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Water Quality in Vicinity of Fenton Hill Site, 1975

by

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WATER QUALITY IN VICINITY OF FENTON HILL SITE, 1975

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W. D. Purtymun, W. H. Adams,
A. K. Stoker, and F. G. West

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ABSTRACT

Water quality at 9 surface water stations, 14 ground water stations, and drilling and testing operations at the Fenton Hill Site has been studied as a measure of the environmental impact on the Los Alamos Scientific Laboratory's geothermal site in the Jemez Mountains. Slight variations in the chemical quality of the water at individual stations were observed during the year. Predominant ions and total dissolved solids in the surface and ground water declined slightly in comparison to previous data. These variations in quality are not considered significant considering seasonal and annual stream flow variations. Surface water discharge records from three U.S. Geological Survey gaging stations on the Rio Guadalupe and Jemez River were analyzed to provide background data for the impact study. Direct correlations were determined between mean annual discharge at each of two stations in the upper reach of the drainage and at the station in the lower reach.

1. INTRODUCTION

A preliminary study was made in 1973 of the water quality in the Jemez River and Rio Guadalupe drainage areas.¹ Additional water quality data were obtained in 1974 from surface water samples taken in the vicinity of the Fenton Hill Site (TA-57) and from springs along Lake Fork Canyon and the Jemez River.² This report presents data on the quality of water from the Fenton Hill Site vicinity collected and analyzed during 1975 as part of a continuing program of environmental impact studies conducted by the Los Alamos

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Scientific Laboratory (LASL). The report also includes surface water discharge data for the years 1960 through 1975 from three US Geological Survey (USGS) surface stations (of which two are funded by the Laboratory) in the area.

The Fenton Hill Site is bounded on the east by San Antonio Creek and on the west and northwest by the Rio Cebolla (Fig. 1). Lake Fork Canyon, to the south, drains the immediate area of the site and is tributary to the Rio Cebolla. Lake Fork Canyon and the canyon to the north of the site have only intermittent streams.

The preliminary geologic and hydrologic investigations made during geothermal test drilling in the Jemez Mountains and the Fenton Hill Site provided the basis for selecting the locations of the water quality monitoring stations.^{3,4}

II. WATER QUALITY

Routine chemical analyses were made for silica, calcium, magnesium, sodium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, total hardness, total dissolved solids (TDS), conductance, and pH. Analyses were made following the methods described in Ref. 5. The discussion on the surface and ground water quality is organized according to the group of predominant ions and TDS. The annual mean and the standard deviation of principal ions and TDS are compared for 1974 and 1975. The variation ($\pm$) from the annual mean does not indicate the precision of individual analyses, but rather the deviation of the distribution of analyses at a single station.

A. Surface Water

Surface water in the tributaries (Redondo, Sulphur, and San Antonio Creeks) to the Jemez River is monitored to determine any impacts caused by geothermal exploration in the area. The Rio Cebolla below Lake Fork Canyon and the Rio Guadalupe above the Jemez River are monitored because of the contributions of ground water from volcanic rocks underlying the Fenton Hill Site and surface water running from the site.

Fig. 1.
Location of Sampling Stations.

Station Location Key

F	Sulphur Creek	JF-1	Limestone Spring
J	Jemez River	JF-5	Soda Dam
N	San Antonio Creek	JF-9	Madera Spring
Q	Rio Guadalupe	27	Hofheins Flowing Well
R	Jemez River	31	Cold Spring
S	Jemez River	H-2	Test Hole Valle Toledo
T	Rio Cebolla	H-7	Test Hole Valle Grande
U	Redondo Creek	RV-1	San Antonio Warm Spring
V	Sulphur Creek	RV-2	San Antonio Hot Spring
JS-2, -3	Jemez Springs water supply	RV-4	Spence Spring
JS-4, -5	Jemez Springs water supply	RV-5	McCauley Spring
4	La Cueva water supply		

Analyses of surface water from nine stations along the Jemez River, the Rio Guadalupe, and their tributaries are tabulated in Table I. Station locations are shown by capital letters in Fig. 1 and are keyed to the analyses presented in Appendix A. The base flow of these streams is principally from a shallow ground water system in the Valles Caldera, from perched aquifers in volcanics, and from thermal or mineral springs. Each base flow source has a particular chemical characteristic which may be modified by additional runoff from precipitation.

There are four general types of surface water in the area based on predominant ions: (1) sodium and chloride, (2) calcium and sulfate, (3) calcium and bicarbonate, and (4) sodium and bicarbonate.

