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Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545

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W. D. Purtymun
R. J. Peters
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GEOHYDROLOGY OF WHITE ROCK CANYON OF THE RIO GRANDE FROM OTOWI TO FRIJOLES CANYON

by

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ABSTRACT

Twenty-seven springs discharge from the Totavi Lentil and Tesuque Formation in White Rock Canyon. Water generally acquires its chemical characteristics from rock units that comprise the spring aquifer. Twenty-two of the springs are separated into three groups of similar aquifer-related chemical quality. The five remaining springs make up a fourth group with a chemical quality that differs due to localized conditions in the aquifer. Localized conditions may be related to recharge or discharge in or near basalt intrusion or through faults. Streams from Pajarito, Ancho, and Frijoles Canyons discharge into the Rio Grande in White Rock Canyon. The base flow in the streams is from springs. Sanitary effluent in Mortandad Canyon from the treatment plant at White Rock also reaches the Rio Grande.

I. INTRODUCTION

The Los Alamos Scientific Laboratory (LASL) and the communities of Los Alamos and White Rock are located on the Pajarito Plateau west of the Rio Grande. The eastern edge of the plateau terminates along White Rock Canyon. This canyon is formed by downcutting of the Rio Grande (Fig. 1). The elevation of the Rio Grande is about 1680 m at Otowi decreasing to 1620 m at the confluence of Frijoles Canyon, about 18 km to the south. The western rim of the canyon is formed by the Pajarito Plateau, which rises as much as 340 m above the river. The eastern rim of the canyon is formed by the uplands of La Mesita and Cerros del Rio that rise above the river 200 m to 380 m, respectively.

The Pajarito Plateau, west of the Rio Grande, is drained by Los Alamos, Sandia, Mortandad, Pajarito, Water, Ancho, Chaquihui, and Frijoles Canyons. The area east of the river is drained by Cañada Ancha and several smaller, unnamed canyons. With two exceptions, the canyons drop precipitiously into White Rock Canyon. The channels in Los Alamos Canyon and Cañada Ancha slope steeply to the river (Fig. 2).

Sanitary effluent from the treatment plant at White Rock forms a perennial flow in lower Mortandad Canyon that discharges into the Rio Grande. Base flow in streams in Pajarito and Ancho Canyons is from spring discharge from the Totavi Lentil. The springs provide perennial flow to the Rio Grande. The flow in lower Frijoles Canyon is intermittent, with discharge reaching the river when evapotranspiration rates are low. Some water is discharged directly into the river from alluvial fans at the mouth of Los Alamos and Frijoles Canyons.

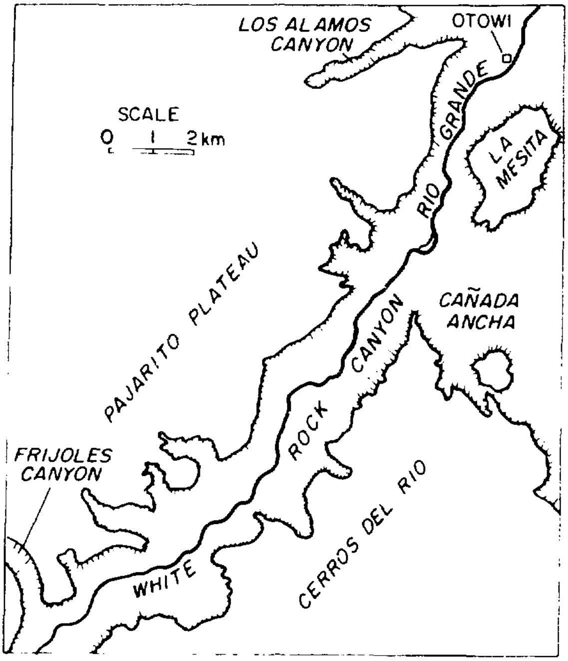


Fig. 1.
Topographic features adjacent to White Rock Canyon.

Twenty-seven springs and seeps are located in White Rock Canyon from Otowi to Frijoles Canyon. Of these, seven are located on the east side of the Rio Grande. These springs discharge ground water from the upper surface of the main aquifer of the Los Alamos area (west of White Rock Canyon), which rises westward from the river through the Tesuque Formation.[1,2] To the east the aquifer remains within the Tesuque Formation. East of the river, basalts intruded in and through the Tesuque Formation (at La Mesita and Cerros del Rio) form a partial barrier to ground water movement toward the river.[3]

In 1964, a study was made of the geohydrology of the White Rock Canyon.[4] The chemical quality of 21 springs and 3 streams was described. These springs and stations on the streams are used as a part of the present water quality monitoring system. The springs and streams are sampled on an average of every two years for chemical and radiochemical analyses. The purpose of this paper is to update the 1964 report. This will provide a better basis for interpreting of water quality data for the annual report issued by LASL, "Environmental Surveillance at Los Alamos."[5-7]

II. GEOLOGY

White Rock Canyon is located near the center of the Española Basin, which contains sediments and interbedded basalts.[8] The canyon was formed by the downcutting of the Rio Grande through the basaltic rocks of Chino Mesa. The basaltic rocks form the rim and upper parts of the canyon walls (Figs. 3, 3A, 3B, 3C). The Puye Formation underlies the basalts and is exposed in the canyon above the siltstones, sandstones, and interbedded basalts of the Tesuque Formation. The latter forms the lower part of the canyon walls and floor.

The Tesuque Formation and the Totavi Lentil (lower member of the Puye Formation) are described in detail as these units contain springs and seep areas. The description of the units is drawn largely from Griggs and are described from oldest to youngest.[9]

The Tesuque Formation is a sequence of light-colored sediments laid down as coalescing alluvial fan and flood plain deposits in the Rio Grande depression. It is composed of moderately well-cemented beds of fine to coarse grained arkosic siltstone and sandstone and some conglomerate and clay lenses. The Tesuque Formation also contains some volcanic debris and interbedded basalts. North of the confluence of Water Canyon and the Rio Grande the sediments are mostly fine-grained. They are shown in Figs. 3A-3C as TS(FG). South of the confluence of Water Canyon and the river, the outcrops of the Tesuque Formation contain interbedded basalt flows. The sediments above and below the basalts contain volcanic debris that is much coarser than the sandstone that is found in the Tesuque Formation to the north. These basalts and coarser sandstones are shown in Fig. 3C as TS(CG). The coarser sandstones and interbedded basalts are younger than the main body of the Tesuque Formation that is present from Otowi to Water Canyon.

The Puye Formation consists of two members. The lower member is a channel fill deposit named the Totavi Lentil. The upper member, the fanglomerate member, is composed of volcanic debris.

