ADEQUACY OF NASQAN DATA TO DESCRIBE AREAL AND TEMPORAL VARIABILITY OF WATER QUALITY OF THE SAN JUAN RIVER DRAINAGE BASIN UPSTREAM FROM SHIPROCK, NEW MEXICO

By Carole L. Goetz and Cynthia G. Abeyta

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CONVERSION FACTORS

For readers who prefer to use International System (SI) units rather than the inch-pound units used in this report, the following conversion factors may be used.

Multiply inch-pound units	By	To obtain SI units
	Length	
foot	0.3048	meter
	Area	
square mile	2.590	square kilometer
acre	0.004047	square kilometer
	Flow	
cubic foot per second	0.02832	cubic meter per second
	Mass	
ton	907.2	kilogram
	Volume	
acre-foot	1,233	cubic meter

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ABSTRACT

Analyses indicate that water quality in the San Juan River drainage basin upstream from Shiprock, New Mexico, is quite variable from station to station. Analyses are based on water-quality data from the U.S. Geological Survey WATSTORE files and the New Mexico Environmental Improvement Division's files.

In the northeastern part of the basin, most streams have calcium bicarbonate water. In the northwestern and southern part of the basin, the streams have calcium sulfate and sodium sulfate water. Geology, climate, land use, and water use affect water quality. Streamflow from snowmelt in high-mountain regions of the study area is largely calcium bicarbonate. Metals mining contributes sulfate to streamflow in parts of the basin. Irrigation-return flow contributes sodium to streamflow. Porous sandstones and interbedded shales in the southern part of the basin increase dissolved-solids concentration in runoff.

Based on box-and-whisker plots, dissolved-iron and suspended-sediment concentrations have the greatest temporal variability at individual sites. Areal variability from station to station also is great. Specific-conductance, pH, dissolved-orthophosphate phosphorus, dissolved-sodium, dissolved-sulfate, and dissolved-manganese data are next in variability. Dissolved-radium-226 data are the least variable. Water-quality variability is greatest at stations downstream from small flows from point-source discharges or stations located on ephemeral streams. Constituent concentrations frequently are large at these stations; the median specific conductance is 1,000 or more microsiemens per centimeter at 25 °Celsius. These stations have little influence on downstream water quality because of the low volumes of flow.

A trend in one or more water-quality constituents for October 1, 1973, through September 30, 1981, was detected at 14 of 36 stations tested. Of those 14 stations, 5 are downstream from point-source discharges from power-generation facilities. At the upstream National Stream-Quality Accounting Network (NASQAN) station, Animas River at Farmington, New Mexico, 09364500, suspended-sediment concentration decreased 78 milligrams per liter per year. At the downstream NASQAN station, San Juan River at Shiprock, New Mexico, 09368000, no trends were found. At other upstream stations there were some increases and some decreases. The most consistent temporal trend in the basin was the decrease in pH at six stations.

The NASQAN stations, Animas River at Farmington and San Juan River at Shiprock, New Mexico, record large volumes of flow and represent an integration of the flow from many upstream tributaries. They do not represent what is occurring at specific points upstream in the basin; they provide accurate information on how water quality is changing over time at the station location. If a persistent change occurs upstream and involves a large volume of streamflow, it also will likely be detected at the downstream NASQAN stations at Farmington and Shiprock, New Mexico. A water-quality streamflow model would be necessary to accurately predict what is occurring simultaneously in the entire basin. Simultaneous sampling suitable for input into a model of water quality and streamflow in the San Juan River drainage basin upstream from Shiprock, New Mexico, needs to supplement the NASQAN data-collection program.

INTRODUCTION

The National Stream-Quality Accounting Network (NASQAN) was established in the early 1970's to describe the areal and temporal variability of water quality in the Nation's principal streams and to provide a data base for national and regional water-use planning. Accounting Unit 140801, upstream from Shiprock, New Mexico, was one of eight drainage basins chosen for evaluation of how well the data collected under the NASQAN program describe water-quality conditions and changes within the basin. Water-quality data at two NASQAN stations are compared to water-quality data available from 23 other surface-water stations within the basin.