The principal ions in the base flow at Locations U, R, and S are sodium and chloride (Table I). Location U, Redondo Creek, drains a small basin in the Valles Caldera. The maximum discharge at the time of sample collection was estimated at 15 l/s. Locations R and S are on the lower reach of the Jemez River (Fig. 1). The maximum discharges at the two stations at the time of sample collection were estimated at 910 and 680 l/s, respectively.

The principal ions in the base flow at Locations N, T, and Q are calcium and bicarbonate (Table I). Location N, San Antonio Creek, drains the western and northern parts of the Valles Caldera. The maximum discharge at the station at the time of sample collection was estimated at 110 l/s. Locations T and Q are on the Rio Cebolla and Rio Guadalupe (Fig. 1). The maximum discharges at the two stations at the time of sample collection were estimated at 85 and 230 l/s, respectively.

The principal ions in base flow at Locations V and F are calcium sulfate (Table I). Locations V and F are on Sulphur Creek. Drainage at location V is from a small interior basin of the Valles Caldera. Location F is the combined flow of Sulphur Creek and Redondo Creek. The maximum discharge at both stations at the time of sample collection was estimated at 30 l/s.

The principal ions in base flow at Location J are sodium and bicarbonate (Table I). Location J is below the confluence of the

TABLE I
A COMPARISON OF PREDOMINANT IONS AND
TOTAL DISSOLVED SOLIDS AT SURFACE WATER STATIONS
1974 - 1975
(in milligrams/liter)

Sodium and Chloride						
Location	1974			1975		
	Na	Cl	TDS	Na	Cl	TDS
U (Redondo Creek)	40	94	312	12(±3)	27(±11)	149(±22)
R (Jemez River)	60(±32)	76(±45)	411(±99)	53(±34)	65(±46)	349(±127)
S (Jemez River)	84(±41)	116(±56)	483(±144)	63(±32)	81(±40)	376(±120)

Calcium and Bicarbonate						
Location	1974			1975		
	Ca	HCO ₃	TDS	Ca	HCO ₃	TDS
N (San Antonio Creek)	16(±3)	70(±16)	190(±31)	13(±6)	69(±20)	159(±31)
T (Rio Cebolla)	21(±2)	88(±4)	160(±14)	17(±3)	65(±13)	123(±25)
Q (Rio Guadalupe)	54(±8)	187(±34)	292(±73)	38(±14)	129(±53)	170(±16)

Calcium and Sulfate						
Location	1974			1975		
	Ca	SO ₄	TDS	Ca	SO ₄	TDS
V (Sulphur Creek)	90	364	680	57(±31)	248(±133)	440(±204)
F (Sulphur Creek)	43(±8)	120(±41)	338(±75)	30(±5)	48(±20)	212(±40)

Sodium and Bicarbonate						
Location	1974			1975		
	Na	HCO ₃	TDS	Na	HCO ₃	TDS
J (Jemez River)	18(±8)	69(±19)	174(±37)	12(±4)	53(±13)	129(±27)

Note (±) is range of values at a given station.

east fork of the Jemez and San Antonio Creek, on the Jemez River. The area drained is the combined basins within the Valles Caldera (Fig. 1). Maximum discharge at the time of sample collection was estimated at 450 l/s.

The chemical quality of surface water varies widely with stream discharge due to variations in precipitation in the drainage area. Runoff from precipitation in 1975 was greater than in 1974, resulting in greater dilution of the normal quality of water making up the base flow in the streams. The concentration of constituents at individual stations varied during the year due to differences in amount of stream flow at the time the samples were collected. The variations in chemical quality that were observed in 1975 at individual stations and slight declines in predominant ions and

TDS when compared to previous analyses are not considered significant.

B. Ground Water

Ground water samples were collected on a routine schedule from the water supply for the village of Jemez Springs (two sources), La Cueva (one source), and three springs and one well adjacent to the Fenton Hill Site. Four springs and two test holes were sampled during 1975 in addition to the routine samples. Station locations are shown on Fig. 1 and are keyed to analyses given in Appendix B.

Two types of ground water, categorized by principal ions, occur at the seven routine sampling locations. The principal ions used for discussion are (1) sodium and bicarbonate and (2) sodium and chloride.

