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Preliminary Study of the Quality of Water in the Drainage Area of the Jemez River and Rio Guadalupe

by

W. D. Purtymun
F. G. West
W. H. Adams

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

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PRELIMINARY STUDY OF THE QUALITY OF WATER IN THE DRAINAGE AREA
OF THE JEMEZ RIVER AND RIO GUADALUPE

by

W. D. Purtymun, F. G. West, and W. H. Adams

ABSTRACT

A preliminary study of the quality of surface and ground water was made in the area of a proposed geothermal test hole and experiment by Los Alamos Scientific Laboratory. The study was made to establish background data prior to the geothermal experiment by the Laboratory. The data compiled prior to 1971 were taken from a literature search while data from 1971 through 1973 were collected from field surveys. Analyses are reported from 17 surface water stations, 15 mineral and thermal springs, and 53 ground water stations (wells, test holes, and springs). A general description of sampling stations is presented with a brief description of the chemical quality of the water based on concentrations of dissolved solids. Additional water quality data will be collected prior to, during, and after the experiment.

I. INTRODUCTION

The Fenton Hill Site (TA-57) chosen for a test hole and geothermal experiment by the Los Alamos Scientific Laboratory is located southwest of the Valles Caldera in the Jemez Mountains of northcentral New Mexico. A preliminary study of the quality of water in the drainage area around the site was made by field investigations and a literature search. The purpose of the study was to establish background data on the quality of the water prior to any experimental work by the Laboratory. This study is preliminary only. Additional data will be collected prior to, during, and after the experiment.

The major surface water drainage in the area of the site is the Jemez River, the Rio Guadalupe, and their tributaries. Stream flow in the Rio Cebolla, a tributary

of the Rio Guadalupe, is impounded at Fenton Lake. Ground water occurs in the Valle Toledo and Valle Grande in the Valles Caldera and in volcanics and sediments adjacent to the caldera. Ground water is also found in the alluvium along streams in the area. Shallow wells along the streams supply domestic water for campgrounds and cabins in the area. Water for the larger villages is supplied by wells or springs. Thermal and mineral springs discharge into the Jemez River and its tributaries.

The interpretation of the quality of water is based on dissolved solids, a measure of the mineral concentrations in solution. The dissolved solids concentration in water governs its use for domestic water supply, industry, and irrigation. The U.S. Public Health Service recommends that domestic water supplies contain less than 500

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mg/liter dissolved solids but permits up to 1000 if no other water is available.¹ Most industrial processes cannot tolerate concentrations of dissolved solids of more than 1000 mg/liter, while concentrations above 500 mg/liter present a high to very high hazard for irrigation use.² In this report, the term "low" will designate concentration of dissolved solids of less than 500 mg/liter; "moderate" 500 to 1000 mg/liter; and "high" above 1000 mg/liter.

For domestic and municipal use the U.S. Public Health Service recommends chloride concentrations in water of less than 250 mg/liter. The term "low" will refer to chloride concentrations of less than 250 mg/liter and "high" will refer to concentrations greater than 250 mg/liter. Water hardness is a characteristic of water representing total concentrations of calcium and magnesium. Hardness of water for domestic use does not become particularly objectional until it reaches levels of 100 mg/liter.

Water hardness is classified in the following table:

<u>Range in Hardness</u> (mg/liter)	<u>Classification</u>
1 - 60	soft
61 - 120	moderately hard
121 - 180	hard
180 +	very hard

Water analyses dated 1971, 1972, and 1973 were made by the Los Alamos Scientific Laboratory. Data reported prior to 1971 were compiled from one of the following sources: Renick,³ Conover and others,⁴ Waring,⁵ Griggs,⁶ Summers,⁷ Dinwiddie and others,⁸ and New Mexico Department of Public Health.⁹ Some data were compiled from the unpublished records of the U. S. Geological Survey, Albuquerque, New Mexico. Chemical data on the Jemez River were compiled from the U. S. Geological Survey, "Water Resources Data for New Mexico, Part

2, Water Quality Records for the Years 1964 through 1967."¹⁰ The U. S. Forest Service furnished surface water records from the Jemez River, Sulphur Creek, Rio de las Vacas, and the Rio Guadalupe. The geology of the Jemez Plateau and the logs of test holes drilled by the Laboratory are presented by Purtymun.¹¹

Frank Trainer, U.S. Geological Survey, participated in the data search and in much of the field work. He is studying the hydrology of the Jemez Mountains. Robert Adams, U.S. Forest Service, also assisted in data search. Their assistance is gratefully acknowledged.

II. SURFACE WATER

Analyses of surface water are tabulated from sampling stations on the Jemez River, the Rio Guadalupe, and their tributaries. Locations of sampling stations are shown by capital letters on Fig. 1 and are keyed by the same letters to the analyses as shown on Table I.

A. East Fork of the Jemez

The East Fork of the Jemez River drains the Valle Grande and is confluent to the Jemez River at the junction with San Antonio Creek. Analyses of water from the stream (Table I, analyses A through D) show low dissolved solids, generally less than 100 mg/liter. Base flow is from accretion of ground water to the stream from the near-surface water table in the Valle Grande and from the large amounts of precipitation that occur in the high mountains around the Valles Caldera.

B. Sulphur Creek

Sulphur Creek drains one of two small structural basins between the Valle Toledo and Valle Grande (Fig. 1). Redondo Creek is a major tributary to Sulphur Creek draining the other basin. Sulphur Creek in turn is a tributary to San Antonio Creek. The Sulphur Hot Springs occur along upper Sulphur Creek. Private interest exploratory test holes to determine the geothermal

energy potential are located in the basins drained by Sulphur and Redondo Creeks.

Analyses of water from Sulphur Creek (Table I, analyses E and F) show moderate concentrations of dissolved solids (i.e. greater than 500 mg/liter. The mineralized water is due to discharge from thermal springs along Sulphur and Redondo Creeks. In general, the quality of water improves downstream from the thermal spring area due to the inflow of fresh ground water and run-off from precipitation.

The range and mean of a number of chemical constituents and properties of water from Sulphur Creek are found on Table II (Fig. 1, Location F). Data cover the period 1968 through 1970.

C. San Antonio Creek

San Antonio Creek drains the Valle Toledo to the north of the Valle Grande and an area along the west side of the Valles Caldera and is a tributary to the Jemez River at the confluence with the East Fork of the Jemez (Fig. 1). Several thermal springs discharge into the stream. Sulphur Creek is tributary to the stream. Base flow is from the accretion of the near surface water table in the Valle Toledo and from precipitation. Dissolved solids concentrations are generally low (Table I, Locations G through I); however, the accretion of water from thermal springs and Sulphur Creek tends to increase the dissolved solid concentrations downstream from about 100 mg/liter to 200 mg/liter.

The range and mean of a number of chemical constituents and properties of the water from location N at La Cueva are shown on Table III. Data are for period 1968 through 1970.

D. Jemez River

At the confluence of the East Fork of the Jemez and San Antonio Creek the stream becomes the Jemez River (Fig. 1). Downstream, the Jemez River mineral concentration tends to increase due to the inflow of highly mineralized water from thermal springs (Table I, Locations J and K).

The quality of water at the U.S. Geological Survey Gaging Station (Location J) is presented as a range and average for the period April 1963 through June 1967 (Table IV).

The range and mean for a number of chemical constituents and properties of the water from Location J are shown on Table V. The data are for the period 1967 through 1970.

E. Vallecitos Creek

Vallecitos Creek drains an area to the south of the Valles Caldera. The stream is generally intermittent in the lower reaches as most of the water is diverted for irrigation during the growing season. The dissolved solids concentrations are low (Table I, Location L).

