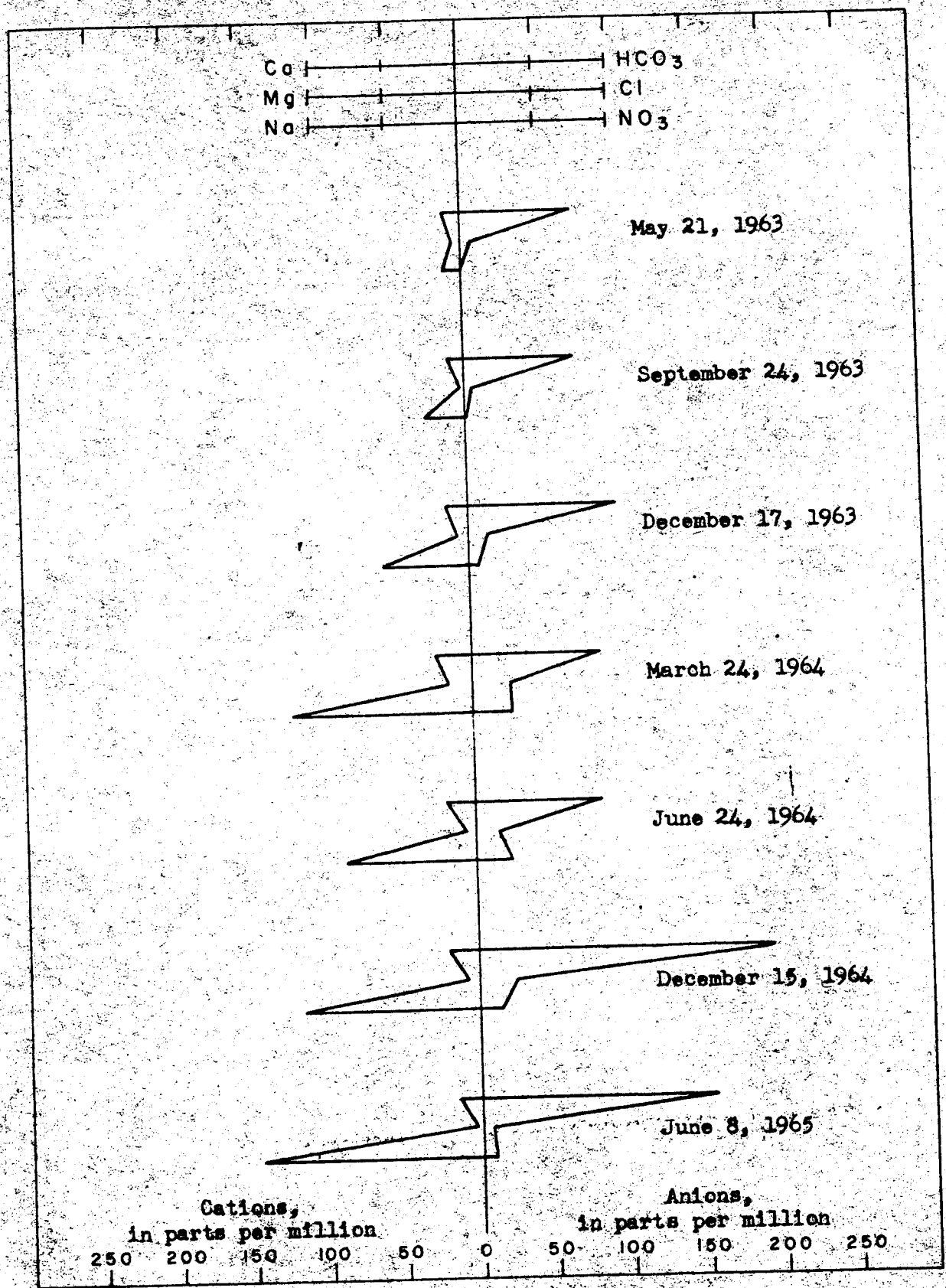


Figure 10.--Graphic comparison of the chemical quality of water from well MCO-2.