The principal ion combinations in water at Locations 4, 27, 31, and JS-2, -3, -4, and -5 are sodium and bicarbonate (Table II). Locations JS-2, -3, -4, and -5 are springs which supply water for the village of Jemez Springs. Springs JS-2 and -3, located east of the village, flow from the east and west forks of Church Canyon, respectively. Samples were collected in the main part of the village and represent the combined flow from the two springs. Springs JS-4 and -5, located northwest of the village on the west side of the Jemez River, were sampled for a combined analysis from the northern end of the village. Location 4, Horseshoe Spring, supplies a part of the water at La Cueva. Location 27, Hofheins Flowing Well, is located near San Antonio Creek at La Cueva and is completed in the siltstones of the Abo Formation. Location 31, Cold Spring, is a small spring in the volcanic rocks of Lake Fork Canyon.

Slight decreases in the averages of principal chemical constituents in the water from these six springs and wells in 1975 were observed from the 1974 average. A normal seasonal variation in chemical concentration exists due to differing amounts of recharge to the aquifer yielding water to the springs or wells. The

TABLE II
A COMPARISON OF PREDOMINANT IONS AND
TOTAL DISSOLVED SOLIDS AT GROUND WATER STATIONS
1974 - 1975
(in milligrams/liter)

Sodium and Bicarbonate

Location	1974			1975		
	Na	HCO ₃	TDS	Na	HCO ₃	TDS
JS-2, -3 (WS Jemez Spring)	18(±1)	84(±5)	214(±31)	13(±1)	68(±8)	144(±37)
JS-4, -5 (WS Jemez Spring)	16(±2)	89(±23)	169(±17)	13(±1)	75(±1)	172(±25)
4 (Horseshoe Spring)	17(±2)	74(±4)	181(±23)	15(±2)	63(±6)	155(±22)
27 (Hofheins Flowing Well)	141	444	576	113(±10)	394(±15)	510(±31)
31 (Cold Springs)	17(±4)	69(±5)	201(±67)	12(±2)	60(±4)	125(±15)

Sodium and Chloride

Location	1974			1975		
	Na	Cl	TDS	Na	Cl	TDS
JF-1 (Limestone Spring)	260(±50)	378(±58)	1260(±119)	198(±69)	305(±100)	1110(±170)
JF-5 (Soda Dam)	772(±171)	1470(±20)	3950(±36)	837(±85)	1360(±11)	3600(±172)
JF-9 (Madera Spring)	--	--	--	728	302	2800

Sodium and Bicarbonate
(Supplemental Stations)

Location	Previous Analysis			1975		
	Na	HCO ₃	TDS	Na	HCO ₃	TDS
RV-1 ^a (San Antonio Warm Spr.)	--	59	149	27	58	244
RV-2 (San Antonio Hot Spr.)	22	58	202	22	56	166
RV-4 ^b (Spence Spr)	53	120	250	49(±10)	124(±6)	250(±11)
RV-5 ^b (McCauley Spr)	22	92	180	20(±1)	75(±1)	151(±4)
N-2 (Test Hole, Valle Toledo)	--	48	111	11	36	114
N-7 ^a (Test Hole, Valle Grande)	--	55	125	14	44	122

^a Analysis 1949.

^b Analysis 1973.

Note (±) is range of values at a given station.

seasonal or annual variations in concentration are not considered significant.

The principal ions in water from Locations JF-1 and -5 are sodium and chloride (Table II). JF-1 and -5 are thermal and mineral springs associated with the Jemez Fault, and are located west of the Jemez River, north of the village of Jemez Springs. The principal ions in water from JF-9, Madera Spring, are also sodium and chloride. Madera Spring, located on the Jemez Fault, is not a

routine monitoring station, but is included with this group. These and other springs associated with the Jemez Fault that discharge into the Jemez River at and north of the village, affect quality of water below the village as measured at surface water Locations R and S.

Principal ions in water from Locations RV-1, -2, -4, and -5, H-2 (Valle Toledo), and H-7 (Valle Grande) are sodium and bicarbonate (Table II). Samples from these locations are not collected on a routine schedule, but were collected as supplemental data for 1975. The RV series are thermal springs that discharge from recent volcanics along San Antonio Creek and the east fork of the Jemez River (Fig. 1). Test Holes H-2 and H-7 were exploratory holes drilled in the Valles Caldera for a water supply study in 1947. The concentrations of constituents measured in 1975 vary from previous data, but the variations are within expected normal seasonal fluctuation.