F. Fenton Lake

Water impounded at Fenton Lake on the Rio Cebolla is used for recreation purposes. Base flow to the Rio Cebolla is from ground water accretion from the shallow alluvial aquifers along numerous canyon tributaries and from springs on the canyon walls. Analyses show dissolved solids concentrations are low (Table I, Location M).

G. Rio de las Vacas

The Rio de las Vacas drains an area west of the Valles Caldera. The Forest Service maintains two stations on the stream, one at the Administrative Cabin, Location O, and the other at the junction with Trail Creek, Location P.

The dissolved solids (Table VI) are low at Location O. The dissolved solids (Table VII) are also low at Location P. The analyses show an increase in dissolved solids downstream as one would expect.

H. Rio Guadalupe

The Rio Guadalupe drains the area to the west of the proposed project site and includes the tributaries Rio de las Vacas and Rio Cebolla. The range and mean of chemical characteristics and physical properties are shown on Table VIII, Location Q. The data are for the years 1967 through

1970. The chemical quality shows some increases in chemical constituents downstream from Locations O and P on the Rio de las Vacas. The dissolved solid concentrations are low.

I. Seepage Investigation Jemez River Drainage

A seepage investigation was made on September 29, 1972, in which flow discharges were estimated and samples were collected along the East Fork of the Jemez, Sulphur Creek, San Antonio Creek, and the Jemez River. Discharge, water temperature, and dissolved solids are shown on the following table.

SEEPAGE INVESTIGATION			
Stream and Map Location	Discharge (liter/sec)	Temperature (°C)	Dissolved Solids (mg/liter)
East Fork of Jemez			
Location A	70	9	44
Location C	140	9	44
Location D	280	12	60
Sulphur Creek			
Location F	15	8	256
San Antonio Creek			
Location H	100	9	164
Location I	340	12	206
Jemez River			
Location J	600	12	126
Location K	500 ^a	17	424

^aPart of stream diverted into irrigation channel.

In general the accretion of thermal water increased the mineral concentrations downstream in the drainage system. The largest increase is shown in dissolved solids and temperatures between locations J and K on the Jemez River. The thermal spring at Soda Dam discharges into the river between these locations (Fig. 1). Complete chemical analyses of water collected during the seepage run are shown in Table I.

III. THERMAL AND MINERAL SPRINGS

A thermal spring is defined by Waring⁵ and Gilbert¹² as a spring whose temperature exceeds the mean annual air temperature by 8°C (15°F). In the collection of samples for analyses, it was noted that some of the

springs sampled were of a lower temperature than could be classified as a thermal spring; however, they contained high mineral concentrations which were indicative of thermal spring origin. The lower temperature of these waters may be caused by the mixing with near surface ground water, or discharge from landslide deposits, which may dissipate some of the heat carried by the waters from depth.

The thermal and mineral springs fall into three classifications according to their chemical quality and mode of origin. These are: (a) springs associated with recent volcanic rocks, (b) springs within the caldera, and (c) springs associated with the Jemez Fault.

Locations of the thermal and mineral springs are shown on Fig. 1 and chemical analyses are presented on Table IX. In areas where a number of springs occur, the quality may vary from one spring to the next so several analyses are presented.

A. Springs Associated with Recent Volcanic Rocks

Thermal springs along the outer rim of the caldera are associated with recent volcanic rocks (RV series, Fig. 1 and Table IX). These springs are not classified as mineral springs because the dissolved solid concentrations are low.

San Antonio Warm Springs (RV-1). San Antonio Warm Springs (RV-1) issues from the contact at the base of Quarternary volcanic intrusives. The discharge of the spring is estimated at 2 liters/sec at a temperature of 38°C. The dissolved solids are low, about 150 mg/liter (Table IX).

San Antonio Hot Springs (RV-2). San Antonio Hot Springs issue from a contact between two Quarternary volcanic flow rocks of slightly different ages. The discharge of the spring is about 3 liters/sec at a temperature of 49°C. The dissolved solids are low, about 200 mg/liter (Table IX).

Near San Antonio Hot Springs (RV-3). The small spring west of San Antonio Creek is probably a part of the thermal springs RV-2.

Chemical analyses are quite similar. The dissolved solids are low, about 200 mg/liter (Table IX).

Spence Hot Springs (RV-4). Spence Hot Springs consist of a series of springs that discharge from a contact or fault zone between the Permian rock beds and Quarternary volcanic rock. The spring discharge is about 3 liters/sec. The temperature of the water ranges from 29°C to 38°C. The dissolved solids concentrations in the water are low, about 240 mg/liter (Table IX).

McCauley Hot Springs (RV-5). McCauley Springs issue from the contact between Permian red beds and Quarternary volcanic rocks. The discharge is about 22 liters/sec. The temperature of the water ranges from 30°C to 37°C. The dissolved solids concentrations in the water are also quite low, about 165 mg/liter (Table IX).

B. Interior Caldera

The interior caldera thermal and mineral springs are associated with a structural deformation and are fault controlled, being associated with the intracaldera doming of Redondo Mountain to the east, (I series, Fig. 1, Table IX). The water from the springs is very acid, high in sulfate, silica, calcium, magnesium, and dissolved solids.

Alamo Canyon (I-1). The springs in Alamo Canyon extend over about one half acre. There are some fumaroles emitting mainly CO₂, and some sulfurous gases also. The area is underlain by caldera fill. The fill has been faulted, and the springs and fumaroles are issuing through the faults or fault zones. The water is acidic and contains a larger concentration of sulfate than occurs in springs associated with the recent volcanics formed around the rim of caldera (Table IX).

Sulphur Springs (I-2). Sulphur thermal and mineral springs are located along Sulphur Creek (Fig. 1). There has been extensive exploration in the area for geothermal energy. The springs issue from caldera fill

and are fault controlled. The eight major springs discharge about 32 liters/sec at temperatures ranging from 30°C to 83°C. There are numerous fumaroles emitting CO₂ and sulfurous gases. The mineral concentrations in the water from the different springs vary; however, in general, water with lower temperatures contains lower mineral concentrations than the water at higher temperatures. The silica, calcium, magnesium, and sulfate concentrations are quite high. As a result, dissolved solids are high (Table IX).

C. Jemez Fault

The Jemez Fault is a northeast-southwest trending fault that parallels the Jemez River. The northern part of the fault is covered by recent volcanics around the caldera. The southern part of the fault breaks rocks of Precambrian, Pennsylvanian, and Permian age. A number of thermal and mineral springs issue from fracture zones associated with the Jemez Fault (JF series, Fig. 1, Table IX). In general, the waters from these springs contain moderate to high concentrations of dissolved solids. In many places, deposition of tufa is taking place with precipitation of CaCO₃ from the water.

West of Battleship Rock (JF-1). The spring west of Battleship Rock issues from a fracture zone in rocks of Pennsylvanian age. The spring discharge is less than 1 liter/sec with a water temperature of about 19°C. Calcium, magnesium, and chlorides are high, as are the dissolved solids (Table IX).

Near Stream Level below Battleship Rock (JF-2). A series of seeps of thermal and mineral waters occur about one mile south of Battleship Rock on the west bank of the Jemez River. The seeps are in the rocks of Pennsylvanian age and have sulfate concentrations that are high, while the chloride concentrations are low, Table IX).

West side of State Road 4 (JF-3). Several small seeps of thermal and mineral water occur in a small canyon west of State Road

4. The seeps are depositing tufa in the stream channel. The seep discharge is less than 1 liter/sec in a landslide area of Pennsylvanian rock. The temperature of the water is about 9°C. The dissolved solids are moderate, while chloride remains low as at JF-2 (Table IX).

Russell Spring (JF-4). Russell Spring discharges from a landslide area in the Pennsylvanian rocks east of State Road 4. The spring forms a small pool. The discharge is estimated at less than 1 liter/sec. The temperature of the water is about 9°C. The water is similar to that of JF-2, and -3. Calcium, magnesium, and bicarbonates are high, while chlorides are low. The dissolved solid concentrations are moderate (Table IX).