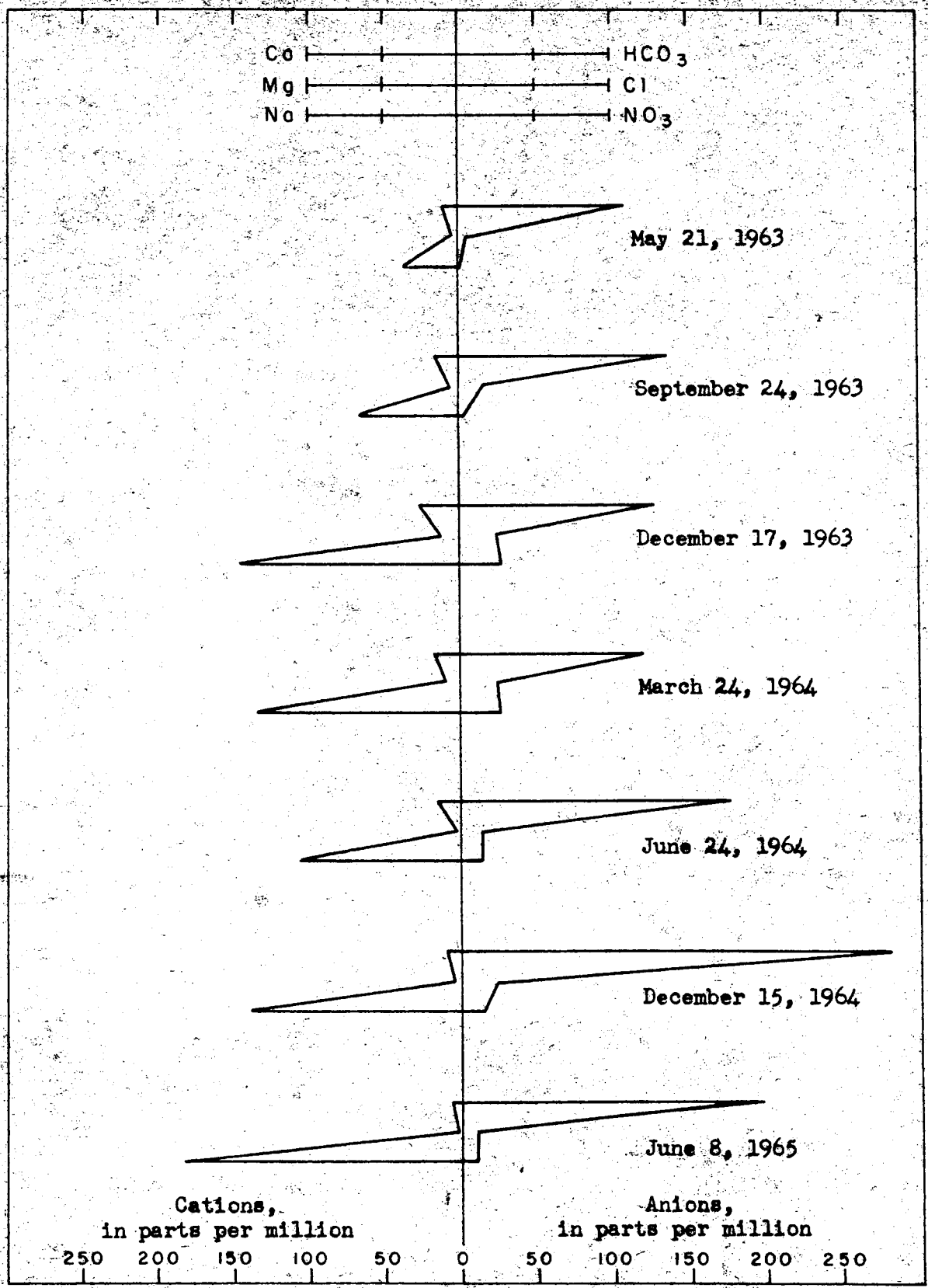


Figure 11.--Graphic comparison of the chemical quality of water from well MCO-4.