C. Water Quality at Fenton Hill Site (TA-57)

Samples of water used in drilling operations and testing of holes GT-2 and EE-1 were analyzed in the same manner as the other water samples (refer to Appendix C). Water samples of residual fluids from drilling operations, as well as runoff from precipitation at the lower pond at GT-2, were collected in January. This water was released slowly into Lake Fork Canyon to allow dilution with spring runoff during March and April. The residual solids in the pond were removed and buried. No adverse effects were or have been detected. Fluids were pumped into the upper and lower ponds at GT-2 while tests were conducted. The sample from the EE-1 pond was taken during drilling operations and is of drilling fluids. Control is maintained and fluids from the ponds are released only under controlled conditions.

III. SURFACE WATER

There are three surface water gaging stations operated by the USGS on the Jemez River and Rio Guadalupe. The operation of stations near Location J and Q have been funded by LASL for the past

two years. The third station near Location R is a permanent USGS station.

The station at Location J is on the Jemez River below the confluence of the East Fork of the Jemez and San Antonio Creek (Fig. 1). The drainage area above the station is 448 km^2 . Discharge at the station includes the runoff from the Valles Caldera as well as adjacent areas. Partial records from the station began in 1949. The maximum recorded discharge occurred on April 21, 1958, and was $71 \text{ m}^3/\text{s}$. The minimum discharge for the period 1960-75 was $0.09 \text{ m}^3/\text{s}$ and maximum $29.2 \text{ m}^3/\text{s}$ (Table III). The annual volume of water passing the station for the same period ranged from 13.9 hm^3 to 58.2 hm^3 .

The station at Location Q is on the Rio Guadalupe above the confluence with the Jemez River (Fig. 1). The drainage area above the station is 609 km^2 . Discharge at the station includes drainage from the western rim of the Caldera and the flanks of the mountains to the west. Canyons with intermittent streams north and south of the Fenton Hill Site drain into the Rio Guadalupe. Partial records from the station began in 1951. The maximum discharge recorded was $40.8 \text{ m}^3/\text{s}$ on April 21, 1958. The minimum discharge for

TABLE III
SURFACE WATER RECORDS OF THE JEMEZ RIVER
NEAR BATTLESHIP ROCK, LOCATION J

Year	Discharge m^3/s (ft^3/s)		Mean Annual	Annual Volume hm^3 ($\times 10^3$ ac-ft)
	Min	Max		
1960	0.17 (6)	11.5 (405)	0.96 (34)	30.3 (24.6)
61	.28 (10)	17.0 (600)	1.1 (40)	36.6 (29.7)
62	.27 (9.8)	11.0 (390)	.93 (33)	29.6 (24.0)
63	.23 (8)	13.0 (460)	.57 (20)	17.5 (14.2)
64	.20 (7)	8.5 (300)	.51 (18)	15.7 (12.7)
65	.20 (7)	9.1 (320)	.71 (25)	22.2 (18.0)
66	.16 (5.6)	9.6 (340)	.62 (22)	19.6 (15.9)
67	.15 (5.0)	3.3 (115)	.45 (16)	13.9 (11.3)
68	.17 (6.0)	11.0 (390)	.96 (34)	30.9 (25.1)
69	.09 (3.3)	10.2 (360)	1.0 (36)	32.4 (26.3)
70	.19 (6.6)	8.2 (290)	.79 (28)	25.2 (20.4)
71	.19 (6.9)	2.4 (86)	.45 (16)	14.1 (11.4)
72	.23 (8.0)	4.5 (160)	.57 (20)	17.9 (14.5)
73	.24 (8.6)	24.1 (850)	1.8 (65)	58.2 (47.2)
74	.23 (8.0)	4.0 (140)	.57 (20)	17.9 (14.5)
75	.24 (8.7)	29.2 (1030)	1.4 (49)	43.8 (35.5)