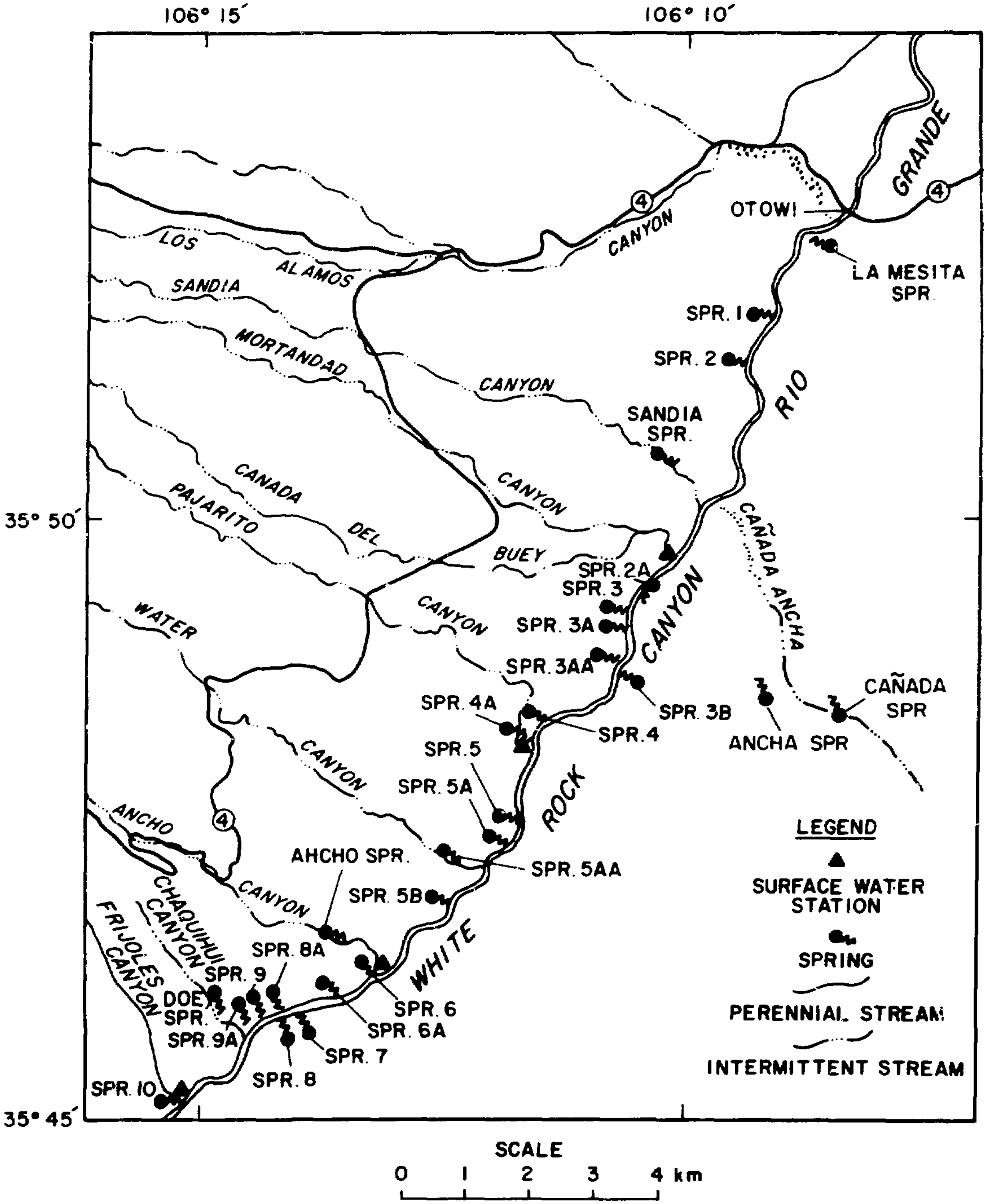


Fig. 2.
Generalized location of springs in White Rock Canyon.

The Totavi Lentil overlies the Tesuque Formation along the Rio Grande to a point below Ancho Canyon. Here it wedges out between the underlying Tesuque Formation and the overlying basaltic rocks of Chino Mesa (Fig. 3C). The Lentil consists mainly of subrounded to well-rounded quartzite and quartz pebbles and boulders. Sorting is generally poor, but well-sorted lenses of silt and sand are present. The thickness ranges from a few meters to about 15 m. The Totavi Lentil is shown in Figs. 3A-3C as QTp(TL).

The fanglomerate member of the Puye Formation is a gray fanglomerate composed of rhyolite, latite, quartz latite, some basalt, and water laid pumice in a matrix of silt and sand. The fanglomerate overlies the Totavi Lentil south of Los Alamos Canyon and wedges out between the lentil and basaltic rocks of Chino Mesa about 3 km south of Otowi. The fanglomerate does not outcrop along the eastern edge of White Rock Canyon. The fanglomerate member is shown as QTp in Fig. 3A. No springs or seeps issue from the fanglomerate member.

The basaltic rocks of Chino Mesa consist of numerous reddish-brown to black basalt flows. These are vesicular to dense and include interflow zones of clay, silt, and basalt fragments. The basalts rest on the Tesuque Formation south of Ancho Canyon and on the Totavi Lentil and fanglomerate member north of Ancho Canyon. Along Los Alamos Canyon, younger basalt flows overlie the fanglomerate member. Basalt intrusion through the Tesuque Formation forms numerous plugs in La Mesita and Cerros del Rio. The basaltic rocks of Chino Mesa are shown in Figs. 3A-3C as QTb. The basaltic rocks of Chino Mesa contain no springs or seeps.

Recent alluvium along the Rio Grande consists of silt to boulder-size debris of a variety of materials. Near Otowi the alluvium may be as much as 8 m thick; southward it forms a thin sheet overlying the Tesuque Formation. At the mouth of Los Alamos, Sandia, Mortandad, Pajarito, Ancho, and Frijoles Canyons large alluvial fans are deposited, causing the water to flow against the east canyon wall. The alluvium along the Rio Grande is not shown on Figs. 3A-3C as it was not of consequence to this study.