The objectives of this study are as follows: (1) To describe, on both a spatial and temporal basis, the stream water quality throughout Accounting Unit 140801 upstream of the NASQAN station, 09368000, San Juan River at Shiprock; (2) to relate the water-quality variability to general causes, such as basin characteristics including land and water use; (3) to determine whether water-quality data collected at NASQAN station 09368000 and station 09364500, Animas River at Farmington, New Mexico, represent, on both a spatial and temporal basis, water quality at upstream stations; and (4) if water quality at NASQAN stations 09368000 and 09364500 does not represent upstream water quality, to describe the minimum data-collection program that might do so.

DESCRIPTION OF THE STUDY AREA

The study area is the San Juan River drainage basin upstream from NASQAN station 09368000 located at Shiprock, New Mexico (fig. 1). The drainage basin upstream from the San Juan River at Shiprock includes approximately 12,900 square miles, a diverse area that includes deserts in New Mexico and 14,000-foot mountain peaks in Colorado. The drainage basin includes mountain, cobble streams in the north and ephemeral sand channels in the south. It is the second largest tributary of the Colorado River. A number of reservoirs are located in the drainage basin including the large Navajo Reservoir. Water from the San Juan River is used for agriculture, power generation, industrial and public supply, and recreation.

Population

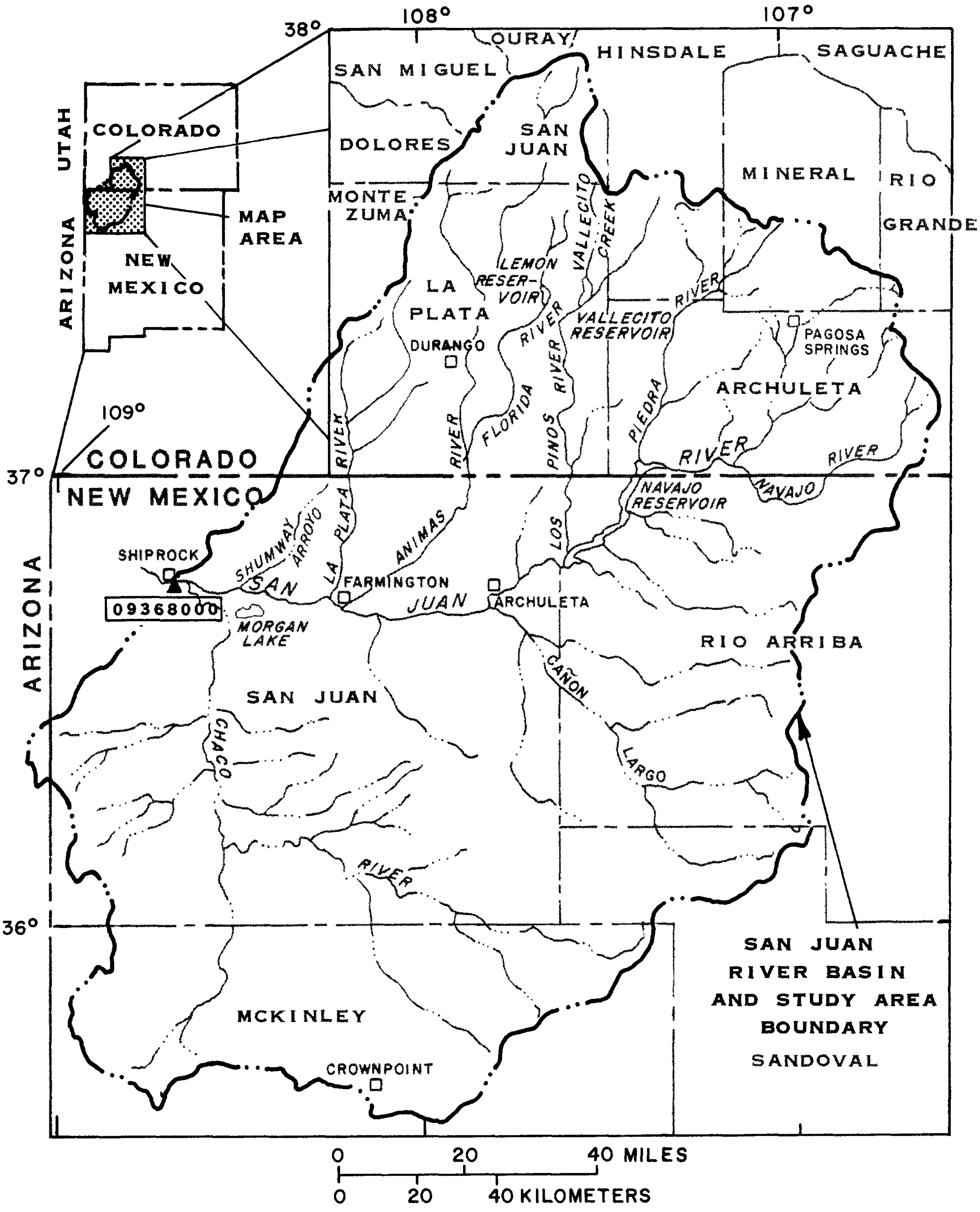
Water use for public supplies and other cultural activities including agriculture, mining, and industries has increased with population growth in the basin. The San Juan River basin population trend is shown in figure 2. A review of population trends from 1860 through 1980 (U.S. Department of Commerce, 1860-1980) indicates that population fluctuated between 10,000 and 20,000 from 1860 until 1900. Population gradually increased from 32,000 to 46,000 between 1910 and 1950. Between the 1950 and the 1960 census, a population boom occurred, increasing the census count to more than 80,000 for both 1960 and 1970. The population remained stable between 1960 and 1970 but then increased dramatically in 1980. The 1980 census records a population of more than 120,000 in the San Juan River drainage basin above Shiprock, New Mexico.