TABLE IV
SURFACE WATER RECORDS OF THE RIO GUADALUPE
NEAR LOCATION Q

Year	Discharge m^3/s (ft^3/s)		Mean Annual	Annual Volume hm^3 ($\times 10^3$ ac-ft)
	Min	Max		
1960	0.12 (4.2)	10.5 (370)	1.2 (42)	37.7 (30.6)
61	.16 (6.0)	10.8 (380)	1.3 (45)	39.9 (32.4)
62	.12 (4.4)	13.3 (470)	1.2 (43)	38.6 (31.3)
63	.10 (3.6)	5.4 (190)	.54 (19)	17.1 (13.9)
64	.09 (3.3)	2.8 (100)	.45 (16)	14.3 (11.6)
65	.17 (5.9)	9.3 (330)	1.2 (41)	36.9 (29.9)
66	.11 (3.9)	4.5 (160)	.68 (24)	21.1 (17.1)
67	.10 (3.5)	5.7 (200)	.40 (14)	12.8 (10.4)
68	.14 (5.0)	11.0 (390)	1.2 (44)	39.1 (31.7)
69	.24 (8.3)	8.5 (300)	1.4 (49)	43.9 (35.6)
70	.22 (7.9)	9.3 (330)	1.0 (36)	32.9 (26.7)
71	.12 (4.3)	3.1 (110)	.62 (22)	19.9 (16.1)
72	.11 (3.9)	2.8 (100)	.62 (22)	19.4 (15.7)
73	.22 (7.9)	32.2 (1350)	2.8 (100)	89.9 (72.9)
74	.18 (6.2)	3.4 (120)	.59 (21)	19.1 (15.5)
75	.24 (8.6)	14.4 (510)	1.8 (65)	55.4 (44.9)

the period 1960-75 was $0.09 m^3/s$ and the maximum was $32.2 m^3/s$ (Table IV). The annual volume of water passing the station for the same period ranged from $12.8 hm^3$ to $89.9 hm^3$.

The station at Location R is on the Jemez River below the confluence of the Rio Guadalupe (Fig. 1). The drainage area above the station is $1\ 220 km^2$. Discharge at the station includes runoff passing through the stations at Location J and Q as well as some runoff from the southern rim of the Caldera. Partial records of stream discharge and volumes of water passing the station are available from 1936. The maximum discharge recorded at the stations was $167 m^3/s$ on April 21, 1958. The minimum discharge for the period 1960-75 was $0.24 m^3/s$ and the maximum was $64 m^3/s$ (Table V). The annual volume of water passing the station ranged from $31.1 hm^3$ to $161.2 hm^3$.

Stream flow characteristics at the three stations are well defined, with over 16 years of continuous records. The annual volumes of water at the stations at Locations J and Q can be estimated from records of the station near Location R. Linear regressions of the mean annual discharge of stations at Locations J and Q (y variable) vs the station at Location R (x variable) have excellent

correlations with $r^2 = 0.98$ ($P < 0.01$) and $r^2 = 0.99$ ($P < 0.01$), respectively, as shown on Figs. 2 and 3. Using data from these regressions, a hydrograph was prepared to estimate the annual volumes of water passing stations at Location J and Q using the station at Location R for control (Fig. 4). The latter is equipped with a digital, as well as a standard water-stage recorder. Thus the day, hour, and peak discharges can be determined.

The discharge at the three stations ranged from $0.09 \text{ m}^3/\text{s}$ to $64 \text{ m}^3/\text{s}$ during the period 1960-75. The station ratings are accurate to only $\pm 10\%$; thus, with the variable discharge, any small increase or decrease in flow would be impossible to determine. The USGS concurs that no additional useful data can be obtained at this time by continued operation of the stations near Locations J and Q, and the stations are to be abandoned in June 1976.

TABLE V
SURFACE WATER RECORDS OF THE JEMEZ RIVER
NEAR JEMEZ PUEBLO NEAR LOCATION R

Year	Discharge m^3/s (ft^3/s)		Mean Annual	Annual Volume hm^3 ($\times 10^3$ ac-ft)
	Min	Max		
1960	0.28 (10)	16.8 (595)	2.1 (74)	66.5 (53.9)
61	.45 (16)	24.9 (880)	2.5 (87)	77.8 (63.1)
62	.40 (14)	19.2 (675)	2.3 (81)	72.3 (58.6)
63	.27 (9.6)	17.0 (600)	1.2 (42)	37.7 (30.6)
64	.31 (11)	9.6 (340)	.99 (35)	31.1 (25.2)
65	.45 (16)	11.3 (400)	1.9 (68)	60.7 (49.2)
66	.28 (10)	12.7 (450)	1.4 (51)	45.6 (37.0)
67	.27 (9.7)	9.9 (350)	1.0 (36)	31.9 (25.9)
68	.42 (15)	21.8 (770)	2.4 (84)	75.5 (61.2)
69	.45 (16)	14.2 (500)	2.6 (92)	81.7 (66.3)
70	.42 (15)	13.2 (465)	1.8 (65)	57.8 (46.9)
71	.24 (8.3)	6.8 (240)	1.2 (42)	37.4 (30.3)
72	.28 (9.9)	6.5 (230)	1.3 (46)	40.8 (33.1)
73	.37 (13)	64 (2260)	4.8 (170)	161.2 (130.7)
74	.31 (11)	4.8 (170)	1.1 (38)	34.2 (27.7)
75	.48 (17)	48 (1710)	3.4 (120)	103.4 (83.9)

Fig. 2.
Regression analysis showing relationship between mean annual discharge at gaging stations near Locations J and R.