Soda Dam (JF-5). The thermal and mineral springs at Soda Dam consist of springs and seeps issuing from fracture zones associated with the Jemez Fault. The fault has displaced the basement rocks, moving the Precambrian gneiss up against the Pennsylvanian limestone. The temperature of the water ranges from 24°C to 41°C. The water is highly mineralized, containing high concentrations of calcium, magnesium, sodium, bicarbonate, and chloride (Table IX). The sulfates are low while dissolved solids are high. The highly mineralized water from the springs has deposited a large volume of tufa which extends outward from the west canyon wall into the stream, hence Soda Dam. The canyon floor south of Soda Dam is underlain by tufa.

Jemez Hot Springs (JF-6). Jemez Hot Springs consist of about 10 springs flowing at about 13 liter/sec from fractures in the Pennsylvanian rocks that are associated with the Jemez Fault. The temperatures of the water range from 34°C to 76°C. The quality of water from the individual springs varies but is generally high in concentrations of calcium, magnesium, sodium, bicarbonate, and chlorides (Table IX);

however, sulfates are low. There are places where the springs deposit tufa as at Soda Dam.

Owl Spring (JF-7). Owl Spring is located about 2 miles northwest of Jemez Pueblo. The spring issues from a fracture zone in the Pennsylvanian rock. The fracture zone is probably associated with the Jemez Fault. The spring yields about 2 liters/sec from a collection pipe buried in the stream channel. The calcium, magnesium, and sodium concentrations in the water are high (Table IX). There is some deposition of tufa in the spring area.

Indian Springs (JF-8). Indian Springs issue from a fracture system that is probably associated with the Jemez Fault. It is a series of small seeps and springs that in some places have built up deposits of tufa. Renick³ reports that they occur both east and west of Jemez River. East of the river the springs are covered by alluvium and are a possible source of recharge to the supply well for Jemez Pueblo. The temperature of the water ranges from 35°C to 49°C. The water is highly mineralized, containing high concentrations of calcium, bicarbonates, sulfate, and chloride (Table IX). The dissolved solid concentrations are also high.

IV. GROUNDWATER AND WATER SUPPLY

Groundwater occurs in the caldera fill in the Valles Caldera and in volcanic rocks and sediments adjacent to the Caldera. Water supply to two of the larger villages is from springs at Jemez Springs and from a well at Jemez Pueblo. Water for domestic and recreational use is obtained from shallow wells completed in the alluvium of stream channels, or from springs.

A number of test holes were drilled in the Valle Toledo and Valle Grande in 1949 to determine if a water supply could be developed in these areas for Los Alamos.

Testing indicated a delicate balance between the ground water and stream flow. Pumpage of wells in these areas would deplete stream flow. Development of water supply for Los Alamos in these areas was abandoned for this reason.

Test holes were drilled along Sulphur Creek by independent companies in the early 1960s to determine the geothermal potential. In the past several years additional exploratory test holes have been drilled along Sulphur and Redondo Creeks. No data are available on these later test holes.

In 1972, the Los Alamos Scientific Laboratory, as part of the geothermal program, drilled four test holes ranging in depth from 152 to 229 m, and one deep exploratory test hole 785 m, west of the caldera. The holes were drilled for geological and hydrologic information.

Locations of sampling stations are referenced to Fig. 2 and Table X.

A. Valle Toledo. Five test holes ranging in depth from 87 to 199 m were completed into the caldera fill of the Valle Toledo (Fig. 2). Water was encountered under artesian pressures. The ground water from the test holes H-1, H-2, H-3, H-4, and H-6 is low in dissolved solids but high in silica and fluorides (Table X). Water temperatures ranged from 13° to 17°C.

B. Valle Grande. Four test holes ranging in depth from 180 m to 361 m were completed into the caldera fill of the Valle Grande (Fig. 2). As in the Valle Toledo, the test holes encountered water under artesian conditions. Analyses of water from the test holes H-7, H-8, H-9, and H-10 indicate low concentrations of dissolved solids and high silica concentrations (Table IX). Fluorides were much lower than in water from the test holes in the Valle Toledo. Temperatures of the water ranged from 12°C to 17°C.

C. Jemez Springs Water Supply. Springs in Church Canyon east of the village and two springs north on the west wall of Jemez Canyon supply water for the village of Jemez Springs (Fig. 2). The water comes

from various perched zones in a limestone and sandstone sequence overlain by recent volcanics. Samples JS-1 are composite samples taken in the village. Sample JS-2 was taken from the west fork and JS-3 from the east fork of Church Canyon. Sample JS-4 is from Sino Springs while JS-5 is from Aqua Durme Springs on the west wall of Jemez Canyon. The analyses show water of a good quality, low in dissolved solids (Table X).

D. Jemez Pueblo Water Supply. A 25-m-deep well was drilled into the alluvium at the Jemez Pueblo (Fig. 2). The well yields about 16 liters/sec. The water from the well contains moderate concentrations of dissolved solids (JP-1, Table X). Recharge to the well may in part be from the Jemez River; however, thermal springs with mineralized water in the area may be a part of the recharge to the well.

E. Wells, Test Holes, and Springs.

Thirty-eight water samples from wells, test holes, and springs were collected in the area of study. The following list presents a brief description of each station sampled. Location is referenced in Fig. 2 and analyses in Table X.

Location 1. Several test holes were drilled along Sulphur Creek in the early 1960s to explore the geothermal energy potential in the area (Fig. 2). The test holes penetrated caldera fill and probably sections of Permian and Pennsylvanian rock and were abandoned upon reaching Precambrian crystalline rocks. Analyses are reported to be of the steam condensate from blow down from one of the test holes (Table X). The concentrations of chemical ions, such as sulfate, sodium, chlorides, and fluorides, are high. The water is somewhat similar to that of thermal springs along Sulphur Creek. Dissolved solid concentrations are high, ranging between 2,000 and 3,000 mg/liter.

Location 2. A Forest Service well furnishes water for Redondo Campground and is located adjacent to Redondo Creek. The well, drilled in 1966, is completed to a

Fig. 2. Location of wells, test holes, and springs.

depth of 23 m in volcanic debris. The static water level is reported to be about 1 m below land surface. The analysis indicates the water is low in dissolved solids at about 300 mg/liter. The hardness is due to the high concentration of calcium-magnesium.

Location 3. A Forest Service well furnishes water for the San Antonio Campground and is located adjacent to San Antonio Creek. The well is about 30 m deep and is completed in the alluvium with a yield of about 0.4 liter/sec. The concentration of dissolved solids is low at 220 mg/liter.

Location 4. Horseshoe Spring is located on the west slope of San Antonio Canyon. The spring discharge, from the base of Cenozoic volcanics, is collected in a gallery and piped into a storage tank for domestic use in summer homes. The concentration of dissolved solids is low, at about 300 mg/liter.

Location 5. The domestic well for Brown's cabin is located in the Horseshoe Spring cabin area. Analysis of a sample collected from a water tap indicates that the water may be from the alluvium and is similar in quality to water from other wells in the area. The dissolved solids are low at 320 mg/liter.

Location 6. The spring discharges from the alluvium in the valley west of San Antonio Creek. The concentration of dissolved solids is low at 230 mg/liter.

Location 7. The spring discharges from the base of Cenozoic volcanics on the west of San Antonio Creek. Dissolved solids are low at about 210 mg/liter.

Location 8. The Hazlett cabin domestic well near La Cueva is probably completed in the alluvium. It was drilled 23 m deep and the water surface is located about 9 m below the land surface. The analysis indicates low dissolved solids (200 mg/liter) but moderate hardness (108 mg/liter). The water is similar to other sources in La Cueva area (Locations 3,4,5,6, and 8).