Water Use

Agriculture has been, and currently is, the largest single use for water in the San Juan River basin. According to a report by the Colorado Water Conservation Board and U.S. Department of Agriculture (1974, p. IV-6 to IV-7), agricultural use accounted for nearly 93 percent of the total water depletion during 1965 and was projected to equal 77 percent of total depletion by 1980. Electric-power generation is the second largest water user, accounting for less than 4 percent of the total water depletion during 1965, but projected to equal 16 percent of total depletion by 1980.

Irrigated Cropland

Irrigated cropland in acres for the study area is given in figure 3. A continual increase from 25,000 acres to nearly 160,000 acres of irrigated cropland occurred from 1889 to 1949 (U.S. Department of Commerce, 1860-1980). Irrigated cropland decreased to 120,000 acres in 1959, then increased to 150,000 acres in 1969. Irrigated cropland has been decreasing since 1969 at a rate of about 1,400 acres per year. Most of the irrigated cropland is located along stream valleys (fig. 4). Streamflow from the San Juan River and its tributaries is the source of the irrigation water, which is supplied through a system of reservoirs and ditches.



EXPLANATION

▲ 09368000 — U.S. GEOLOGICAL SURVEY NASQAN GAGING STATION, SAN JUAN RIVER AT SHIPROCK, NEW MEXICO

Figure 1.--Location of study area.