III. HYDROLOGY

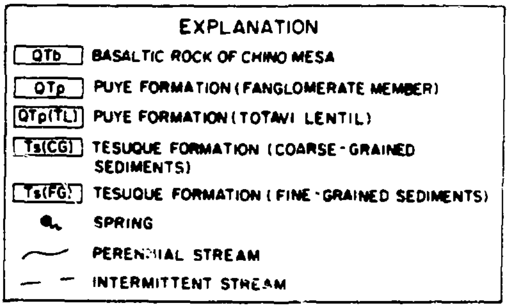
Water from springs generally acquires its chemical characteristics by solution of minerals in the rock units that compose the aquifer. Based on similar water quality and aquifer characteristics, the springs have been separated into four groups. Group I – springs that discharge from the Totavi Lentil; Group II—springs that discharge from the Tesuque Formation coarse-grained sediments, Group III springs that discharge from Tesuque Formation fine-grained sediments, and Group IV – springs that discharge near intrusion basalts or faults having slightly different chemical characteristic because of localized conditions of the aquifer. These Group IV springs discharge from the fine-grained Tesuque Formation along the east side of the canyon. They are in the area of numerous basalt flows and intrusions that form La Mesita and Cerros del Rio.

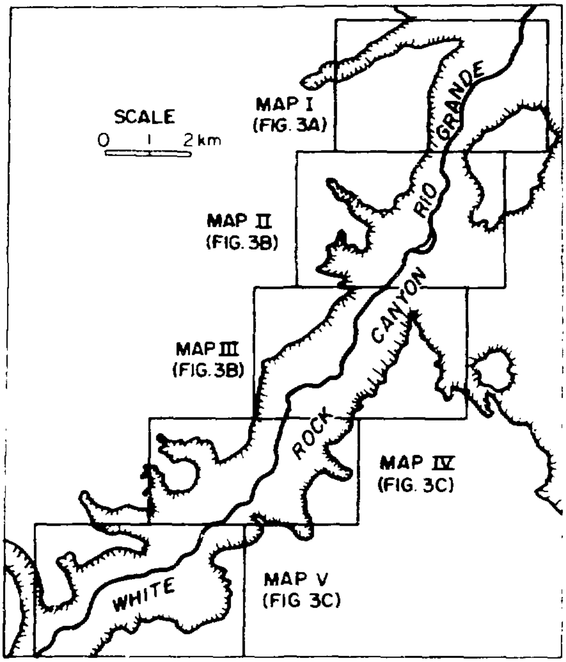
High flow in the Rio Grande has covered some of the springs at times when samples were collected, so that in some years these data are missing. A near complete set of data was collected in 1978. These chemical data are considered to be representative of the quality of water from the individual springs. The missing data were filled in from the most recent years.

The chemical analyses were performed to determine the types of water and if chemical quality changes takes place with time. No samples were collected and analyzed for bacteria.

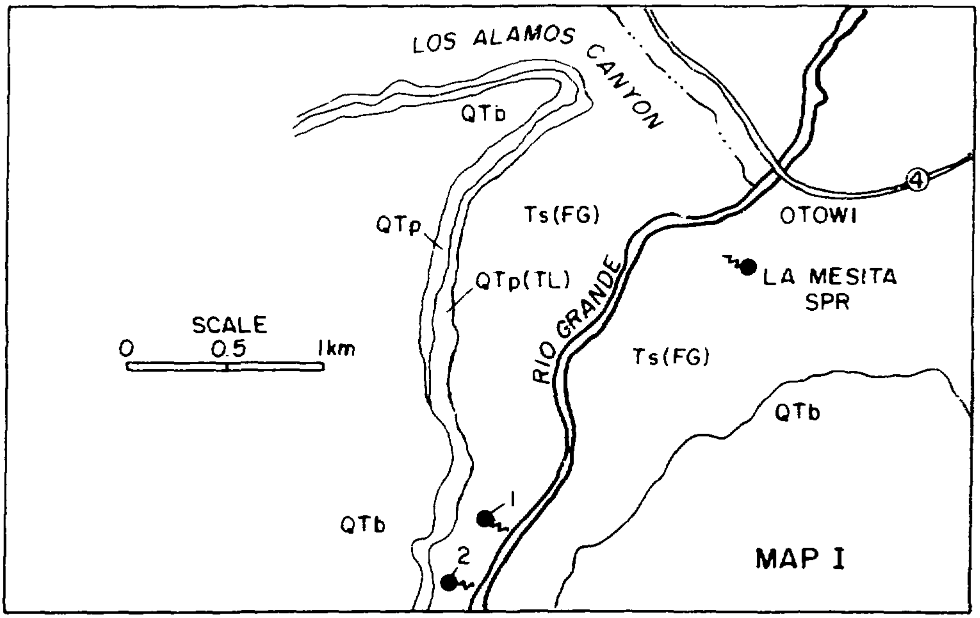
In comparing data from individual springs and streams over the years, some slight variation in chemical quality is evident. The chemical variations are small and are due to seasonal influences such as changes in air temperature and the effects of evapotranspiration on spring discharge. The variations in water quality are within the range normally expected and are not considered significant.

Radiochemical analyses of spring and stream water are performed along with chemical analyses. Radiochemical analyses are for gross alpha, gross beta, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{3}H, and total U. The concentrations of ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{3}H have been below limits of detection in samples collected since 1967. During 1978 the limits of detection for ^{137}Cs was <120 pCi/ℓ; ^{238}Pu, and ^{239}Pu were <0.02 pCi/ℓ;