Location 9. The water supply for Battleship Picnic Area was taken from a stream north

of the area on the east side of the canyon. The stream is fed from discharge from springs in Cenozoic volcanics. The dissolved solids concentrations are low at about 250 mg/liter.

Location 10. The water supply for YMCA Camp Shaver is a well located on the east side of Jemez River. The well is probably completed in the alluvium at a depth of 12 m. The depth to water is about 6 m. The water has a low dissolved solids concentration of 135 mg/liter.

Location 11. The domestic well for Russell's cabin, located on the west side of the stream, is probably completed in the alluvium. Although the dissolved solids in this water are nearly twice as high as those for Locations 6,7,8,9, and 10, the dissolved solids are low (i.e., less than 500 mg/liter). The total hardness results from thermal or mineral springs which contribute to the recharge of the well.

Location 12. The domestic well, located west of the stream, was drilled in 1957 to a depth of 17 m and is probably completed in the alluvium. Depth to water is reported at 10 m. Although a complete analysis of this water is not reported, the specific conductance and total hardness indicate water of similar quality and may be the same well as reported for older analyses for Location 11.

Location 13. The well reported (1954) to be located at Via Coeli probably is abandoned and the water supply for the monastery now comes from the Jemez Springs water system. The water may be classified as moderate with respect to dissolved solids (indicated by the specific conductance). The well is probably completed in the alluvium and recharge is in part from the stream and nearby thermal springs. Depth to water reported in 1954 was 2.4 m.

Location 14. The well supplied water for Mr. Bell's home in 1954. The analyses indicates water quality similar to that at location 13 with moderate concentrations of dissolved solids (indicated by specific conductance).

Location 15. The domestic supply at Redwood Grove Restaurant is a well completed in the alluvium. The water table is about 2 m below land surface. The analysis shows moderate concentrations of dissolved solids at about 700 mg/liter.

Location 16. The spring supplying water for the campground on Vallecito Creek is located south of the caldera (Fig. 2). The spring is probably in the alluvium as the concentration of dissolved solids is low at about 100 mg/liter.

Location 17. Test hole C was drilled to a depth of 229 m. The water level is at a depth of 99 m. Water occurs in the lower part of the Abiquiu tuff and underlying rocks of Permian age. The water from this hole contains low concentrations of dissolved solids (140 mg/liter).

Location 18. Test hole B was drilled to a depth of 198 m. The water level is at 137 m in rocks of Permian age. This water is also low in dissolved solids (400mg/liter).

Location 19. Granite Test 1 was drilled through the Cenozoic volcanics, and rocks of Permian and Pennsylvanian age, and was completed into rocks of the Precambrian. The test hole was completed in June 1972 at a depth of 785 m. Blank casing is set to a depth of 732 m, or about 90 m into the Precambrian rocks. The lower 53 m of the hole is open. Water was standing in the hole to a depth of about 91 m in August 1972. The U.S. Geological Survey collected a series of water samples at selected depths in the casing and open hole. These samples were collected and analyzed to determine if any changes in water quality occurring at depth could be attributed to a hole in the casing or to leakage where the casing is cemented into the Precambrian rocks. The results indicate there is no significant change in quality that could be attributed to a hole in the casing or to leakage around the cement seal. The water was residual water left in the casing from drilling operations. The quality of water is different,

more highly mineralized than the water from Fenton Lake which was the source of drilling fluid. This is due to minerals taken into solution from the Precambrian rocks during the coring operation and the addition of drilling mud to aid in removing cuttings.

Location 20. Test hole A was drilled to a depth of 180 m. The water level is at a depth of 149 m in rocks of Permian age. The dissolved solids concentrations are low, below 500 mg/liter.

Location 21. Calaveras Spring discharges from joints or fractures in the Bandelier Tuff. The spring, located in the stream channel, discharges about 2 liters/sec. Numerous seeps occur in open joints and fractures in the tuff on the north side of the stream channel. The concentrations of dissolved solids are low at 94 mg/liter.

Location 22. The spring discharges from joints and fractures in the Bandelier Tuff on the west wall of the canyon near Calaveras State Campground. The spring, which discharges water at about 2 liter/sec, contains water similar in quality to that listed for Location 21. The dissolved solids concentration is about 100 mg/liter.

Location 23. A series of springs discharge from open joints and fractures in the Bandelier Tuff on the north wall of Rio Cebolla Canyon. The spring discharge is collected and used for domestic purposes and in the rearing pond of the State Fish Hatchery. The concentration of dissolved solids is low at 114 mg/liter.

Location 24. The sample was collected at the fish hatchery rearing ponds and is a composite of water from Location 23 and springs in the Rio Cebolla and Calaveras Canyon. The discharge was estimated at 19 liters/sec. This water contains about 100 mg/liter dissolved solids.

Location 25. The sample was collected from a gallery set in the alluvium of Barley Canyon and reflects the quality of water moving through the alluvium. Although this

water contains significantly more dissolved solids than the water in locations 21, 22, 23, and 24, the concentrations are classified as low (190 mg/liter).

Location 26. Test hole D was drilled to a depth of 152 m and is completed in the Abo Formation. The water level is at about 10m. The dissolved solids concentrations are low at 272 mg/liter.

Location 27. Hofhein's well is drilled to a depth of about 29 m. The alluvium is about 9 m thick and is probably underlain by rocks of Permian age. The well is flowing less than 1 liter/sec. The dissolved solids concentrations are moderate at about 650 mg/liter.

Location 28. The spring at the Forest Service Guard Station flows less than 1 liter/sec from the Bandelier Tuff. The dissolved solids concentrations are low at 150 mg/liter.

Location 29. The springs at the mouth of Spring Canyon flow less than 1 liter/sec from the Bandelier Tuff. The dissolved solids concentrations are low at 130 mg/liter.

Location 30. The test hole was drilled by LASL for heat flow measurements and is completed at a depth of about 27 m into the Abiquiu Tuff. Water level stands at about 10 m. The dissolved solids concentrations are low at 165 mg/liter.

Location 31. A small spring in Lake Fork Canyon discharges from rocks of the Bandelier Tuff. The dissolved solids concentrations are low at 150 mg/liter.

Location 32. A test hole drilled by the U.S. Geological Survey is completed at a depth of about 16 m into rocks of Pennsylvanian age. The dissolved solids concentrations are high at 2200 mg/liter.

Location 33. A test hole drilled by the U.S. Geological Survey is completed to a depth of 47 m into rocks of Permian age. The dissolved solids concentrations are high at 2200 mg/liter.

Location 34. Morgan's well is dug to a depth of about 5 m. The dissolved solids concentrations are moderate at 650 mg/liter.

Location 35. The abandoned well near Redwood Grove Restaurant is completed to a depth of about 39 m into rocks of Permian age. The dissolved solids concentrations are high at 1900 mg/liter.

Location 36. A test hole drilled by the U.S. Geological Survey is completed at a depth of 17 m into rocks of Pennsylvanian age. The dissolved solids concentrations are low at 400 mg/liter.

Location 37. A test hole drilled by the U.S. Geological Survey is completed at a depth of 61 m into rocks of Precambrian age. The dissolved solids concentrations are low at about 290 mg/liter.

Location 38. Several springs that furnish water supply for the Jemez Valley School discharge from rocks of Precambrian age. The dissolved solids concentrations (660 mg/liter) indicate recharge to the spring may be from rocks of Permian or Pennsylvanian age.

V. SUMMARY

This report was prepared to provide basic data regarding the quality of water in the area of the geothermal site at TA-57. A few generalizations regarding the quality of water are presented as the summary.