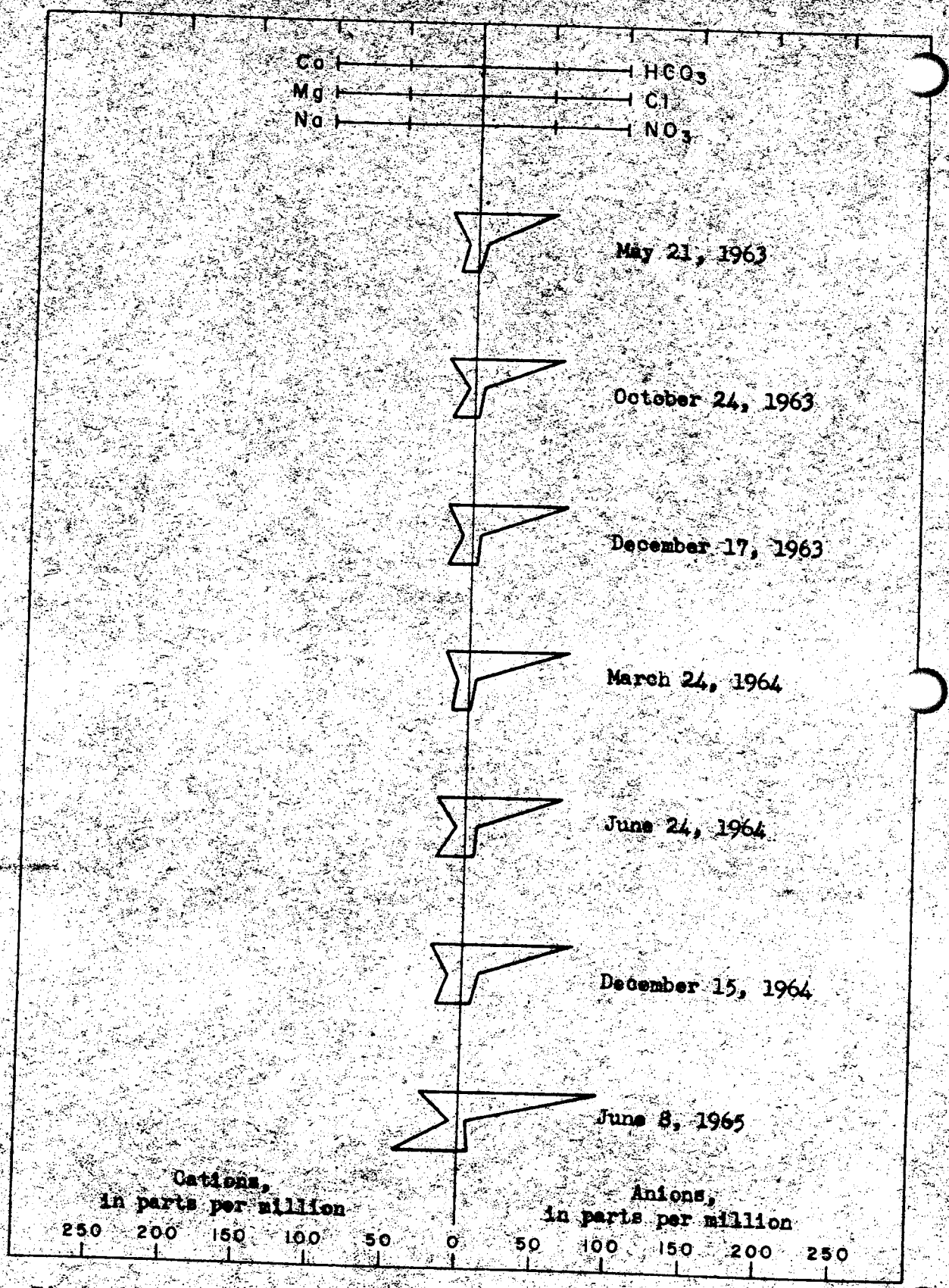


Figure 12.--Graphic comparison of the chemical quality of water from well MCO-6.

The radiochemical contamination varied throughout the disposal area with the larger amounts occurring near the effluent outfall in the upper canyon in well MCO-1. Plutonium contamination of varing amounts occurred in water from all the wells and was greatest in well MCO-1 (fig. 13). The variations of amounts of plutonium in water from

Figure 13 (caption on next page) belongs near here.

the wells is due to variable composition of the effluents, to slug type discharge of the effluent and dilution of effluents with waste water and storm runoff. Uranium was reported from well MCO-5 prior to the discharge of effluents into the canyon from TA-50. The uranium may be from waste water discharged from New Sigma. Beta-gamma emmiters were found in water from wells throughout the disposal system (fig. 14).

Figure 14 (caption on next page) belongs near here.

They were highest in the upper canyon at well MCO-1 and generally decreased downgradient in the disposal area. Periods of high beta-gamma emitters occurred in well MCO-1, December 1963, 1,843 pc/l (picocuries per liter) and November 1964, 2,224 pc/l; well MCO-2, November 1964, 1,494 pc/l; and well MCO-3, November 1964, 1,787 pc/l during the two year period July 1963 to June 1965.

Dilution of the industrial effluents with storm runoff and waste water reduces the concentration of radioactivity carried downgradient in the disposal area. The binding of the radionuclides in the effluents to the alluvial material in the disposal area also aids in reducing the amount of radioactivity in the water moving through the alluvium or into the tuff.