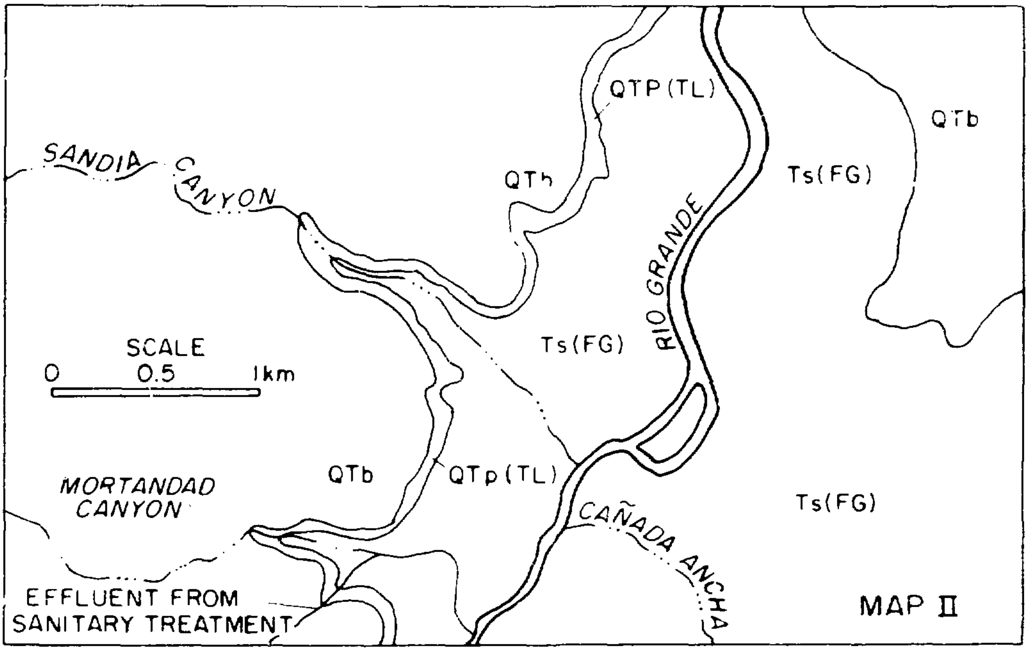


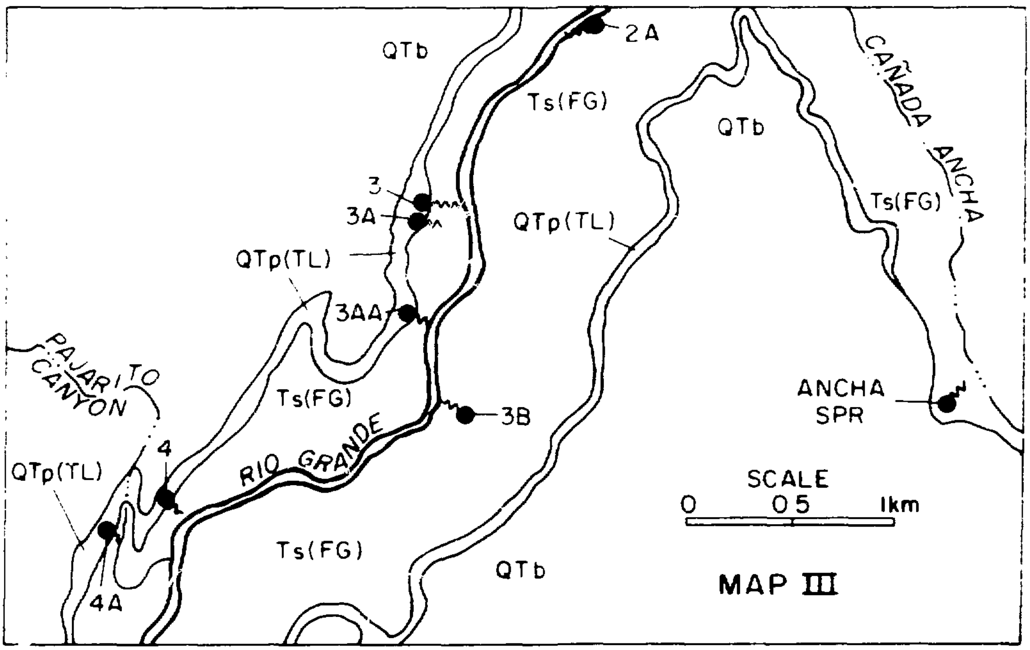
INDEX MAP



A. Map I.

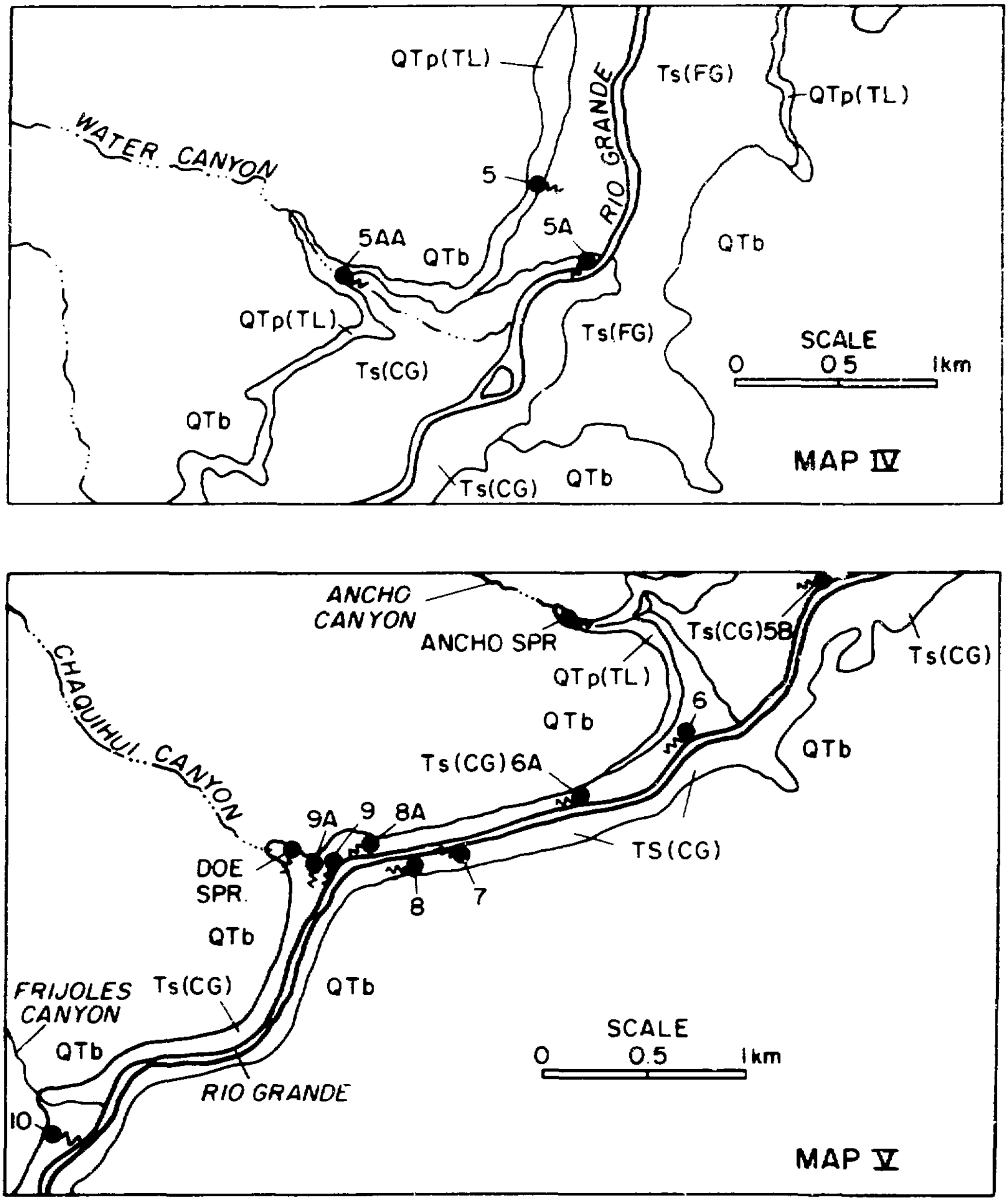
Fig. 3.
Geologic map of White Rock Canyon.