The dissolved solids concentrations in surface water in the area are generally low and increase downstream as would be expected. A rapid increase in concentrations of dissolved solids in the upper reach of the Jemez River is due to the inflow of highly mineralized water from thermal spring associated with the Jemez fault. Surface water during low flow along Sulphur Creek contains high concentrations of dissolved solids due to the inflow of water from thermal and mineral springs. The concentrations of dissolved solids of surface water in San Antonio Creek, Vallecitos Creek, Fenton Lake, Rio de las Vacas, and Rio Guadalupe are low and show a normal increase downstream.

Thermal and mineral springs associated with the Jemez fault and in the interior of the caldera contain water with moderate to high concentrations of dissolved solids. Those thermal and mineral springs associated with the recent volcanic rocks along the outer rim of the caldera yield water with low concentrations of dissolved solids.

The concentrations of dissolved solids in ground water in the area vary from low to high depending on area of recharge and type of rocks in contact with the ground water.

The concentrations of dissolved solids in ground water in the Valle Toledo and Valle Grande are low, but in geothermal test holes along Sulphur Creek, the concentrations are high. In the area of La Cueva and to the north and west, test holes and wells penetrating the alluvium and rocks of Permian age yield ground water with low to moderate concentrations of dissolved solids. Ground water in the alluvium and rocks of Permian or Pennsylvanian age along the Jemez River contain moderate to high concentrations of dissolved solids. Shallow wells completed in the alluvium at Jemez Springs and at Jemez Pueblo are probably recharged in part from the Jemez River and in part from thermal and mineral springs associated with the Jemez fault. Ground water that discharges from springs in the Bandelier Tuff have low concentrations of dissolved solids.

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TABLE I
SURFACE WATER

Location	A ^a	B ^a	C ^a	D ^a	E ^b	F ^b	G ^c	H ^c	I ^c	J ^d	J ^d	J ^d
Date of collection	6-20-50	9-23-72	9-23-72	9-23-72	10-22-49	9-23-72	10-16-49	9-23-72	9-23-72	4-1-71	11-11-71	5-10-71
Chemical analysis (mg/liter)												
Silica (SiO ₂)	60	--	--	--	83	--	57	--	--	--	--	--
Calcium (Ca)	6	11	13	14	164	78	3	16	19	16	16	14
Magnesium (Mg)	2	4	3	6	24	15	2	4	6	9	4	6
Sodium (Na)	--	11	10	23	16	43	--	15	13	14	17	13
Carbonate (CO ₃)	--	0	0	0	0	0	0	--	0	0	0	0
Bicarbonate (HCO ₃)	43	43	52	64	0	16	45	64	34	64	72	72
Sulfate (SO ₄)	2.1	--	--	--	1160	--	2.9	--	--	--	--	--
Chloride (Cl)	1.5	4	2	4	4	164	2	2	8	<1.0	4	4
Fluoride (F)	0.8	0.8	0.8	0.8	0.3	0.4	1.3	1.3	1.3	1.0	0.6	0.7
Nitrate (N)	<0.1	0.5	<0.1	0.1	<0.1	<0.1	0.2	0.3	0.1	0.1	<0.1	0.1
Dissolved solids	103	96	58	104	1600	662	105	164	206	120	153	132
Total hardness	23	44	44	60	503	256	27	56	72	76	56	60
Specific conductance (μmhos)	85	90	95	110	2270	700	30	130	170	145	140	155
pH	--	7.1	6.9	7.2	2.5	6.0	--	7.0	7.2	7.4	7.2	7.3
Temperature (°C)	--	9	9	12	--	3	13	9	12	--	--	--

^aA through D, East Fork of the Jemez.

^bE and F, Sulphur Creek.

^cG through I, San Antonio Creek.

^dJ, Jemez River.

TABLE I (Continued)

SURFACE WATER

Location	J ^a	J ^a	J ^a	K ^a	L ^b	M ^c	M ^c	M ^c	M ^c	M ^c
Date of collection	9-23-72	10-4-72	8-8-73	9-23-72	6-8-73	4-1-71	11-11-71	5-10-72	10-4-72	10-9-73
Chemical analysis (mg/liter)										
Silica (SiO ₂)	--	--	--	--	--	--	--	--	--	--
Calcium (Ca)	18	14	19	43	48	14	13	13	13	11
Magnesium (Mg)	4	6	3	5	11	10	6	4	4	3
Sodium (Na)	17	19	4	69	37	11	11	10	11	8
Carbonate (CO ₃)	0	0	0	0	16	0	0	0	0	0
Bicarbonate (HCO ₃)	76	72	72	164	188	56	52	60	60	52
Sulfate (SO ₄)	--	--	--	--	--	--	--	--	--	--
Chloride (Cl)	6	4	8	106	6	<1.0	2	<1.0	2	4
Fluoride (F)	1.6	1.2	0.5	1.2	0.6	0.5	0.4	0.3	0.8	0.2
Nitrate (N)	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved solids	126	144	176	424	350	86	100	112	78	118
Total hardness	60	60	60	128	164	76	56	48	48	40
Specific conductance (µmhos)	155	150	180	600	370	100	110	110	110	95
pH	6.9	7.4	7.6	7.2	8.5	7.3	7.1	7.3	6.7	7.4
Temperature (°C)	12	--	--	17	--	--	--	--	--	--

^aJ and K, Jemez River.^bL, Vallecitos Creek.^cM, Fenton Lake.

TABLE II

SULPHUR CREEK, LOCATION F
(Data from U.S. Forest Service)

Parameter	Units	No. Samples	Minimum	Maximum	Mean
Water temperature	°C	11	0	23	9
Air temperature	°C	11	-3	29	13
Stream flow	l/sec	9	31	116	53
pH	-	11	4.6	8.0	6.1
Total alkalinity (CaCO ₃)	mg/liter	10	0	35	13
Phenolphthalein	mg/liter	10	0	20	2
Residue (filterable)	mg/liter	1	150	150	150
Dissolved solids	mg/liter	10	0	330	149
Total hardness	mg/liter	11	60	190	102
Ca hardness (CaCO ₃)	mg/liter	11	50	160	86
Chloride (Cl)	mg/liter	11	0	70	17
Sulfate (SO ₄)	mg/liter	11	40	265	142
Fluoride (F)	mg/liter	5	0	0.5	0.3
H ₂ S	mg/liter	3	0.1	6.5	2.2

TABLE III

SAN ANTONIO CREEK, LOCATION N
(Data from U.S. Forest Service)

Parameter	Units	No. Samples	Minimum	Maximum	Mean
Water temperature	°C	11	1	24	9
Air temperature	°C	11	-3	29	14
Stream flow	l/sec	11	220	4200	820
pH	-	11	7.5	8.8	8.2
Total alkalinity (CaCO ₃)	mg/liter	10	0	110	60
Phenolphthalein	mg/liter	10	0	70	7
Residue (filterable)	mg/liter	1	60	60	60
Dissolved solids	mg/liter	10	0	95	65
Total hardness	mg/liter	11	39	65	53
Ca hardness (CaCO ₃)	mg/liter	11	25	42	42
Chloride (Cl)	mg/liter	11	0	7.5	3.7
Sulfate (SO ₄)	mg/liter	11	5.0	28.0	11
Fluoride (F)	mg/liter	4	0.8	1.7	1.3
H ₂ S	mg/liter	3	0.0	0.1	<0.1

TABLE IV

JEMEZ RIVER, LOCATION J
(Data from U.S. Geological Survey)