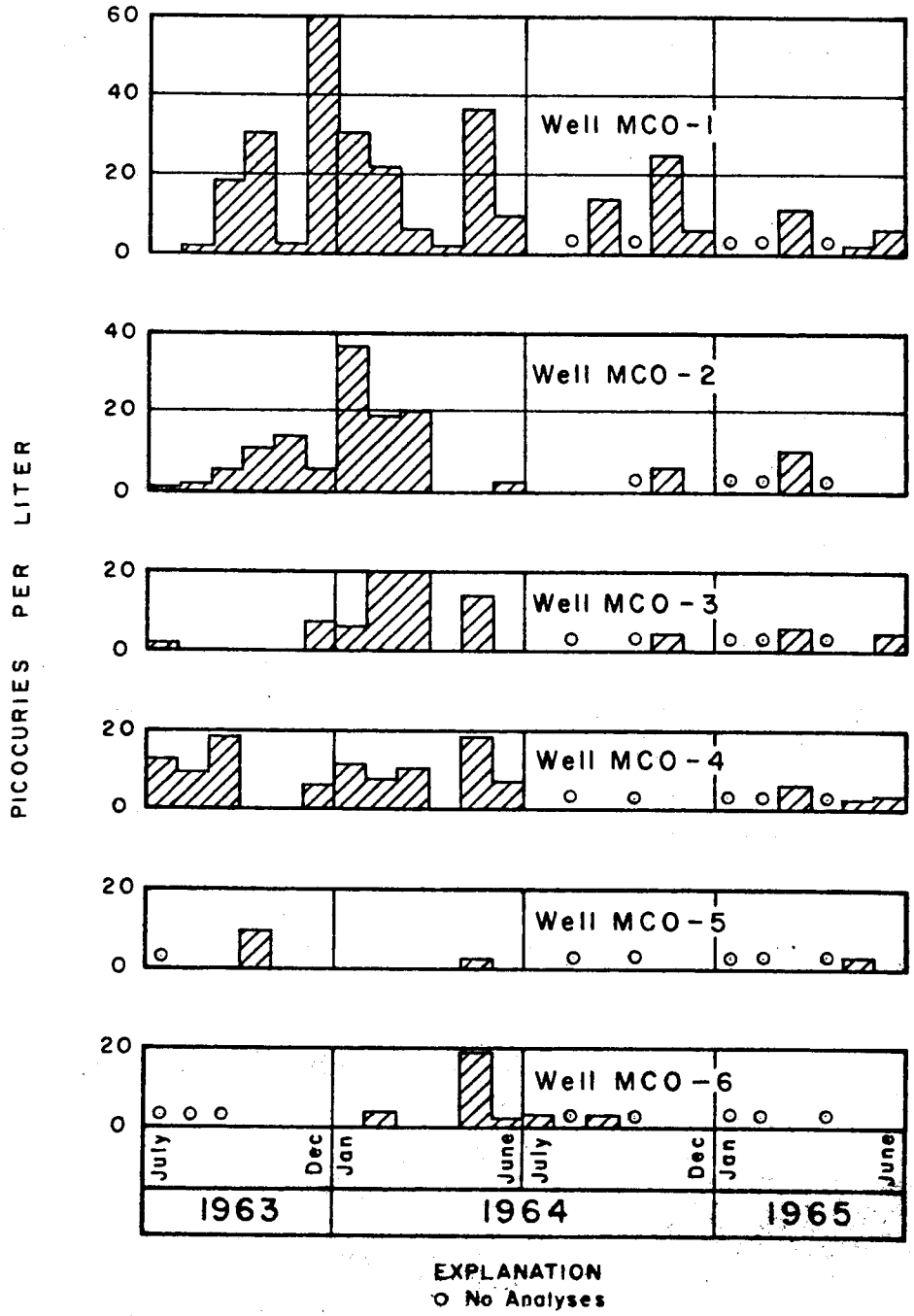


Figure 13.--Graphic comparison of plutonium in water from observation wells.

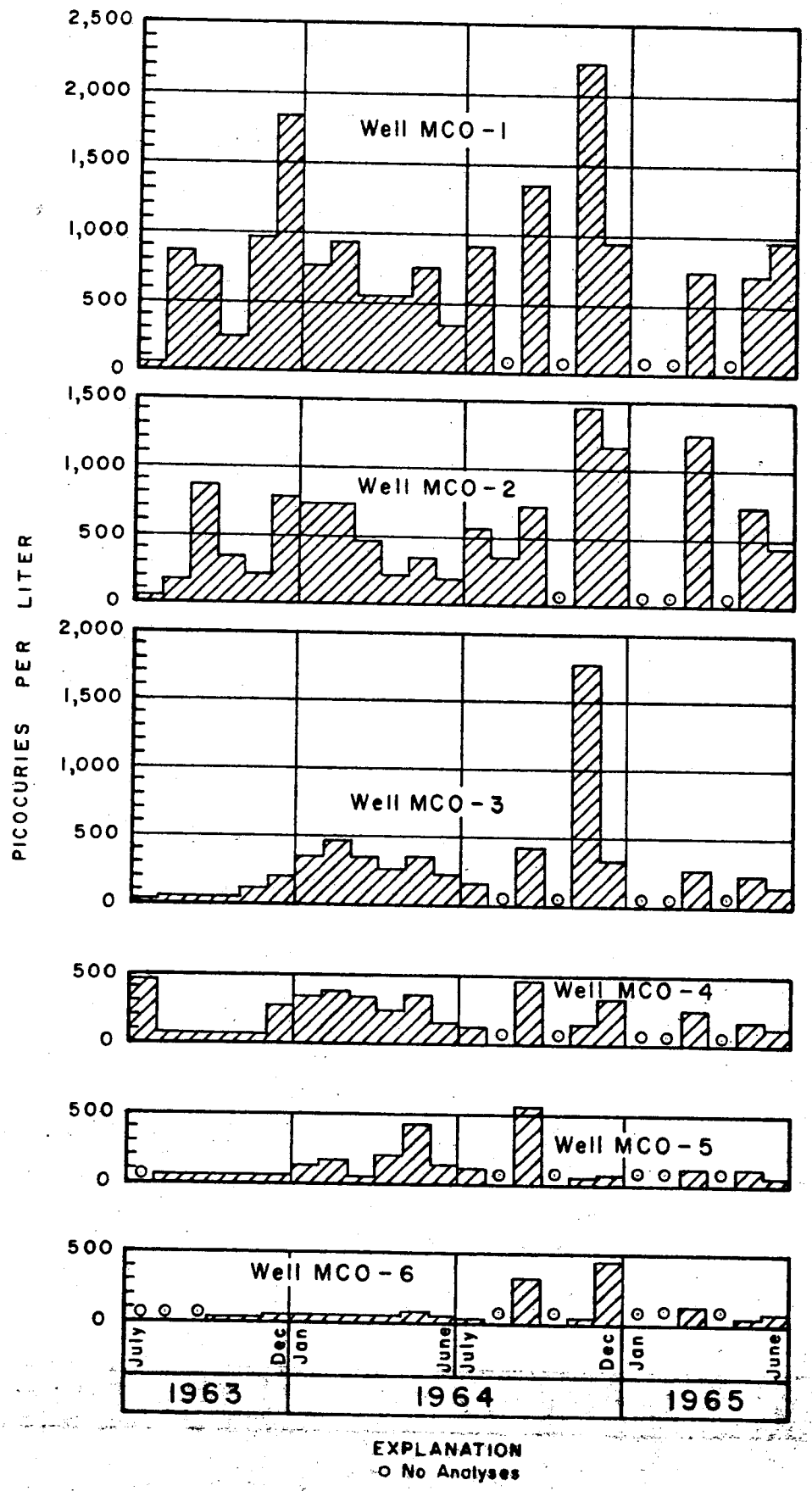


Figure 14.--Graphic comparison of beta-gamma radioactivity in water from observation wells.