B. Maps II and III.

Fig. 3 (Cont)



C. Maps IV and V

Fig. 3 (Cont).

and ^3H was <1500 pCi/ℓ.[8] Thus, only the gross alpha, gross beta, and total U in water from the springs and streams are discussed. This radioactivity is natural, taken in the solution by the ground water moving through the aquifers.

A. Springs

The Group I springs (Totavi Lentil) are all on the west side of the river. They range in elevation from 1737 m in Sandia Canyon to the north to 1683 m near Pajarito Canyon and then increase in elevation to the south to 1737 m near Ancho Canyon where the Totavi Lentil wedges out between the coarse-grained Tesuque Formation and basaltic rocks of Chino Mesa (Figs. 3A-3C). Springs in this group form the base flow in Pajarito and Ancho Canyon (Table I). Discharge from all but two of the springs reaches the Rio Grande. The discharge in Sandia Canyon (Sandia Spring) and Water Canyon (Spring 5AA) is depleted by infiltration into the alluvium and evapotranspiration before reaching the river.

Discharge from the Group I springs is a calcium and bicarbonate water (Fig. 4). The average sulfate and chloride concentrations are about 4 mg/ℓ. Total dissolved solids (TDS) range from 112 to 210 mg/ℓ, with an average concentration of 163 mg/ℓ (Table II).

The Group II springs (Tesuque Formation, coarse-grained sediments) are located on both sides of White Rock Canyon. Six of the springs (Springs 5A, 5B, 6, 6A, 7 and 8) are located at the edge of the channel (Fig. 2). These springs discharge about 30 ℓ/s directly into the river. Springs in or near Chaquehui Canyon (Springs 8A, 9, 9A, and Doe) are located 40 to 60 m above the river. They provide water for large areas of vegetation. All discharge from Doe and Spring 9A is lost to infiltration or evaporation before reaching the river. Spring 10 discharges <0.1 ℓ/s from the edge of the alluvial fan at the mouth of Frijoles Canyon.

The discharge from the Group II springs is a sodium and bicarbonate water. The average sulfate and chloride concentrations are about 3 mg/ℓ. The TDS range from 154 to 262 mg/ℓ, with an average concentration of 183 mg/ℓ.

The Group III springs (Tesuque Formation, fine-grained sediments) are located on the west wall of the canyon below Otowi (Fig. 3A). The springs form large seep areas that are covered with vegetation. There is no discharge to the river because of the large losses to evapotranspiration.

Discharge from the Group III springs is also a sodium and bicarbonate water. Chemical concentrations in general are higher than in the Group I and Group II springs. Sulfate concentrations are about 10 mg/ℓ while chlorides are low at 3 mg/ℓ. The TDS ranges from 194 to 236 mg/ℓ, with an average of 215 mg/ℓ.

There are five springs in Group IV, La Mesita, Ancha, 2A, 3B, and Cañada (Fig. 2, Table II); these springs are located on the east side of the river. These springs discharge from the fine-grained Tesuque Formation where there are numerous basalt flows and plugs as well as faults.

La Mesita Spring is a seep area in and adjacent to a small channel that drains the steep western side of La Mesita (Fig. 1). La Mesita is formed by a series of intruded basalts. The seeps are in a part of the fine-grained Tesuque Formation. At the source are the remains of a gallery set into the bank above the channel. The water from the gallery was probably used by the now abandoned Denver and Rio Grande Railroad. La Mesita spring is about 20 m above the Rio Grande (Fig. 2). The spring discharges into the channel. The channel below the springs contains heavy growth of shrubs and trees, and only when evapotranspiration rates are low does water from the spring reach the Rio Grande. The discharge from La Mesita Spring is a sodium and bicarbonate water. Sulfate is about 12 mg/ℓ, chloride 6 mg/ℓ, and TDS about 286 mg/ℓ.

Ancha Spring is located about 2.6 km east of the Rio Grande in a small canyon cut into the Cerros del Rio (Fig. 2). The small canyon is a tributary to Cañada Ancha. Water from the spring issues from near the contact of the basalt with underlying volcanic sediments. Water from the spring does not reach Cañada Ancha. Discharge from the spring is a calcium and sulfate water. Sulfates are 212 mg/ℓ, chloride 5 mg/ℓ, and TDS 508 mg/ℓ, about twice the TDS concentrations found in other springs in White Rock Canyon.

Spring 2A is located on the east side of the river at about river level. The spring appears to discharge from fine-grained sediments of the Tesuque Formation; however, the chemical characteristics differ

TABLE I

RECORDS OF SPRINGS IN WHITE ROCK CANYON

	Elevation (m)	Topographic Situation	Temp (°C)	Discharge at Rio Grande (ℓ/s)	Remarks
Group I (Totavi Lentil)					
Sandia Spring	1737	Seep area in and adjacent to channel	22	0	Sandia Canyon
Spring 3	1695	Gravel terrace above river	22	1	
Spring 3A	1695	Gravel terrace above river	22	3	
Spring 3AA	1688	Gravel terrace above river	19	<1	
Spring 4	1683	Gravel slope above river	19	5.1	
Spring 4A	1683	Grravel terrace above channel	21	37	Pajarito Canyon
Spring 5	1698	Gravel on steep slope above river	21	0.6	
Spring 5AA	1756	Seep in channel forms pools	18	0	Water Canyon
Ancho Spring	1737	Gravels underlying basalt in channel	22	4.3	Ancho Canyon
Group II (Tesuque Fm. Coarse Grained)					
Spring 5A	1645	Fractures in basalt at edge of river	21	1.7	
Spring 5B	1646	Steep slope at edge of river	16	0.6	
Spring 6	1640	Fractures in basalt at edge of river	23	3.6	
Spring 6A	1638	Fractures in basalt at river level	22	9.5	
Spring 7	1637	Slope at edge of river	21	11	
Spring 8	1637	Slope at edge of river	22	4.4	
Spring 8A	1682	Seep in channel on canyon wall	22	1.6	
Spring 9	1679	Large seep area above river	20	0.5	
Spring 9A	1684	Seep area on canyon wall	19	0	Chaquihui Canyon
Doe Spring	1707	Seep area in channel and canyon wall	21	0	Chaquihui Canyon
Spring 10	1634	Edge of alluvial fan above river	19	<1	Frijoles Canyon
Group III (Tesuque Fm. Fine Grained)					
Spring 1	1711	Seep area on slope above river	18	0	
Spring 2	1707	Seep area on slope above river	17	0	
Group IV (Tesuque Fm. Fine Grained Near Basalt Intrusion or Faults)					
La Mesita Spring	1700	Seep area in and above channel	17	<1	Remains of gallery above channel
Ancha Spring	1760	Seep area in channel, volcanic sediments	21	0	
Spring 2A	1675	Gravel along edge of river	22	<1	
Spring 3B	1676	Terrace on slope above river	20	2	
Cañada Spring	1682	Seep area in Cañada Ancha	19	0	