	<u>No. Samples</u>	<u>Minimum</u>	<u>Maximum</u>	<u>Average</u>
Mean discharge (liter/sec)	45	200	1620	475
mg/liter				
Silica (SiO ₂)	20	32	56	47
Iron (Fe)	9	0.01	0.40	0.10
Calcium (Ca)	20	12	20	15
Magnesium (Mg)	20	1.7	3.0	2.4
Sodium (Na)	21	8.3	21	16
Potassium (K)	9	2.3	3.3	2.7
Bicarbonate (HCO ₃)	45	21	90	73
Carbonate (CO ₃)	45	0	6	0.6
Sulphate (SO ₄)	21	7.6	36	15
Chloride (Cl)	45	0.6	7.8	4.4
Fluoride (F)	10	0.4	1.1	0.9
Nitrate (NO ₃)	21	0.0	0.5	0.2
Boron (B)	9	0.0	0.09	0.05
Dissolved solids (calculated - mg/liter):				
ppm	20	98	158	137
Tons per acre-foot	6	0.14	0.21	0.19
Tons per day	6	4.14	17.6	8.7
Hardness as CaCO ₃ : (mg/liter)				
Calcium, Magnesium	45	36	62	45
Noncarbonate	45	0.0	29	1.1
Sodium adsorption ratio	21	0.6	1.3	1.0
Specific conductance (microhms at 25°C)	45	88	207	164
pH	45	6.2	8.5	7.7

TABLE V

JEMEZ RIVER, LOCATION J
(Data from U.S. Forest Service)

<u>Parameter</u>	<u>Units</u>	<u>No. Samples</u>	<u>Minimum</u>	<u>Maximum</u>	<u>Mean</u>
Water temperature	°C	14	1	22	11
Air temperature	°C	14	1	29	17
Stream flow	l/sec	13	250	2800	960
pH	-	14	7.7	8.6	8.3
Total alkalinity (CaCO ₃)	mg/liter	13	0	100	61
Phenolphthalein	mg/liter	13	0	80	6
Residue (filterable)	mg/liter	6	80	100	96
Dissolved solids	mg/liter	3	90	100	97
Total hardness	mg/liter	14	45	110	58
Ca hardness (CaCO ₃)	mg/liter	14	32	80	46
Chloride (Cl)	mg/liter	14	0	7.5	3.9
Sulfate (SO ₄)	mg/liter	14	5.0	60	24
Fluoride (F)	mg/liter	3	0	1.1	0.4
H ₂ S	mg/liter	4	0	1.3	0.7

TABLE VI

RIO DE LAS VACAS, LOCATION O
(Data from U.S. Forest Service)

Parameter	Units	No. Samples	Minimum	Maximum	Mean
Water temperature	°C	11	-1	24	8
Air temperature	°C	10	3	29	13
Stream flow	l/sec	9	80	5000	1300
pH	-	11	7.5	8.4	8.1
Total alkalinity (CaCO ₃)	mg/liter	11	0	60	36
Phenolphthalein	mg/liter	11	0	57	5
Residue (filterable)	mg/liter	6	25	60	50
Dissolved solids	mg/liter	3	45	60	55
Total hardness	mg/liter	11	30	55	46
Ca hardness (CaCO ₃)	mg/liter	11	25	55	37
Chloride (Cl)	mg/liter	11	0	5.0	2.5
Sulfate (SO ₄)	mg/liter	11	2.0	8.0	4.5
Fluoride (F)	mg/liter	3	0.1	0.4	0.2
H ₂ S	mg/liter	3	0	0.1	<0.1

TABLE VII

RIO DE LAS VACAS, LOCATION P
(Data from U.S. Forest Service)

Parameter	Units	No. Samples	Minimum	Maximum	Mean
Water temperature	°C	13	0	24	11
Air temperature	°C	13	-3	21	16
Stream flow	l/sec	11	85	6500	1500
pH	-	13	1.7	8.7	7.8
Total alkalinity (CaCO ₃)	mg/liter	12	0	185	119
Phenolphthalein	mg/liter	12	0	144	12
Residue (filterable)	mg/liter	6	60	190	142
Dissolved solids	mg/liter	3	95	150	132
Total hardness	mg/liter	13	60	170	118
Ca hardness (CaCO ₃)	mg/liter	13	40	160	102
Chloride (Cl)	mg/liter	13	0	5.0	2.3
Sulfate (SO ₄)	mg/liter	13	2.0	15	5.5
Fluoride (F)	mg/liter	3	0	0.4	0.1
H ₂ S	mg/liter	3	0	0.5	0.2

TABLE VIII

RIO GUADALUPE, LOCATION Q
(Data from U.S. Forest Service)

Parameter	Units	No. Samples	Minimum	Maximum	Mean
Water temperature	°C	11	1	21	10
Air temperature	°C	10	1	29	16
Stream flow	l/sec	10	95	7300	1600
pH	-	11	7.9	8.7	8.4
Total alkalinity (CaCO ₃)	mg/liter	10	0	135	92
Phenolphthalein	mg/liter	10	0	150	15
Residue (filterable)	mg/liter	1	75	75	75
Dissolved solids	mg/liter	10	<1.0	150	105
Total hardness	mg/liter	11	65	160	106
Ca hardness (CaCO ₃)	mg/liter	11	50	145	91
Chloride (Cl)	mg/liter	11	0	5.0	3.4
Sulfate (SO ₄)	mg/liter	11	0	15	7.5
Fluoride (F)	mg/liter	4	0.5	0.9	0.7
H ₂ S	mg/liter	3	0	0.1	<0.1

TABLE IX
THERMAL AND MINERAL SPRINGS

Location	RV-1 ^a	RV-2 ^b	RV-2 ^b	RV-3 ^c	RV-4 ^d	RV-4 ^d	RV-5 ^e	RV-5 ^e	I-1 ^f	I-2 ^g	I-2 ^g	I-2 ^g
Date of collection	7-28-49	7-28-49	5-24-73	5-25-73	8-1-47	1-17-73	8-1-47	1-16-73	8-1-47	8-13-47	8-13-47	8-31-49
Chemical analysis (mg/liter)												
Silica (SiO ₂)	81	105	71	88	71	63	53	55	87	170	122	42
Calcium (Ca)	4	6	3	6	8	8	11	44	32	256	7	168
Magnesium (Mg)	0.3	0.5	1.0	2	2	6	4	5	22	35	19	23
Sodium (Na)	-	-	22	16	-	53	-	22	-	-	-	14
Carbonate (CO ₃)	-	-	0	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO ₃)	59	76	58	52	139	120	87	92	0	0	0	0
Sulfate (SO ₄)	7	14	8	<1	17	17	8	6	242	4030	5190	614
Chloride (Cl)	3	3	6	6	11	8	8	8	3	170	649	8
Fluoride (F)	0.8	1.4	0.8	0.5	0.8	0.7	1.0	0.3	0.3	0.7	-	<0.1
Nitrate (N)	0.4	0.4	0.3	0.2	0.2	<0.1	0.4	0.3	0.6	0.4	0.3	0.4
Dissolved solids	149	199	202	206	234	250	152	180	-	-	-	967
Total hardness	10	18	12	24	28	44	45	44	-	-	-	514
Specific conductance (μmhos)	122	164	110	110	283	240	200	140	-	825	1660	1270
pH	-	-	7.5	7.4	7.3	8.1	8.1	7.8	2.9	1.8	1.5	3.1
Temperature (°C)	41	27	22	21	38	38	43	30	-	16	36	-

^aRV-1, San Antonio Warm Springs.

^bRV-2, San Antonio Hot Springs.

^cRV-3, near San Antonio Hot Springs.

^dRV-4, Spence Hot Springs.

^eRV-5, McCauley Hot Springs.

^fI-1, Alamo Canyon.

^gI-2, Sulphur Springs (number of springs in area).