Adsorption of radioactivity in the alluvium

The chemical quality of the industrial effluents change as they move as surface or ground water in the disposal area due to their relatively unstable chemical combinations. The changes occur as adsorption of certain ions in the alluvial material as the effluent adjusts to the environment. One of the factors facilitating the adsorption, retention, and exchange of most of the radionuclides in the alluvial material is the high pH (average about 11) of the industrial effluents and the mineral composition of the alluvial materials.

The alluvial materials in the disposal area are derived by weathering from the Tshirege Member of the Bandelier Tuff. The predominant minerals are quartz, sanidine, and the clay minerals; montomorillonite and illite. Rock fragments are latite, rhyolite, rhyolitic tuff, and pumice. The larger size fragments (pebbles, cobbles, and boulders) are mostly rhyolitic tuff. The porosity of the fragments of tuff and pumice is large (20 to 60 percent by volume in microscopic voids). The surfaces around these microscopic voids, as well as outer surfaces of these rock fragments, are in the process of weathering into clay. The quartz and sanidine are also weathering and are coated with microscopic platy crystals of clay minerals. The end product of weathering in the tuff is mainly the clay minerals montomorillonite and illite, which have high base exchange capacities. Clays attached to the quartz, sanidine, tuff, and pumice fragments vary due to the degree of weathering; however, all contain some clay minerals, and thus facilitate the adsorption and retention of radionuclides.

Distribution of radioactivity relative to particle size

Samples of alluvial material in the stream channel of the disposal area were collected and mechanically separated. The separation was made into seven fractions ranging from silt to granule size. A cumulative curve for the particle size distribution of alluvium from station MCS-1, MCS-4, and MCS-7 show a general increase of finer material downgradient in the disposal area (fig. 15). The

Figure 15 (caption on next page) belongs near here.

increase was due to the reworking of material in the stream channel resulting in finer particle sizes further downgradient.

The seven fractions from each sampling station were analyzed for gross alpha, beta, and gamma radioactivity and radioactive strontium. It was observed that the distribution of the radioactivity corresponds roughly with the size and mineral composition of the various particles. In general, more radioactivity was found in the smaller grain size material (silt, clay, very fine sand, and fine sand) and decreases with increasing particle size (table 5). The silt and clay, very fine sand, and fine sand are made up mainly of clay minerals or products that are rapidly weathering to clays. The granules contain greater gross beta activity, gross gamma activity and radioactive strontium per unit weight than do the more siliceous medium, coarse, and very coarse sand particles at Station MCS-1. This is because the granules consist mainly of tuff and pumice having high microscopic porosity and are in the process of weathering to clay.