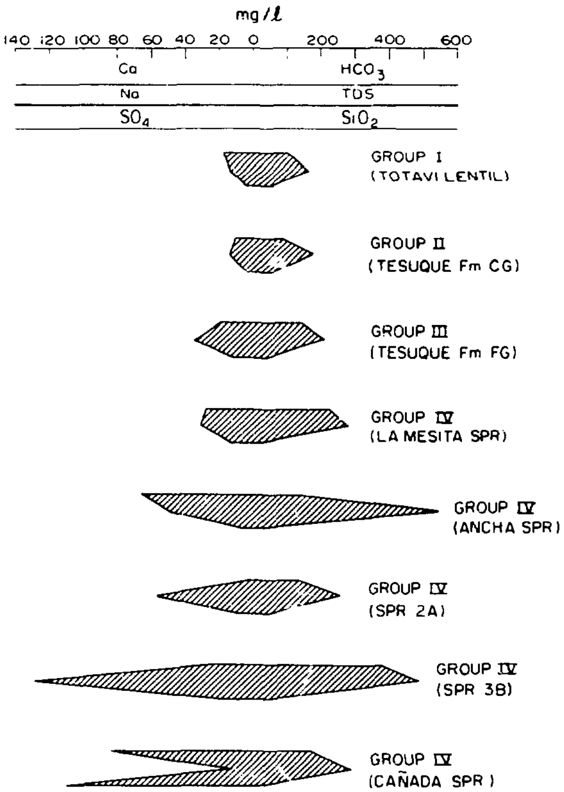


Fig. 4.
Graphic comparison of chemical characteristics of water from springs.

from other springs in the canyon. The discharge to the river is estimated at less than 0.1 ℓ/s. The discharge from spring 2A is a sodium and bicarbonate water. The sulfates are about 7 mg/ℓ, chlorides 2 mg/ℓ, and TDS 270 mg/ℓ.

Spring 3B is located east and about 30 m above the Rio Grande. The main discharge is from the top of a low mound on a moderate slope. The mound is composed of a blue clay containing gravels of rounded quartz and quartzite. The surface of the area is covered with black vescular basalt and red scoria. Numerous seeps supporting a thick cover of salt grass occur in the area. About 2 ℓ/s of discharge from the spring and seeps reach the river. Discharge from spring 3B is also a sodium and bicarbonate water. Sulfates are 16 mg/ℓ, chlorides 4 mg/ℓ, and TDS are elevated at 500 mg/ℓ.

Cañada Spring is located east of the Rio Grande in the channel of Cañada Ancha. It is a seep area in fine-grained sediments of the Tesuque Formation adjacent to a basalt plug. The discharge from the spring is a calcium and bicarbonate water. Sulfates are 106 mg/ℓ, chlorides 3 mg/ℓ, and TDS 298 mg/ℓ (Table II).

Gross alpha, gross beta and total U in water from the springs and streams are due to natural radioactivity taken into solution from the aquifer (Table III). Concentrations of gross alpha and gross beta were similar in Group I, II, and III springs. The concentration of total U in Groups I and II was slightly higher than Group III springs.

Gross alpha, gross beta, and total U were generally higher in Group IV springs (La Mesita, Ancha, 2A, 3B, and Cañada) than in water from Groups I, II, or III. Gross alpha, gross beta, and total U concentration in water from Spring 3B has been consistently higher than water from any of the other springs in the canyon. The radioactivity is natural occurring, leached from the rock units of the aquifer. Water from the Group IV springs is also highly mineralized.

The chemical quality of water from the four groups of springs is quite good. The maximum concentrations of SO_4, Cℓ, F, NO_3, and TDS are well below drinking water standards (Table IV). The concentrations of gross alpha, and total U in water from the Groups I, II, and III springs were below drinking water standards.[10] Measurements of gross alpha in water from the Group IV springs (La Mesita, Ancha, 2A, and 3B) range from 5.5 to 13 pCi/ℓ or above the standard of 5 pCi/ℓ. This may be due to presence of ^{226}Ra. Additional analyses are necessary to validate the water for domestic use. Total U in the Group IV is well below drinking water standards.[11]

B. Streams

Streams from Mortandad, Pajarito, Ancho, and Frijoles Canyons enter the Rio Grande between Otowi and Frijoles Canyons. Base flow in Mortandad is sanitary effluent from the treatment plant at White Rock. Base flow in Pajarito and Ancho Canyons is from springs discharging from the Totavi Lentil near the Rio Grande. Base flow in Frijoles Canyon is from a series of headwater springs located about 13 km west of the Rio Grande on the flanks of