Fig. 3.
Regression analysis showing relationship between mean discharge at gaging stations near Locations Q and R.

Fig. 4.
Hydrograph to estimate volume of flow near
Locations J and Q from U.S. Geological Survey
records from gaging station near Location R.

IV. SUMMARY

The quality of surface water in the drainage area of the Jemez River and Rio Guadalupe varied slightly at individual locations due to variations in stream flow. The predominant ions at each location remained the same; however, annual average concentrations of these ions and total dissolved solids decreased slightly when compared to data collected in 1974. The chemical constituents in ground water from routine sampling locations, springs, and one well varied slightly during the year. There was also a slight decrease in the predominant ions and total dissolved solids in comparison with similar data from 1974.

Supplemental samples were collected from five springs and two holes. The chemical quality of water from these sources has remained about the same when compared to previous analyses.

Surface water gaging stations near Location J on the Jemez River and at Location Q on the Rio Guadalupe will be abandoned in June 1976. Regression analyses of the mean annual discharge at the two stations vs the mean annual discharge at the permanent USGS station near Location R indicate a very good correlation. The regression provides a means of estimating the annual volume of water at Locations J and Q from the records of the gaging station near Location R.

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APPENDIX A

SURFACE WATER QUALITY

Location ^a	Sulphur Creek above San Antonio Creek (F)		Jemez River below Battleship Rock (J)			San Antonio Creek above Sulphur Creek (N)			Rio Guadalupe above Jemez River (Q)			Jemez River above Rio Guadalupe (S)		
Date of Collection (1975)	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8
<u>Chemical Analysis (mg/l)</u>														
Silica (SiO ₂)	32	34	33	49	53	42	51	60	17	30	27	42	50	57
Calcium (Ca)	26	33	13	14	14	14	22	14	23	41	50	20	49	51
Magnesium (Mg)	5	3	4	2	2	4	3	2	2	9	6	10	5	5
Sodium (Na)	15	18	7	14	15	6	15	17	11	14	16	27	84	80
Carbonate (CO ₃)	0	0	0	0	0	0	0	0	0	4	5	0	10	6
Bicarbonate (HCO ₃ as CaCO ₃)	20	14	38	62	60	56	96	58	68	156	163	98	188	192
Sulfate (SO ₄)	61	34	14	9.7	13	8.0	4.9	6.4	10	2.6	7.2	15	14	17
Chloride (Cl)	19	37	3	7	4	<1	3	3	<1	4	4	35	96	141
Fluoride (F)	0.2	0.2	0.3	0.7	0.9	0.5	1.1	1.1	0.2	0.5	0.7	0.4	0.9	1.0
Nitrate (N)	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	<0.1	0.1	0.1	0.1
Total dissolved solids	184	240	98	144	144	136	194	148	152	182	176	240	420	470
Total hardness (as CaCO ₃)	88	96	48	46	44	54	68	42	68	140	148	106	144	148
Specific conductance (µmho/cm)	260	340	140	165	180	150	190	170	140	330	340	340	740	785
pH	8.0	7.2	7.6	7.6	7.2	8.0	8.0	8.1	7.8	8.4	8.3	8.1	8.4	8.3
Temperature (°C)	5	0	6	9	1	6	8	0	6	13	6	7	15	6
Discharge estimated (l/s)	30	30	-	340	450	-	90	110	-	140	230	-	570	680

^a For location see Fig. 1.