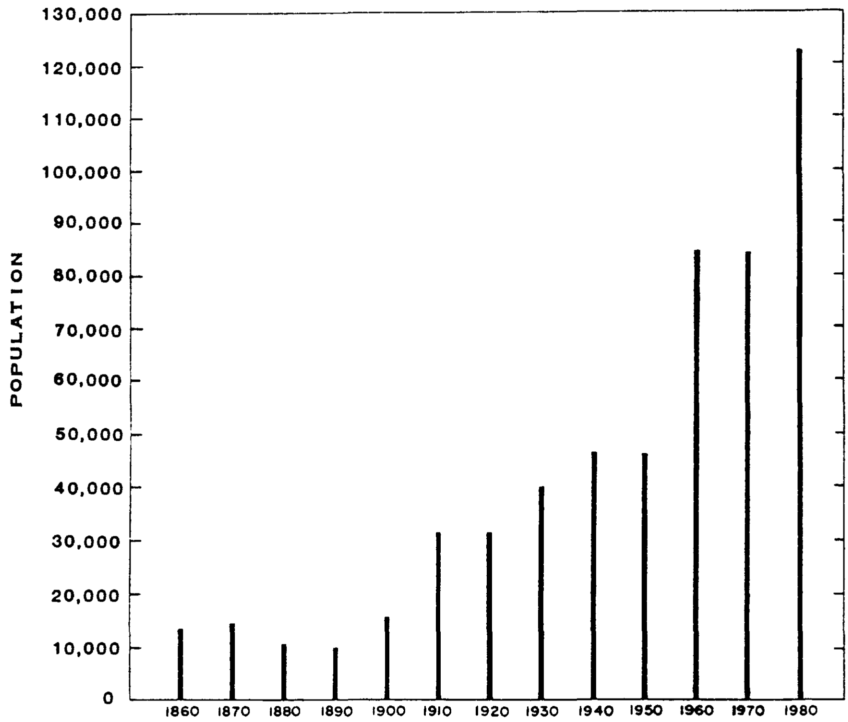


Figure 2.--Population of study area. Estimated from Bureau of the Census data (U.S. Department of Commerce, 1860-1980).

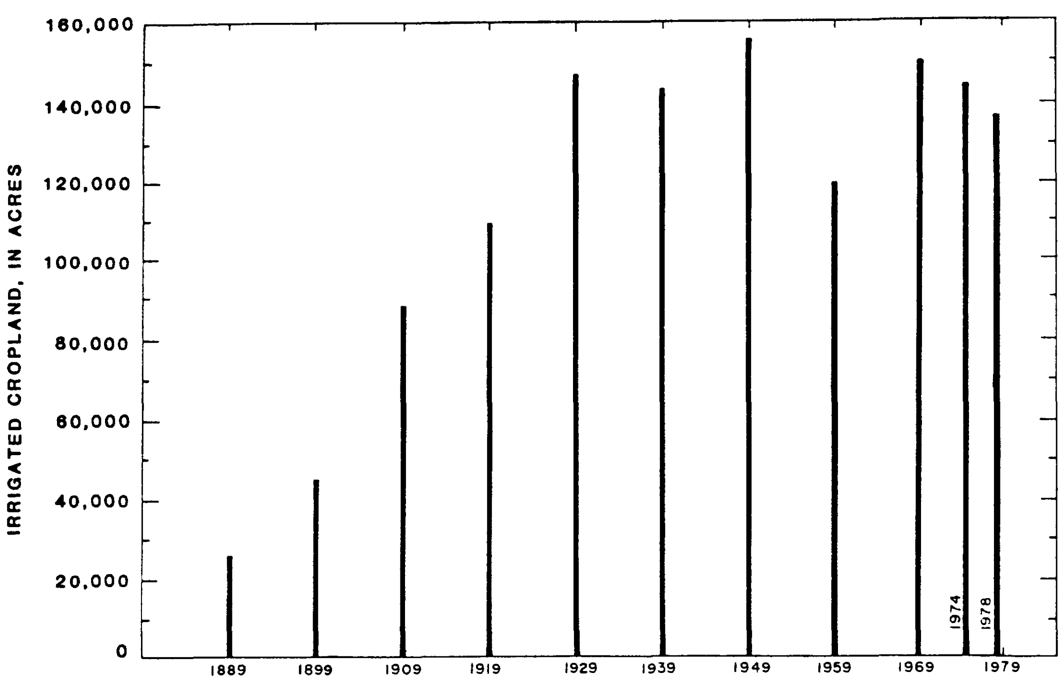


Figure 3.--Irrigated-cropland acreage in study area. Estimated from Bureau of the Census data (U.S. Department of Commerce, 1860-1980).