TABLE II

WATER QUALITY OF SPRINGS AND STREAM IN WHITE ROCK CANYON

	mg/ℓ													μmho	pCi/ℓ		μg/ℓ
	SiO_2	Ca	Mg	Na	CO_3	HCO_3	SO_4	Cℓ	F	NO_3	PO_4	TDS	Total Hard	Specific (Cond.)	Gross Alpha	Gross Beta	Total U
Springs																	
Group I (Tetavi Lentil)																	
Sandia Spring	44	35	2.8	17	0	171	3	4	0.8	<2	<2	210	105	290	<0.5	4.2	0.8
Spring 3	58	15	1.3	14	0	83	4	3	0.4	2	<2	170	49	190	0.5	4.5	0.5
Spring 3A	48	15	1.4	14	0	98	4	2	0.4	2	<2	164	54	170	[illegible]	2.5	0.9
Spring 3AA[a]	36	20	<0.3	15	0	102	4	3	0.4	<2	<2	142	44	240	2.0	4.8	1.9
Spring 4	50	16	4.0	13	0	98	9	6	0.2	<2	<2	152	75	210	2.1	3.7	0.8
Spring 4A	62	14	4.3	12	0	105	5	5	0.5	<2	<2	180	77	200	1.7	1.1	0.7
Spring 5	62	14	4.6	12	0	105	5	4	0.4	<2	<2	112	72	210	0.7	1.7	0.1
Spring 5AA	52	16	4.0	12	0	105	3	4	0.5	<2	<2	188	83	210	2.4	5.4	0.1
Ancho Spring	70	8	2.5	10	0	73	2	2	0.3	<2	<2	145	57	130	<0.5	2.9	<0.1
Group II (Tesuque Fm. Coarse Grained)																	
Spring 5A	54	16	2.5	19	0	102	7	4	0.4	<2	<2	200	68	220	0.5	3.6	1.3
Spring 5B[b]	...	18	3.0	12	0	80	...	5	0.2	<2	...	262	59	190	<0.5	3.4	0.4
Spring 6	33	8	3.1	10	0	85	2	2	0.3	<2	<2	160	58	140	<0.5	2.3	0.6
Spring 6A	35	7	2.2	10	0	63	2	2	0.2	<2	<2	154	41	120	<0.5	2.5	<0.1
Spring 7	35	8	2.3	13	0	73	3	2	0.2	<2	<2	162	50	150	1.5	3.4	0.2
Spring 8	68	13	3.8	22	0	122	7	3	0.3	<2	<2	250	80	220	2.1	3.5	1.8
Spring 8A	72	6	1.7	11	0	66	2	2	0.3	<2	<2	160	35	120	<0.5	2.0	<0.1
Spring 9	70	8	2.5	11	0	173	2	2	0.4	<2	<2	170	60	130	<0.5	2.2	<0.1
Spring 9A	70	7	2.2	11	0	75	2	2	0.5	<2	<2	180	45	130	1.7	0.2	0.4
Doe Spring	66	8	2.5	11	0	73	2	2	0.5	<2	<2	158	42	140	<0.5	3.6	<0.1
Spring 10	62	8	2.5	11	0	78	2	2	0.5	<2	<2	160	70	140	0.7	1.3	<0.1
Group III (Tesuque Fm. Fine Grained)																	
Spring 1	32	24	1.9	32	0	170	13	3	0.7	<2	<2	194	77	290	1.0	3.9	2.3
Spring 2	30	13	0.5	47	0	117	6	3	1.0	<2	<2	236	50	280	0.9	1.8	2.2
Group IV (Tesuque Fm. Fine Grained Near Basalt Intrusions or Faults)																	
La Mesita Spring	19	27	0.6	29	0	222	12	6	0.3	8	<2	286	70	270	6.3	7.0	14
Ancha Spring[c]	16	66	23	49	0	144	212	5	0.3	12	<2	508	214	470	8	11	14
Spring 2A[b]	42	3	0.1	56	0	142	7	2	0.4	2	<2	270	20	280	5.5	4.5	8.0
Spring 3B	44	21	1.8	126	0	388	16	4	0.3	8	<2	500	61	620	13	11	20
Cañada Spring[c]	28	81	4.6	10	0	176	106	3	0.3	32	<2	298	178	350	3.2	5.1	3.7
Streams																	
Mortandad	88	16	7.6	75	5	132	37	29	0.9	60	40	552	95	600	<0.5	18	0.5
Pajarito	64	15	4.3	13	0	93	6	5	0.5	<2	<2	186	84	200	2.5	4.3	0.4
Ancho	68	9	2.8	10	0	102	2	2	0.4	<2	<2	160	50	140	<0.5	2.2	<0.1
Frijoles[d]	...	32	4.0	13	0	121		2	<0.1	2	...	246	102	260	1.7	3.0	0.9
Frijoles[a]	52	12	3.2	10	0	71	4	1	0.3	<2	<2	138	32	100	<0.5	3.4	<0.4

[a]November 1979.
[b]September 1977.
[c]May 1980.
[d]July 1977 after June 1977 wildfire

TABLE III

GROSS ALPHA, GROSS BETA, AND TOTAL URANIUM IN WATER FROM SPRINGS
(Analyses in pCi/ℓ except as noted)

	Min	Max	Gross Alpha $\bar{x}$	s
Group I	<0.5	2.4	1.4	0.9
Group II	<0.5	2.1	0.9	0.6
Group III	0.9	1.0	1.0	0.1
Group IV				
La Mesita	---	6.3	---	---
Ancha	---	8.0	---	---
Spring 2A	---	5.5	---	---
Spring 3B	---	13.0	---	---
Cañada	---	3.2	---	---

	Min	Max	Gross Beta $\bar{x}$	s
Group I	1.1	5.4	3.4	1.5
Group II	0.2	3.6	2.6	1.1
Group III	1.8	3.9	2.8	1.5
Group IV				
La Mesita	---	7.0	---	---
Ancha	---	11.0	---	---
Spring 2A	---	4.5	---	---
Spring 3B	---	11.0	---	---
Cañada	---	5.1	---	---

	Min	Max	Total U[a] $\bar{x}$	s
Group I	<0.01	1.9	0.6	0.6
Group II	<0.1	1.3	0.5	0.6
Group III	2.2	2.3	2.2	0.1
Group IV				
La Mesita	---	14.0	---	---
Ancha	---	14.0	---	---
Spring 2A	---	8.0	---	---
Spring 3B	---	20.0	---	---
Cañada	---	3.7	---	---

[a]μg/ℓ.

the mountains. A comparison of the chemical characteristics of the four streams is shown in Fig. 5 and detailed analyses are presented in Table II. Stream samples are collected above the confluence with the Rio Grande.

The chemical quality of water in Mortandad Canyon is typical of treated sanitary effluent. Sodium is 75 mg/ℓ, sulfate 37 mg/ℓ, chlorides 29 mg/ℓ, nitrates 60 mg/ℓ, and TDS at 552 mg/ℓ (Table II). Most chemical constituents are higher than found in natural waters of the region.

Base flow in Pajarito Canyon is principally a calcium and bicarbonate-type water similar to that discharging from springs in the Totavi Lentil (Table II). Sulfates are about 6 mg/ℓ, chlorides about 5 mg/ℓ, and TDS about 186 mg/ℓ. The base flow in Ancho Canyon is a sodium and bicarbonate water. Though the main base flow is from springs in the Totavi Lentil, water from the coarse-grained sediments of the Tesuque Formation is added to the flow. Consequently, the flow increases downgradient in the canyon. Sulfates and chlorides are about 2 mg/ℓ and TDS 160 mg/ℓ (Table II).