TABLE IX (continued)

Location	I-2 ^a	I-2 ^a	I-2 ^a	I-2 ^a	I-2 ^a	I-2 ^a	JF-1 ^b	JF-2 ^c	JF-3 ^d	JF-4 ^e	JF-5 ^f	JF-5 ^f
Date of collection	8-31-49	8-31-49	8-31-49	8-31-49	8-31-49	11-4-63	1-17-73	4-20-50	3-19-73	3-19-73	6-28-49	10-10-50
Chemical analysis (mg/liter)												
Silica (SiO ₂)	216	219	237	174	206	190	40	66	-	-	47	-
Calcium (Ca)	185	66	110	45	101	7	130	313	174	157	327	-
Magnesium (Mg)	52	17	11	12	23	10	19	30	22	31	27	-
Sodium (Na)	7	-	24	13	10	24	390	-	59	105	-	-
Carbonate (HCO ₃)	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO ₃)	0	0	0	0	0	0	597	872	640	752	1400	1550
Sulfate (SO ₄)	1570	4250	2740	1440	3820	35100	27	196	-	-	51	-
Chloride (Cl)	4	45	20	-	3	24	442	6	12	140	1080	1550
Fluoride (F)	1.1	0.9	0.5	-	1.0	1.2	3	-	1.2	1.4	2.4	-
Nitrate (N)	<0.1	0.1	0.1	0.2	<0.1	<0.1	0.1	<0.1	0.4	0.3	1.3	-
Dissolved solids	1950	3630	2690	1730	3160	-	1528	-	922	984	3060	-
Total hardness	676	234	320	162	346	57	404	794	528	520	927	-
Specific conductance (μmhos)	4570	13900	8510	4370	12700	13800	2000	1480	1140	1280	5160	6620
pH	1.9	1.4	1.6	1.9	1.4	1.8	6.9	-	7.5	7.4	6.8	-
Temperature (°C)	71	43	-	41	-	87	-	-	9	4	36	-

^aI-2, Sulphur Springs (number of springs in area).

^bJF-1, west of Battleship Rock.

^cJF-2, near stream level below Battleship Rock.

^dJF-3, west of State Road 4.

^eJF-4, Russell Spring.

^fJF-5, Soda Dam (number of springs in area).

TABLE IX (continued)

Location	JF-5 ^a	JF-5 ^a	JF-5 ^a	JF-5 ^a	JF-6 ^b	JF-6 ^b	JF-6 ^b	JF-6 ^b	JF-6 ^b	JF-6 ^b	JF-7 ^c	JF-8 ^d	
Date of collection	6-20-50	8-2-49	6-28-49	1-16-73	4-15-47	4-15-47	4-15-47	4-15-47	4-15-47	4-3-56	1-16-73	5-1-53	8-30-62
Chemical analysis (mg/liter)													
Silica (SiO ₂)	-	-	47	46	47	60	91	93	86	84	29	48	
Calcium (Ca)	-	-	344	299	18	47	137	138	136	126	102	100	
Magnesium (Mg)	-	-	29	24	6	14	9	7	10	7	19	9	
Sodium (Na)	-	-		940	12	14	-	572	618	650	144	-	
Carbonate (CO ₃)	0	0	0	0	0	0	0	0	0	0	0	0	
Bicarbonate (HCO ₃)	1550	1580	1580	1236	94	228	740	735	716	600	436	1280	
Sulfate (SO ₄)	-	40	42	36	15	15	51	49	44	42	90	286	
Chloride (Cl)	1550	510	1500	1450	4	4	83	795	870	900	133	1140	
Fluoride (F)	-	-	3.2	3.2	0.8	0.8	4.9	5.2	5.2	4.6	2.0	7.3	
Nitrate (N)	-	-	<0.1	<0.1	0.1	<0.1	0.3	0.2	1	<0.1	<0.1	<0.1	
Dissolved solids	-	-	3880	3962	1530	2700	2170	2150	2190	2364	-	3470	
Total hardness	-	-	978	848	70	175	379	372	380	344	332	285	
Specific conductance (umhos)	6590	6590	6520	5000	1840	3510	3640	3560	3860	3000	1220	5680	
pH	-	-	6.9	6.7	-	-	7.6	7.2	6.7	7.2	-	8.0	
Temperature (°C)	-	43	-	46	-	-	52	71	89	69	-	35	

^aJF-5, Soda Dam (number of springs in area).^bJF-6, Jemez Hot Springs (number of springs in area).^cJF-7, Owl Spring.^dJF-8, Indian Springs.

TABLE X
WELLS, TEST HOLES, AND SPRINGS

Location	H-1 ^a	H-2 ^a	H-3 ^a	H-4 ^a	H-6 ^a	H-7 ^b	H-8 ^b	H-9 ^b	H-10 ^b	JS-1 ^c	JS-1 ^c	JS-2 ^d
Date of collection	7-6-49	10-16-49	10-16-49	10-16-49	10-16-49	11-12-49	10-26-49	10-26-49	10-26-49	1-20-65	1967	5-8-73
Chemical analysis (mg/liter)												
Silica (SiO ₂)	59	51	45	39	54	72	70	74	75	61	-	30
Calcium (Ca)	6	8	15	10	10	6	10	6	13	17	16	19
Magnesium (Mg)	0.9	0.9	1.1	1.6	1.9	0.9	2.7	2.2	2.4	3.3	3.7	3
Sodium (Na)	-	-	-	-	-	-	-	-	-	-	3.7	5
Carbonate (CO ₃)	-	-	-	-	-	-	-	-	-	0	0	0
Bicarbonate (HCO ₃)	40	48	77	42	70	55	75	73	87	91	66	56
Sulfate (SO ₄)	2.6	3.7	3.3	3.5	3.3	2.0	4.1	2.5	9.3	11	11	12
Chloride (Cl)	1.5	2.0	1.0	3.0	2.0	1.5	2.0	1.0	2.0	4.2	<1	4
Fluoride (F)	1.4	3.6	2.8	2.0	1.6	0.4	0.4	0.6	0.2	0.6	0.2	0.3
Nitrate (N)	0.1	0.2	0.2	0.2	<0.1	0.1	<0.1	<0.1	<0.1	1.0	<0.1	0.5
Dissolved solids	103	111	125	90	124	125	142	142	165	178	95	150
Total hardness	18	24	42	32	33	19	9	24	42	56	55	60
Specific conductance (μmhos)	80	85	110	85	100	90	110	125	160	185	120	100
pH	-	-	-	-	-	-	-	-	-	-	-	7.1
Temperature (°C)	10	13	17	18	17	17	16	14	12	-	-	6

^aH-1 through H-4, and H-6, test holes Valle Toledo.

^bH-7 through H-10, test holes Valle Grande.

^cJS-1, water supply, Jemez Spring (composite).

^dJS-2, water supply, Jemez Church Canyon, West Fork.

TABLE X (continued)

Location	JS-3 ^a	JS-4 ^b	JS-5 ^c	JP-1 ^d	JP-1 ^d	1 ^e	1 ^e	2 ^f	2 ^f	3 ^g	4 ^h	5 ⁱ
Date of collection	5-8-73	5-8-73	5-8-73	1-19-65	1967	6-13-63	6-18-63	7-66	6-5-73	6-8-73	11-23-72	6-5-73
Chemical analysis (mg/liter)												
Silica (SiO ₂)	42	70	64	53	-	-	-	-	58	-	51	52
Calcium (Ca)	16	16	18	68	59	28	2	43	48	22	18	62
Magnesium (Mg)	6	6	5	16	18	<1	1.2	8	11	5	1	7
Sodium (Na)	10	12	13	-	122	83	83	8	10	12	31	15
Carbonate (CO ₃)	0	0	0	0	0	-	-	0	0	0	0	0
Bicarbonate (HCO ₃)	68	88	88	385	374	623	854	140	156	68	100	200
Sulfate (SO ₄)	10	3	3	49	44	335	177	14	18	-	4	6
Chloride (Cl)	8	6	6	87	116	121	114	4	14	8	6	13
Fluoride (F)	0.3	0.6	0.6	1.3	1.1	24	24	0.3	0.4	0.3	0.8	0.5
Nitrate (N)	0.3	0.4	0.2	0.1	<1	<0.1	<0.1	0.1	0.1	0.2	0.2	0.1
Dissolved solids	118	188	178	589	597	2970	1700	-	294	220	299	322
Total hardness	64	64	64	236	220	70	10	140	164	76	48	184
Specific conductance (μmhos)	120	135	130	946	980	2225	2070	350	320	170	200	380
pH	7.3	7.4	7.8	7.6	-	8.0	8.3	7.9	7.5	7.3	7.6	7.2
Temperature (°C)	6	21	15	-	-	-	-	-	-	12	-	-

^aJS-3, water supply, Jemez Springs Church Canyon, East Fork.