APPENDIX A (cont)

SURFACE WATER QUALITY

Location ^a	Jemez River below Rio Guadalupe (R)				Rio Cebolla below Lake Fork Canyon (T)			Redondo Creek (U)			Sulphur Creek above Redondo Creek (V)		
Date of Collection (1975)	3/12	5/28	9/30	12/8	5/28	9/30	12/9	5/28	9/30	12/8	5/28	9/30	12/8
Chemical Analyses (mg/l)													
Silica (SiO ₂)	--	22	51	56	43	38	41	28	30	33	41	50	54
Calcium (Ca)	42	25	46	50	14	18	19	15	16	19	22	72	78
Magnesium (Mg)	4	2	7	6	1	2	2	3	2	4	4	10	14
Sodium (Na)	40	11	86	75	7	11	13	10	11	16	8	23	25
Carbonate (CO ₃)	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO ₃ as CaCO ₃)	144	74	184	192	50	72	74	28	34	32	0	0	0
Sulfate (SO ₄)	--	11	23	16	7.0	1.6	3.0	10	7.0	8.6	96	305	344
Chloride (Cl)	56	5	100	102	<1	2	2	18	23	39	<1	6	8
Fluoride (F)	0.8	0.2	1.1	1.0	0.2	0.5	0.5	0.2	0.1	0.2	0.2	0.5	0.6
Nitrate (N)	0.4	0.1	0.1	<0.1	0.1	0.1	<0.1	0.2	0.2	0.1	0.1	0.3	0.3
Total dissolved solids	332	176	428	460	138	94	136	162	124	162	206	530	584
Total hardness (as CaCO ₃)	120	72	146	148	40	54	58	52	48	64	72	200	252
Specific Conductance (µmho/cm)	490	200	700	785	110	165	175	175	165	230	220	695	750
pH	7.9	8.0	7.7	8.3	7.4	7.9	7.9	7.8	7.5	7.2	4.7	3.9	4.0
Temperature (°C)	--	7	15	6	8	15	4	3	5	0	4	5	0
Discharge estimated (l/s)	--	--	710	910	--	85	85	--	15	15	--	30	30

^a For location see Fig. 1.

APPENDIX B

GROUND WATER QUALITY

Location ^a	Water Supply, Jemez Springs; Church Canyon East and West (JS-2,-3)			Water Supply, Jemez Springs; Sino and Agua Durme Springs (JS-4,-5)			Water Supply, La Cueva: Horseshoe Spring (4)			Limestone Spring, West of Battleship Rock (JF-5)			Mineral and Thermal Spring, Soda Dam (JF-5)		
Date of Collection (1975)	5/28	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8	5/28	9/30	12/8
Chemical Analysis (mg/l)															
Silica (SiO ₂)	60	28	23	80	71	71	87	79	85	44	49	52	53	34	45
Calcium (Ca)	14	15	17	14	15	13	11	11	10	108	126	42	220	162	142
Magnesium (Mg)	3	5	3	4	4	5	2	3	3	30	11	12	61	22	22
Sodium (Na)	12	13	14	13	14	13	13	16	16	150	168	277	830	756	926
Carbonate (CO ₃)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO ₃ as CaCO ₃)	60	68	76	74	76	74	56	68	64	320	502	324	660	814	800
Sulfate (SO ₄)	15	5.0	9.5	5.0	0.4	3.5	8.0	2.6	<1.0	31	26	26	36	48	33
Chloride (Cl)	3	3	7	<1	3	4	3	7	4	190	349	375	1350	1350	1370
Fluoride (F)	0.4	0.4	0.5	0.3	0.4	0.5	0.2	0.1	0.2	1.5	2.4	2.1	2.3	3.1	2.7
Nitrate (N)	0.3	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.4	0.1	0.1	1.1	0.1	<0.1
Total dissolved solids	186	126	120	196	174	146	180	140	144	932	1270	1138	3800	3508	3496
Total hardness (as CaCO ₃)	46	58	56	52	56	54	36	40	40	360	362	156	800	494	494
Specific conductance (μmho/cm)	150	160	170	150	175	170	130	135	150	1600	2300	1900	6400	6100	6600
pH	7.4	7.9	7.4	7.8	8.2	7.6	7.2	7.2	7.3	7.4	7.4	7.7	7.1	6.9	7.0
Temperature (°C)	9	17	8	10	19	11	16	20	17	12	16	12	39	39	39

^a For location see Fig. 1.