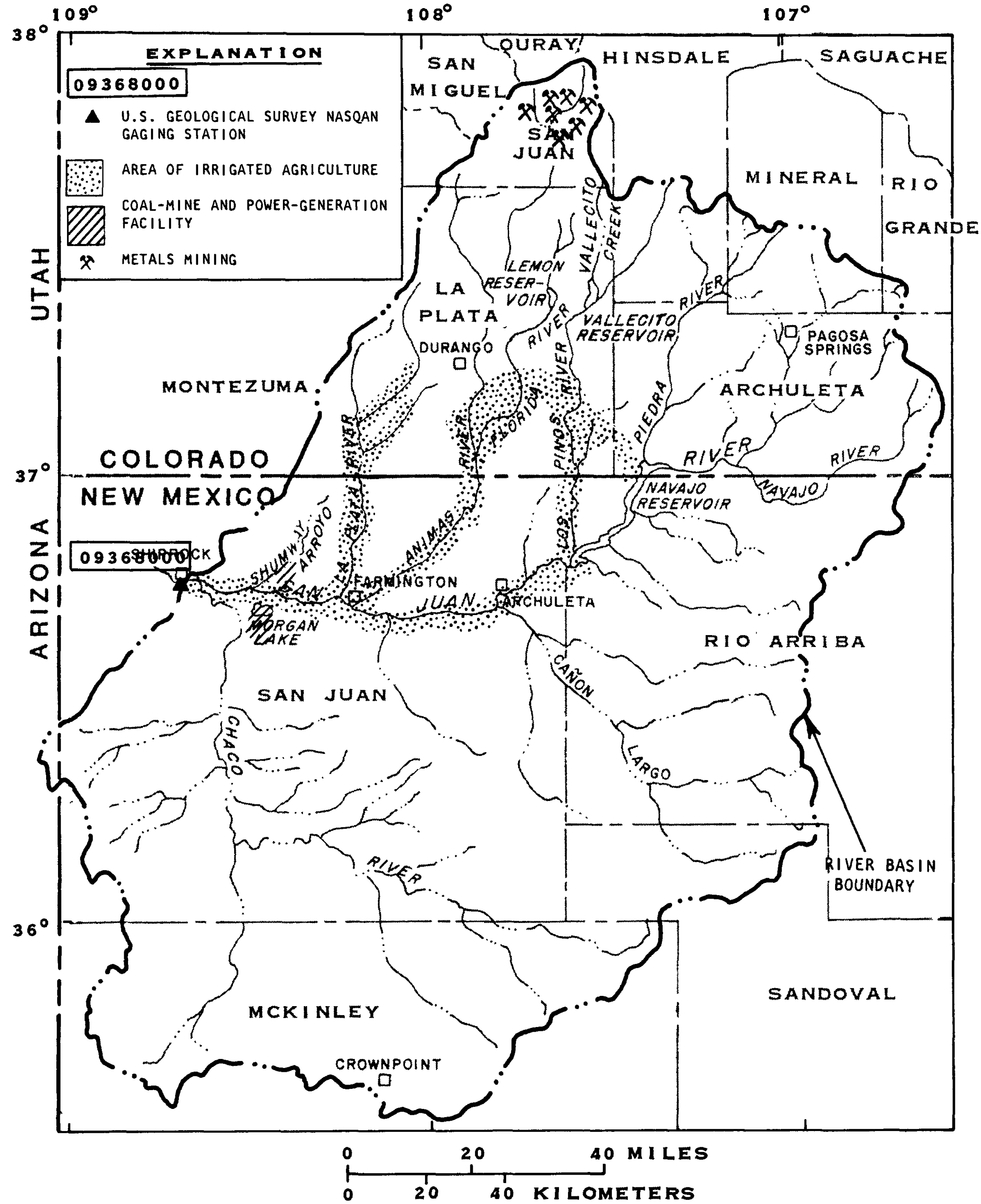


Figure 4.--Location of irrigated agriculture, coal-mine and power-generation facilities, and metals mining.

Reservoirs

There are three large reservoirs in the study area that supply water for irrigation and provide recreation sites. These are Lemon Reservoir, Vallecito Reservoir, and Navajo Reservoir (fig. 4). Lemon Reservoir, the smallest of the three, is located on the Florida River, a tributary to the Animas River. Its capacity of 40,100 acre-feet is 1.4 times the mean annual flow of the Florida River entering the reservoir. It began impounding water in 1964. Vallecito Reservoir, located on the Los Pinos River, began impoundment in 1941. Its capacity of 120,300 acre-feet is 0.5 times the mean annual flow of the Los Pinos River entering the reservoir. The largest of the three, Navajo Reservoir, located on the San Juan River, began impoundment in 1963. Its capacity of 1,696,000 acre-feet is 2.2 times the mean annual flow of the San Juan River entering the reservoir. Release of water from these reservoirs is regulated through the dams and has changed the natural streamflow patterns at downstream sites.