^bJS-4, water supply, Jemez Springs, Sino Spring.

^cJS-5, water supply, Jemez Springs, Aqua Durme.

^dJP-1, water supply, Jemez Pueblo.

^e1, Sulphur Creek, condensate steam test hole.

^f2, Redondo Camp Ground (well).

^g3, San Antonio Camp Ground (well).

^h4, Horseshoe Spring.

TABLE X (continued)

Location	6 ^a	7 ^b	8 ^c	9 ^d	10 ^e	11 ^f	12 ^g	13 ^h	14 ⁱ	15 ^j	16 ^k	17 ^l
Date of collection	6-8-73	4-30-73	6-8-73	1-17-73	5-8-73	6-1-73	12-13-57	10-14-54	10-14-54	6-8-73	6-8-73	1-22-73
Chemical analysis (mg/liter)												
Silica (SiO ₂)	-	74	-	51	34	-	-	59	35	-	-	<1
Calcium (Ca)	19	11	35	24	22	99	-	93	117	85	26	8
Magnesium (Mg)	5	3	5	5	5	9	-	12	17	18	10	6
Sodium (Na)	20	16	14	36	9	23	-	-	-	128	12	40
Carbonate (CO ₃)	0	0	0	0	0	0	5	0	0	0	0	0
Bicarbonate (HCO ₃)	68	64	124	72	84	292	338	370	465	284	108	68
Sulfate (SO ₄)	-	7	-	22	11	-	-	28	81	-	-	<1
Chloride (Cl)	<1	4	2	54	6	14	9	129	106	176	6	32
Fluoride (F)	0.6	0.2	0.7	1.1	0.7	0.8	-	1.0	1.8	1.6	0.3	2.1
Nitrate (N)	8.6	0.2	0.3	0.2	0.3	0.6	-	0.1	<0.1	0.1	0.2	0.2
Dissolved solids	230	210	204	250	134	402	-	-	-	692	170	138
Total hardness	68	40	108	80	76	284	266	280	360	288	104	44
Specific conductance (μmhos)	180	130	220	300	140	580	560	995	1140	1000	190	200
pH	7.4	7.4	7.5	7.6	7.1	7.6	8.3	-	-	7.6	7.8	8.6
Temperature (°C)	-	16	9	-	-	-	-	17	-	15	18	18

^a6, La Cueva Spring.

^b7, spring, west side of creek.

^c8, Hazlett Well.

^d9, Battleship Rock Camp Ground (stream).

^e10, Camp Shaver (well).

^f11, Russell (well).

^g12, Lehaney (well).

^h13, Via Coeli (well).

ⁱ14, Bell (well).

^j15, Redwood Grove Rest (well).

^k16, Paliza (spring).

^l17, test hole C (IASL).

TABLE X (continued)

Location	18 ^a	19A ^b	19B ^b	19C ^b	19D ^b	20 ^c	21 ^d	22 ^e	23 ^f	24 ^g	25 ^h	26 ⁱ
Date of collection	5-24-73	8-25-72	8-25-72	8-25-72	8-25-72	5-24-73	1-17-73	1-17-73	1-17-73	1-17-73	1-23-73	1-22-73
Chemical analysis (mg/liter)												
Silica (SiO ₂)	1	6	3	2	3	3	36	40	33	33	69	<1
Calcium (Ca)	5	6	6	6	6	3	11	6	16	16	14	6
Magnesium (Mg)	1	2	1	1	1	2	3	6	2	4	4	17
Sodium (Na)	101	166	166	170	155	167	10	10	9	9	12	70
Carbonate (CO ₃)	8	0	0	0	0	40	0	0	0	0	0	0
Bicarbonate (HCO ₃)	92	128	124	124	128	356	60	52	64	56	64	140
Sulfate (SO ₄)	5	38	35	34	35	<1	3	3	4	3	5	<1
Chloride (Cl)	120	176	172	176	176	22	6	2	2	2	6	60
Fluoride (F)	0.3	1.6	1.1	1.1	1.1	1.7	0.4	0.7	0.7	0.2	0.5	0.5
Nitrate (N)	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.1
Dissolved solids	406	542	566	556	580	498	94	102	114	106	188	272
Total hardness	16	24	20	20	16	16	40	40	48	56	52	88
Specific conductance (µmhos)	480	760	760	760	760	700	95	80	90	100	120	400
pH	9.0	7.3	7.5	7.4	7.3	9.1	7.4	7.2	7.5	7.1	6.7	8.6
Temperature (°C)	31	-	-	-	-	31	12	14	9	10	9	9

^a18, test hole B, IASL.

^b19, granite test 1, IASL; A, 1500 ft; B, 2300 ft; C, 2410 ft, D, 2575 ft.

^c20, test hole A, IASL.

^d21, Calveras Spring.

^e22, Calveras Camp Ground (spring).

^f23, Seven Springs (water supply, fish hatchery).

^g24, Seven Springs at hatchery (composite).

^h25, Barley Canyon (spring).

ⁱ26 Test Hole D, IASL.

TABLE X (continued)

Location	27 ^a	28 ^b	29 ^c	30 ^d	31 ^e	32 ^f	33 ^g	34 ^h	35 ⁱ	36 ^j	37 ^k	38 ^l
Date of collection	8-14-73	9-13-73	9-13-73	10-9-73	8-14-73	10-24-73	10-24-73	9-27-73	10-26-73	10-30-73	11-2-73	8-21-73
Chemical analysis (mg/liter)												
Silica (SiO ₂)	59	-	-	-	22	-	-	-	-	-	-	-
Calcium (Ca)	34	11	11	22	19	172	14	70	6	101	50	30
Magnesium (Mg)	9	3	1	4	5	53	13	14	7	14	12	8
Sodium (Na)	162	21	9	11	7	400	600	92	600	14	37	185
Carbonate (CO ₃)	0	0	0	0	0	0	36	8	28	0	0	0
Bicarbonate (HCO ₃)	480	56	60	84	68	1156	1292	308	1156	300	216	296
Sulfate (SO ₄)	5	-	-	-	2	-	-	-	-	-	-	-
Chloride (Cl)	4	6	6	8	4	300	200	116	290	16	10	48
Fluoride (F)	1.1	0.9	0.4	<0.1	<0.01	1.5	2.1	1.7	5.2	0.4	2.3	8.4
Nitrate (N)	0.2	0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.6	<0.1	0.1	<0.1	<0.1
Dissolved solids	652	150	130	164	148	2258	2190	634	1964	398	284	660
Total hardness	120	40	32	72	68	648	88	232	44	308	172	108
Specific conductance (µmhos)	880	105	105	160	140	2500	2500	1000	2320	500	390	780
pH	7.5	7.3	7.3	7.0	6.8	7.4	8.2	8.1	8.4	7.7	8.0	7.8
Temperature (°C)	20	9	13	-	11	15	17	18	16	11	13	-

^a27, Hofhein Well.^b28, spring, USFS.^c29, spring, Spring Canyon.^d30, test hole near Fenton Lake.^e31, spring, Lake Fork Canyon.^f32, USGS test hole.^g33, USGS test hole.^h34, Morgan Well.ⁱ35, abandoned well.^j36, USGS test hole.^k37, USGS test hole.^l38, spring, Jemez Valley School.