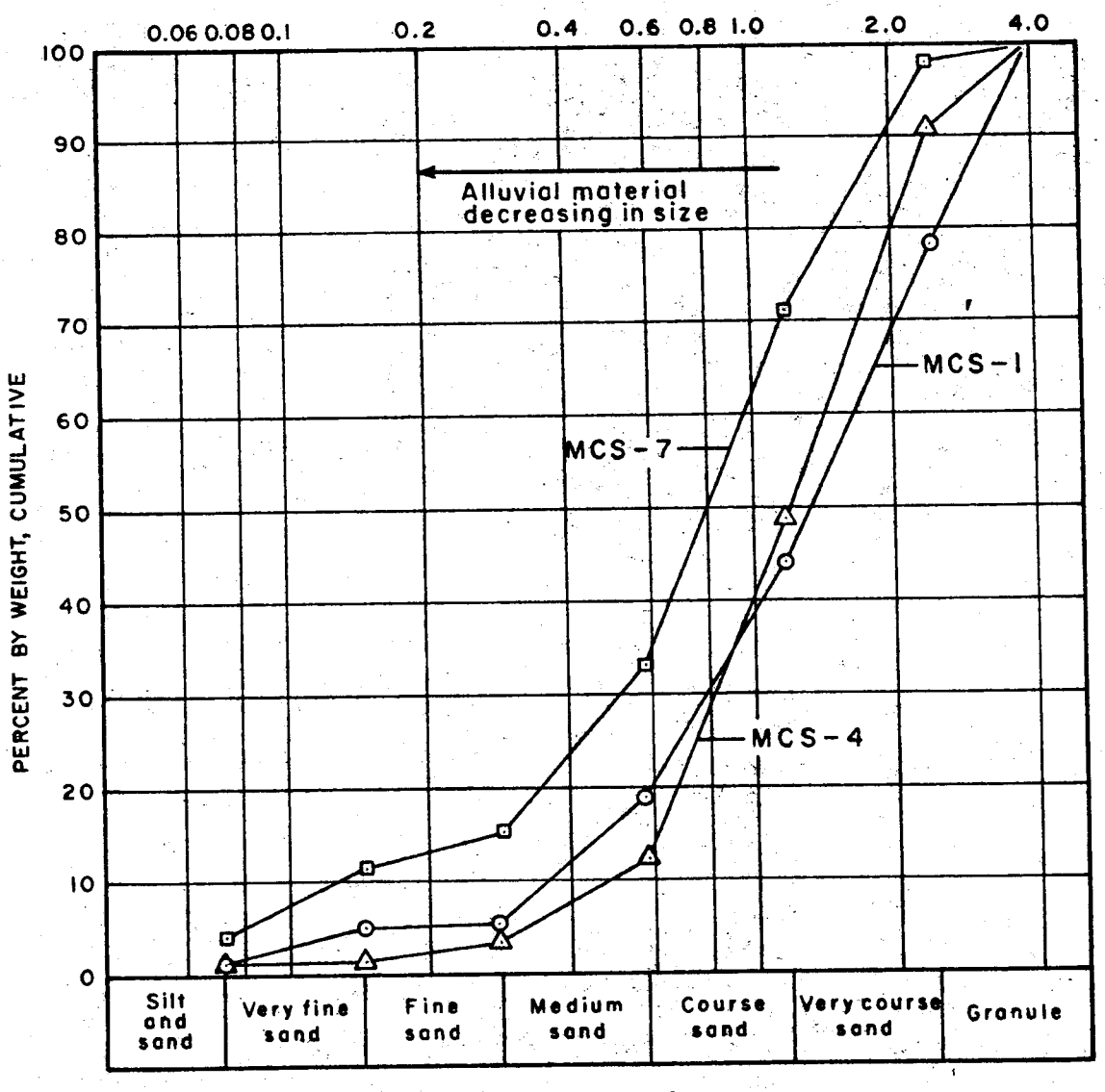


Figure 15.--Cumulative curve of particle size of alluvium in stream channel at stations MCS-1, MCS-4, and MCS-7.

Table 5.--Gross alpha, beta, and gamma radioactivity and radioactive strontium of respective fractions of alluvium from station MCS-1. (Analyses by the Los Alamos Scientific Laboratory, Group H-7)

Fraction	Particle			Counts per minute per gram (dry weight)			
	Size (millimeters)	Distribution (percent by weight)	Cumulative (percent by weight)	Gross Alpha activity	Gross gamma activity	Gross Beta activity	Radioactive strontium
Silt and clay	.074 -	1.0	1.0	45	128	1,751	42
Very fine sand	.074 - .147	3.5	4.5	33	75	799	49
Fine sand	.147 - .295	.5	5.0	24	61	771	27
Medium sand	.295 - .589	13.5	18.5	15	33	396	23
Coarse sand	.589 - 1.17	25.5	44.0	8	32	414	17
Very coarse sand	1.17 - 2.36	34.0	78.0	5	24	239	15
Granule	2.36 - 3.96	22.0	100.0	4	35	425	31

Relative distribution of radioactivity in the disposal area

Distribution of the radionuclides in the seven particle size fractions show that radioactivity has a greater affinity for the silt and clay, very fine sand, and fine sand; however, these fractions make up less than 5 percent (by weight) of the total amount of alluvium (silt and clay to granule size fraction) at MCS-1 and MCS-4. Silt and clay, very fine sand, and fine sand increase from MCS-4 to MCS-7 where they make up about 14 percent (by weight) of the alluvium. Thus, most of the radionuclides are found in the medium, coarse, and very coarse sand and granule particle size fraction simply because more of this coarse material is available (fig. 15).

The radioactivity decreases with depth in the alluvium. Gross alpha activity decreases about 70 percent and gross gamma activity about 98 percent between the surface and a depth of 3 feet. Radioactive strontium was retained in the upper foot of alluvium.

Most of the radionuclides are retained or adsorbed on the alluvial materials between Station MCS-1 and Station MCS-3 (fig. 16). The

Figure 16 (caption on next page) belongs near here.

environment maintained by the effluents in that part of the canyon (mainly a high pH) facilitates retention and adsorption of radionuclides with the alluvial materials in this reach of stream channel.