Mineral Production

At present, income from mineral production in the basin far exceeds that obtained from agriculture, which was the primary source of income until about 1945 (Sorenson, 1967). Metals mining constituted an initial stimulus for the settlement of the northern part of the basin and continues to be important. By the mid-1940's oil and gas production became part of the economy throughout the basin.

In recent years, coal mining has become important, particularly in the western part of the basin, where strippable coal deposits cross the San Juan River, and in the south along the Chaco River drainage basin where extensive coal mining is planned. Two large, surface coal mines are located near and on opposite sides of the San Juan River as shown in figure 4. These two mines supply coal for electrical-power generation at a mine-mouth, electrical power-generation facility. The first mine began mining operations and electrical-power generation in 1963. Additional power-generation units were added in 1964, 1969, and 1970. The second mine began mining operations and power generation in 1973 with additional power-generation units added in 1976 and 1979. Coal production from these two mines increased from 2 million tons during 1964 to 11 million tons during 1981 (Nielsen, 1982).

Geology

Rocks in the San Juan River basin include Precambrian, Cambrian, Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary rocks (Dane and Bachman, 1965; Tweto, 1979). Precambrian granitic and metamorphic rocks and Tertiary igneous rocks crop out along the northern section of the San Juan River's drainage basin where the headwaters of the Animas and Los Pinos Rivers emerge (fig. 5). The metamorphic rocks include slate, phyllite, gneiss, and schist. The volcanic rocks predominately are intermediate to felsic rocks, diabase, gabbro, andesite, breccia, tuff, conglomerate, and quartz latite. Headwaters of the