A wildfire in June 1977 burned about 26 km^2 of the drainage area in upper Frijoles Canyon. Investigation of the chemical quality of the stream at Bandelier National Monument Headquarters (about 4 km from the river) indicates slight post-fire increases in calcium, bicarbonate, chloride, fluoride, and TDS in the base flow when compared to data collected from 1957 through March 1977.[12] Analyses of the water from Frijoles stream at the Rio Grande in July 1977 indicated slightly higher concentrations of calcuim, bicarbonate, and TDS when compared to analyses of water collected in November 1979 (Table II). Principal ions in 1979 were calcium and bicarbonate with sulfate concentrations of 4 mg/ℓ, chlorides 3 mg/ℓ, and TDS 138 mg/ℓ (Table II). With continued flushing of the burn area by storm runoff and recovery of the vegetative cover, the quality of water in the stream will return to normal within 3 to 5 yr.

Gross alpha, gross beta, and total U concentrations are normal in water from the stream near the Rio Grande, with the exception of gross beta (18 pCi/ℓ) from Mortandad Canyon (Table V). Treated sanitary effluents almost always contain higher gross beta activity than natural waters due to higher concentrations of potassium.[7]

The chemical quality of water from the streams is generally quite good. The concentrations of SO_4, Cℓ, F, NO_3, and TDS meet the drinking water standards with the exception of NO_3 in sanitary effluents in Mortandad Canyon. The NO_3 of the effluents is about 20 mg/ℓ greater than permitted for domestic use (Table IV). The gross alpha and total U are below standards or criteria.[10]

The release of sanitary effluent in Mortandad Canyon has little or no effect on the chemical quality of water in the Rio Grande because of the dilution factor. The discharge of effluent at the Rio Grande is <0.03 m^3/s compared to the mean discharge of the Rio Grande of about 30 m^3/s.[13]

TABLE IV

COMPARISON OF MAXIMUM CONCENTRATIONS OF SELECT CHEMICAL AND RADIONUCLIDE CONCENTRATIONS WITH DRINKING WATER STANDARDS

	mg/ℓ					Gross	Total
	SO_4	Cℓ	F	NO_3	TDS	Alpha[b]	U[c]
Standards[a]	600	250	1.6	45	1000	5	1800
Springs							
Group I	9	6	0.8	2	210	2.6	1.9
Group II	7	5	0.5	<2	262	2.1	1.3
Group III	13	3	1.0	<2	236	1.0	2.3
Group IV	212	6	0.4	32	508	13	20
Streams							
Natural[d]	6	5	0.5	2	246	2.5	0.9
Effluent[e]	37	29	0.9	60	552	<0.5	0.5

[a]USEPA National Interim Primary Drinking Water Standards and NMEID Water Supply Regulations.[10,11]
[b]pCi/ℓ.
[c]μg/ℓ.
[d]Pajarito, Ancho, and Frijoles stream.
[e]Mortandad stream, sanitary effluent.

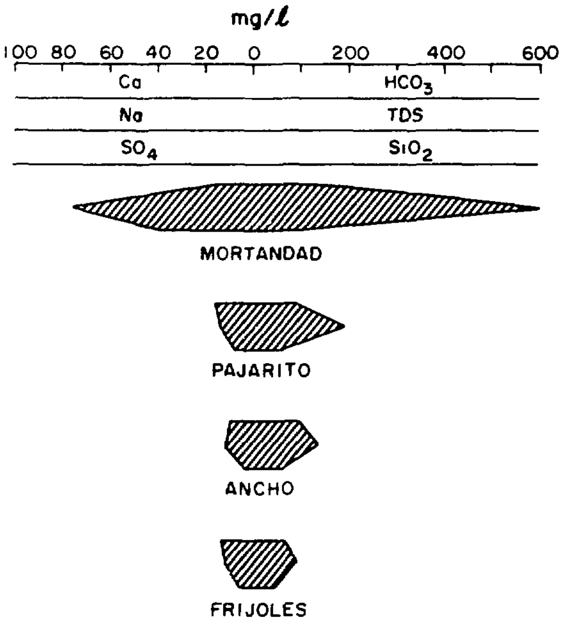


Fig. 5.
Graphic comparison of chemical characteristics of water from streams.

TABLE V

GROSS ALPHA, GROSS BETA, AND TOTAL U IN WATER FROM STREAMS
(Analyses in pCi/ℓ except as noted)

Stream	Gross Alpha	Gross Beta	Total U[a]
Mortandad	<0.5	18	0.5
Pajarito	2.5	4.3	0.4
Ancho	<0.5	2.2	<0.1
Frijoles	<0.5	3.4	<0.4

[a]μg/ℓ.

IV. SUMMARY AND CONCLUSIONS

Twenty-seven springs are located in the reach of White Rock Canyon from Otowi to the confluence of Frijoles Canyon. Chemical quality of water from the springs is separated into four groups. Three groups have similar aquifer related chemical quality. Group I springs discharge a calcium and bicarbonate type water from the Totavi Lentil. Group II springs discharge a sodium and bicarbonate type water from coarse-grained sediments of the Tesuque Formation. Group III springs discharge a sodium and bicarbonate water from fine-grained sediments of the Tesuque Formation. Water from Group III springs contains slightly higher chemical concentrations than the water from Group II springs. Group IV consists of five springs, La Mesita, Ancha, 2A, 3B, and Cañada, each having slightly different chemical characteristics because of localized conditions of the aquifer. In general, chemical constituents in water from the Group IV springs are higher than those found in Groups I, II, and III springs.

Chemical quality of water from individual springs has varied slightly in samples collected from 1964 through 1979. The variations are normal due to seasonal variations and are not considered significant.

Four streams enter the Rio Grande in White Rock Canyon from Otowi to the confluence of Frijoles Canyon. The quality of water in Mortandad Canyon reflects the quality of treated sanitary effluent released from the plant at White Rock. The effluent has little or no effect on the quality of water in the Rio Grande because of the dilution factor. The quality of water in Pajarito Canyon reflects the base flow from Group I springs in the Totavi Lentil. The quality of water in Ancho Canyon reflects mainly the base flow from Group I springs in the Totavi Lentil, which is modified slightly by some discharge from the coarse-grained sediments of the Tesuque Formation before the stream reaches the Rio Grande. Base flow in Frijoles Canyon is from springs about 13 km west of the Rio Grande. The wildfire in June 1977 in the drainage area of Frijoles Canyon had only slight effect on the quality of water at the river.

The chemical quality of water from the springs and streams is good. The concentrations of SO_4, $C\ell$, F, NO_3, and TDS are below drinking water standards with the exception of NO_3 in sanitary effluents found in Mortandad Canyon. It should be noted that no bacteria samples were collected and analyzed. Thus, the chemical quality may be good, but the water from the springs and streams may not be potable due to bacteria.

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