APPENDIX B (cont)
GROUND WATER QUALITY

Location ^a	Cold Spring, Lake Fork Canyon (31)			Hofheim Flowing Well (27)			San Antonio Warm Springs (RV-1)	San Antonio Hot Springs (RV-2)	Spence Spring (RV-4)		McCauley Spring (RV-5)	
Date of Collection (1975)	5/28	9/30	12/9	5/28	9/30	12/9	8/14 ^b	8/12	9/24 ^c	12/9	9/24 ^d	12/9
Chemical Analysis (mg/l)												
Silica (SiO ₂)	56	54	52	68	63	72	97	83	65	68	53	59
Calcium (Ca)	10	14	14	26	30	28	6	6	7	7	10	10
Magnesium (Mg)	4	5	2	10	8	8	<1	<1	2	2	4	5
Sodium (Na)	10	14	12	109	124	107	27	22	49	49	19	20
Carbonate (CO ₃)	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO ₃ as CaCO ₃)	60	57	64	410	390	382	58	56	120	128	76	74
Sulfate (SO ₄)	6.0	5.3	<1.0	5.11	2.6	2.3	10	7.0	15	16	3.5	5.0
Chloride (Cl)	3	4	4	2	8	5	6	14	8	10	4	4
Fluoride (F)	0.7	1.2	0.9	1.0	0.9	1.0	1.3	0.9	0.6	0.7	0.8	1.0
Nitrate (N)	0.2	0.1	0.1	0.8	0.9	0.9	0.8	0.3	<0.1	0.1	0.3	<0.1
Total dissolved solids	138	110	128	534	476	522	244	166	242	258	154	148
Total Hardness (as CaCO ₃)	52	56	46	104	108	102	18	16	26	28	40	44
Specific conductance (µmho /cm)	130	140	160	750	670	740	120	195	290	280	170	170
pH	7.5	7.8	7.3	7.5	7.6	7.7	7.6	7.5	8.0	8.3	7.9	8.0
Temperature (°C)	6	7	8	13	21	16	38	41	41	40	32	30

^aFor location see Fig. 1.

^bCollected R.L. Borton, SEO, flow 0.6 l/s.

^cCollected R.L. Borton, SEO, flow 1.0 l/s.

^dCollected R.L. Borton, SEO.

APPENDIX B (cont)
GROUND WATER QUALITY

<u>Location ^a</u>	<u>Valle Toledo Test hole (H-2)</u>	<u>Valle Grande Test hole (H-7)</u>	<u>Madera Seep (JF-9)</u>
<u>Date of Collection (1975)</u>	<u>11/16^b</u>	<u>11/6^c</u>	<u>12/9</u>
<u>Chemical Analysis (mg/l)</u>			
Silica (SiO ₂)	51	75	33
Calcium (Ca)	7	6	16
Magnesium (Mg)	<1	1	40
Sodium (Na)	11	14	728
Carbonate (CO ₂)	0	0	56
Bicarbonate (HCO ₃ as CaCO ₃)	36	44	1620
Sulfate (SO ₄)	<1.0	1.4	300
Chloride (Cl)	2	2	302
Fluoride (F)	1.8	0.3	5.0
Nitrate (N)	0.2	0.2	<0.1
Total dissolved solids	114	122	2800
Total hardness (as CaCO ₃)	20	18	206
Specific conductance (umho/cm)	90	90	4620
pH	7.7	7.4	8.5
Temperature (°C)	15	18	11

^a For location see Fig. 1.

^b Collected R. L. Borton, SEO, flow 13 to 19 l/s.

^c Collected R. L. Borton, SEO, flow 0.5 l/s.

APPENDIX C
FENTON HILL SITE WATER QUALITY

<u>Source</u>	<u>Lower Pond</u>		<u>Upper</u>	<u>Mud</u>
	<u>GT-2</u>	<u>GT-2</u>	<u>Pond</u>	<u>Pit</u>
			<u>GT-2</u>	<u>EE-1</u>
<u>Date Collected (1975)</u>	<u>1/28</u>	<u>9/30</u>	<u>9/30</u>	<u>9/30</u>
<u>Chemical Analysis (mg/l)</u>				
Silica (SiO ₂)	--	19	70	59
Calcium (Ca)	29	33	26	81
Magnesium (Mg)	1	2	4	6
Sodium (Na)	--	99	96	165
Carbonate (CO ₃)	310	0	0	0
Bicarbonate (HCO ₃ as CaCO ₃)	570	120	120	168
Sulfate (SO ₄)	--	128	33	360
Chloride (Cl)	470	56	37	17
Fluoride (F)	2.0	0.5	1.1	0.9
Nitrate (N)	2.2	0.4	0.4	0.3
Total dissolved solids	2600	478	500	1264
Total hardness (as CaCO ₃)	76	92	82	226
Specific conductance (μmho/cm)	3400	740	650	2080
pH	11.0	8.0	7.4	7.4