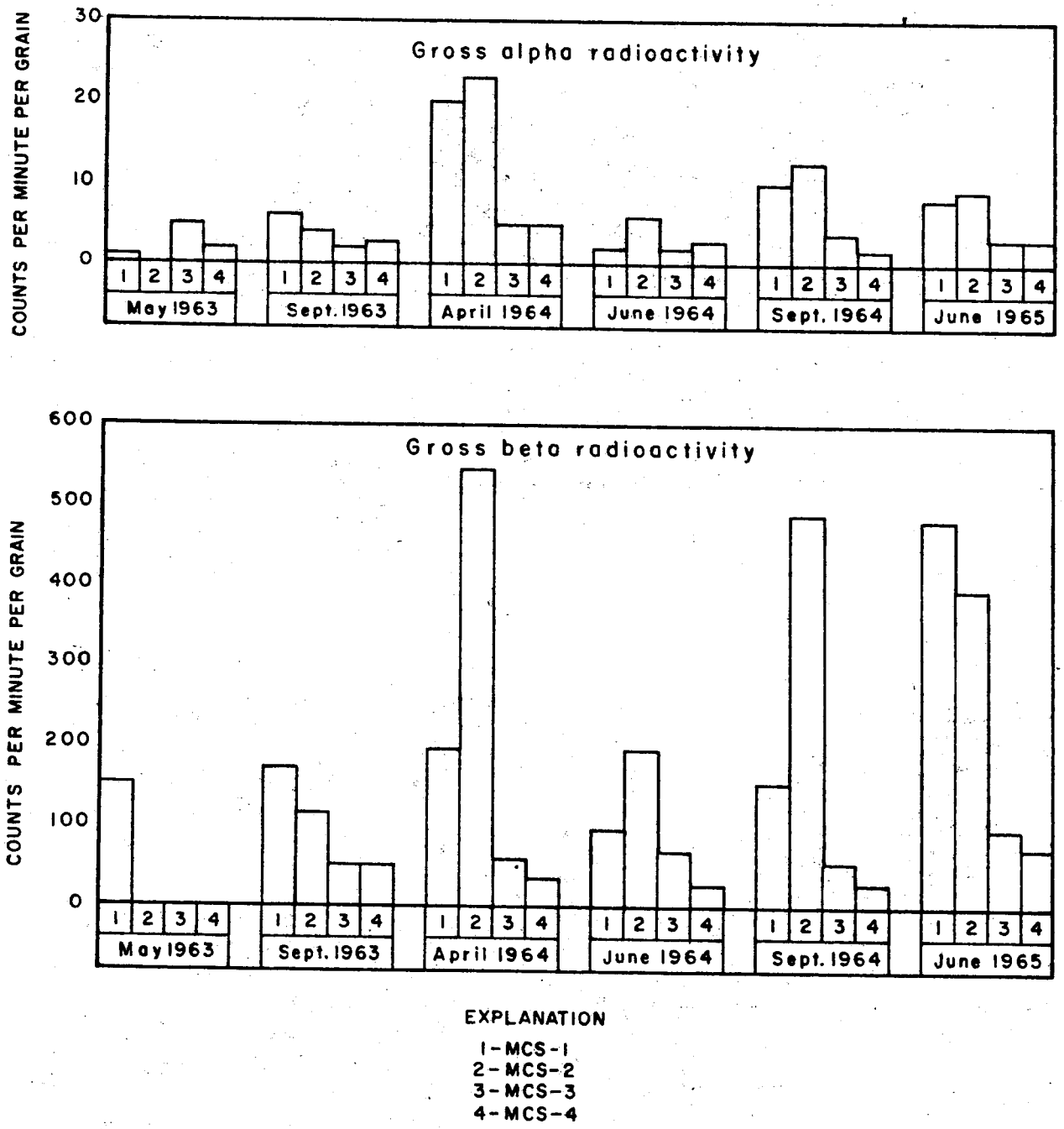


Figure 16.--Distribution of radioactivity in alluvium in the upper canyon.

A decline of gross alpha and beta activity occurred in the upper canyon from April 1964 to June 1964, a period when a large discharge of waste water was released (fig. 16). The radionuclides dislocated by the waste water were deposited with the translocated sediment; however, as they were dispersed over a larger area further sampling and analyses of alluvial material east of MCS-3 failed to show an increase in radioactivity. As a result, the radiochemical quality of the water in the alluvium in the disposal area has remained good because the concentrations of radioactivity is reduced by dilution of the effluents with waste water and storm runoff and by retention and adsorption of the radionuclides by the alluvial materials.

Main aquifer

The top of the main aquifer of the Los Alamos area at well T-8 in the disposal area in Mortandad Canyon is approximately 990 feet below land surface. The water is confined in the lower part of the fanglomerate member of the Puye Conglomerate. When the base of the confining bed was penetrated, water rose in the hole to 962.6 feet below land surface. The well was drilled to a total depth of 1,065 feet, about 80 feet into the upper part of the main aquifer. Unsaturated tuff and pumice sediments, and basalt occurred between the perched water in the alluvium and the main aquifer. Although no perched water was present in the unsaturated materials, potential perching beds are present. These beds retard improvement of contaminates downward.

The gradient on the eastward-sloping potentiometric surface of the main aquifer in the vicinity of well T-8 is about 70 feet per mile, and the water is generally moving eastward toward the Rio Grande. The general slope of the potentiometric surface indicates that the recharge area is to the west, in the deep canyons cut into the western part of Pajarito Plateau or the east flank of the Sierra de los Valles.

A water stage recorder was operated on well T-8 for about a year after completion of the well in early 1961 and periodic water level measurements were made when the recorder was removed. Diurnal changes were reflected by slight water-level fluctuations. The water-stage records and periodic water level measurements indicated no periods of differing recharge because the average water level in the well remained constant.

Movement of water in main aquifer

An aquifer test was made to determine the hydrologic characteristics of the part of the main aquifer tapped by well T-8. The water was bailed at an average rate of 16 gpm during a 2-hour test. The residual drawdown, 5 minutes after vailing ended, was 0.35 foot. Recovery to the original water level was complete 8 minutes after bailing ended. It was impossible to determine the total amount of drawdown and rate of recovery during the first 5 minutes after bailing ended due in part to the depth to water and rapid rate of recovery. Thus, the coefficient of transmissibility and the permeability computed from the data obtained in the bailing test are considered to be only approximations.

The coefficient of transmissibility is defined as the rate of flow, in gallons per day, of water under a unit hydrologic gradient at prevailing temperature through a 1-foot wide vertical strip equal to the thickness of the aquifer. The coefficient of transmissibility is determined from the rate of drawdown or recovery of the water level during or after a period of pumping or bailing, and the rate of withdrawal which is a method devised by Theis (1935, p. 522) and later described by Wenzel (1942, p. 96). The coefficient of transmissibility is calculated to be 2,400 gpd per ft (gallons per day per foot) for the part of the main aquifer penetrated by well T-8. This figure may be slightly higher or lower than the actual transmissibility, because the rapid recovery of the water level resulted in fewer measurements that are usually considered necessary to determine the rate of recovery. The field coefficient of permeability (estimated from the transmissibility) is about 30 gpd sq. ft for the lower part of the fanglomerate member of the Puye Conglomerate at well T-8.

The movement of water in the fanglomerate member at well T-8 was estimated from the available hydrologic data, gradient of the potentiometric surface 70 feet per mile, coefficient of permeability of 30 gpd/ft^2 and an estimated porosity of the aquifer of 25 percent by volume. The movement of water in the aquifer penetrated by well T-8 probably is about 0.2 foot per day or about 70 feet per year.

The distance from the disposal area to the Rio Grande (natural discharge point for ground water) is 6 miles. At a rate of movement of about 70 feet per year it would take more than 100 years for any contamination remaining in the water to reach the river.

Because of the time elapsed between the end of the bailing test and the drawdown measurement, the total amount of drawdown is not known. However, by using the transmissibility, the specific capacity (gallons per minute per foot of drawdown) is estimated to be about 1 gpm per foot of drawdown (Bentall, 1963, p. 334).

Quality of water in main aquifer

Chemical analyses of water from well T-8 show that it is low in dissolved solids and is soft. Calcium, magnesium, and sodium are in almost equal amounts and are the principal cations. More than 90 percent of the anions are bicarbonate. The temperature of the water (67 degrees F) is similar to that of other test wells on the Pajarito Plateau that have been completed into the top of the main aquifer. Samples of water collected during the investigation show no significant change in chemical constituents (table 4).

Radiochemical analyses indicate that the concentrations of radionuclides are low and show no signs of contamination from industrial effluents discharged into Mortandad Canyon.

Movement of ground water from the disposal area

Low-level radioactive effluents, waste water, and storm runoff infiltrate into the alluvium of the disposal area to recharge a body of water perched in the alluvium overlying the Bandelier Tuff. As the water moves downgradient (eastward) some is lost to evapotranspiration while the largest amounts infiltrate into the underlying tuff. The greater loss into the tuff occurs in the upper canyon of the disposal area because the alluvium is more permeable overlying the tuff. In the lower part of the middle canyon and lower canyon the lower unit of alluvium consists of a sandy silt that is of low permeability that reduces the amount of water lost in to the tuff.

The movement of water is downward through the tuff; however, the rates of movement of the water varies due to different hydrologic characteristics of the tuff. The fanglomerate member of the Puye Conglomerate and the basaltic rocks of Chino Mesa underlying the tuff contain some lenses of silt and clay that would tend to perch and distribute over a large area the water moving downward to the main aquifer. The main aquifer of the Los Alamos area is overlain by about 1,000 feet of unsaturated volcanic rocks and sediments. The movement of water in the main aquifer is eastward toward the Rio Grande where part is discharged through a series of springs above the river channel and directly into the channel. It would take more than 100 years for the water in the upper part of the main aquifer to move from the disposal area to the natural discharge area along the river.

Conclusions

Mortandad Canyon is the major disposal area for low-level radioactive effluents at Los Alamos. It is an isolated canyon cut into the Bandelier Tuff, which forms the Pajarito Plateau. The drainage area of the canyon above and within the disposal area is small. The alluvium in the canyon, derived from weathering of the tuff, is thin in the upper canyon but thickens eastward into the middle and lower canyon. The small drainage area and the volume of alluvium (to absorb the storm runoff) reduces the chances for sudden storms to produce enough runoff to flush contaminates from the disposal area to the Rio Grande. About 1,000 feet of unsaturated volcanic rocks and sediments of the Bandelier Tuff, Puye Conglomerate and basaltic rocks of Chino Mesa overlie the main aquifer in the disposal area. The movement of the water in the upper part of the main aquifer is slow, about 70 feet per year. The slow movement of the water in the aquifer would allow ion-exchange and half life decay of radionuclides of any contaminates that should reach the aquifer, so that no contamination would remain in the water when it reaches its natural discharge area.

Chemical and radiochemical quality of water (surface and water in the alluvium) of the disposal area improves downgradient from the point effluent discharge. This is due to: 1) dilution of the effluent with storm runoff and waste water in the disposal area; and 2) by adsorption of certain ions and radionuclides by clay minerals in the alluvium.

The geology and hydrology of the disposal area in Mortandad Canyon is ideal for the disposal of low-level radioactive effluents. The effluents are confined within the disposal area and the environment (physical and chemical) is such as to further reduce chemical and radiochemical contamination of the effluents.

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