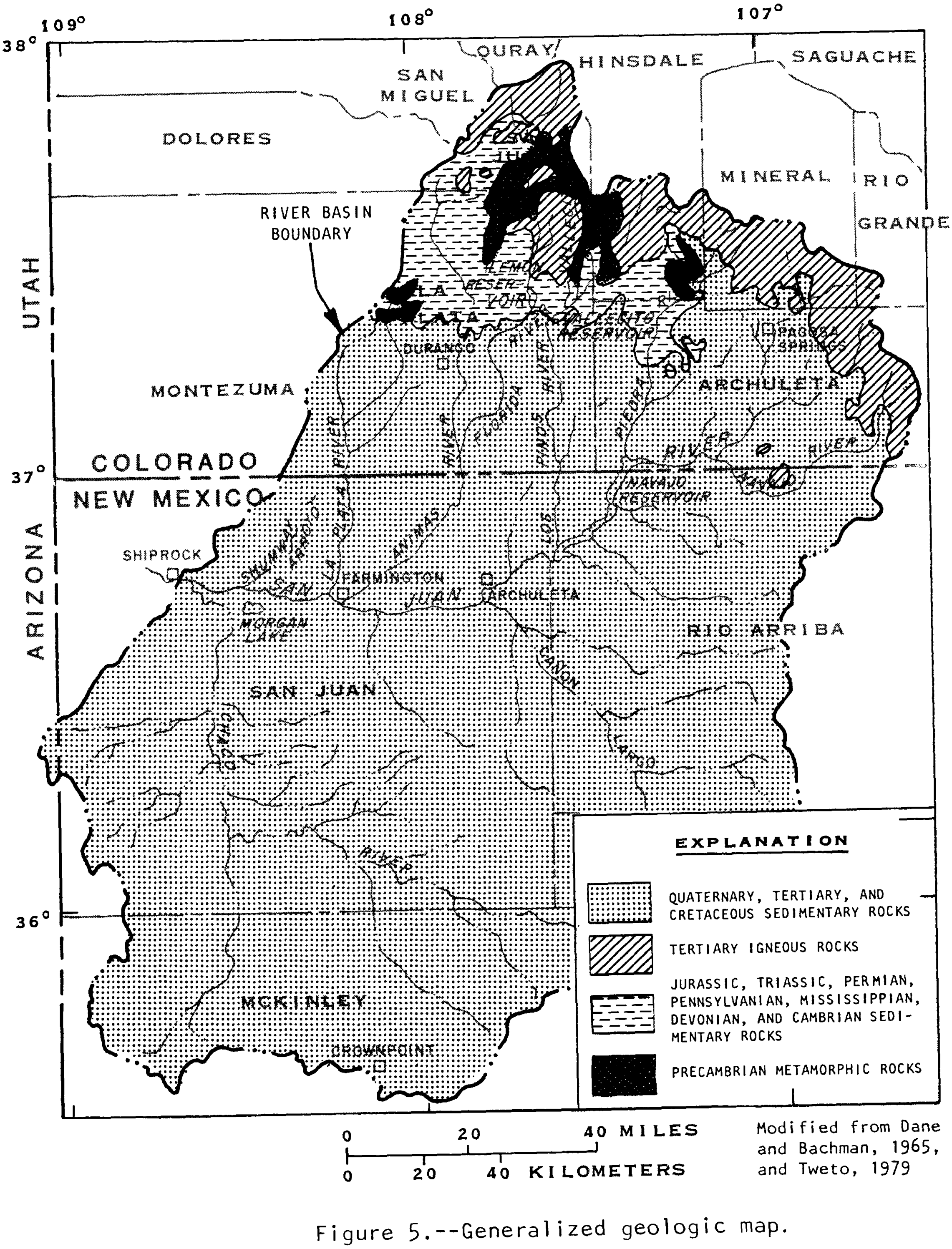


Figure 5.--Generalized geologic map.

Piedra, San Juan, and Navajo Rivers emerge from the volcanic andesitic lava, breccia, tuff, and conglomerate. Igneous intrusive rocks of intermediate to felsic composition crop out near the northwest rim of the study area where the La Plata River emerges. Cambrian through Jurassic sedimentary rocks bound the Precambrian metamorphic and Tertiary volcanic rocks to the south. These sedimentary rocks consist mostly of quartzose and arkosic sandstone, shale, limestone, and some dolomite. The surface geology of the remainder of the basin, which includes the majority of the San Juan River valley and drainage area south of it, is composed primarily of Cretaceous and Tertiary sedimentary rocks and Quaternary alluvium. These sedimentary rocks consist mostly of interbedded sandstone and shale. The Quaternary alluvium is deposited along several of the stream channels.

DATA USED IN THIS REPORT

Two NASQAN stations are located upstream from Shiprock, New Mexico, and within Accounting Unit 140801. They are station 09368000, San Juan River at Shiprock, New Mexico, and station 09364500, Animas River at Farmington, New Mexico (fig. 6). These stations began operation as part of the NASQAN network on October 1, 1973, and April 4, 1979, respectively, continuing as NASQAN stations to the present. Because it was desired to analyze data collected through the NASQAN program, the period of record for data analysis is October 1, 1973, through September 30, 1981, a total of 8 years of record.

Additional streamflow and water-quality data used for this study include: (1) Streamflow and water-quality data collected and analyzed by the U.S. Geological Survey and maintained on its computerized Water Data Storage and Retrieval System (WATSTORE), and (2) self-monitoring, water-quality data for a mine-mouth power plant maintained on file by the New Mexico Environmental Improvement Division. A list of stations where data were collected is provided in table 1. Station locations are shown in figure 6.

Daily measurements of streamflow and some water-quality constituents were collected by the U.S. Geological Survey throughout the study area. Most water-quality constituents, however, are collected monthly or less frequently at U.S. Geological Survey stations. Records at some stations for some constituents were collected regularly from October 1, 1973, through September 30, 1981. Other stations have shorter or intermittent periods of record. Specific-conductance data were collected most frequently during water years 1974 through 1981 with daily records available for several stations. Data for major cations and anions, pH, and nutrients were collected fairly frequently, with monthly collection at selected stations. Metal and radiochemical data were collected less frequently with metals collected quarterly and radiochemicals collected semiannually at selected stations. Measurements of streamflow used in this report are daily means while measurements of water-quality constituents are instantaneous values.

The locations of the water-quality sites for the mine-mouth power plant are denoted as FC1 through FC6 in figure 6. These water-quality data were collected, analyzed, and computed as monthly mean values by the power-generation facility.

Table 1. Streamflow and water-quality stations used in this report

[Eight-digit station numbers are U.S. Geological Survey national station numbers; station numbers prefixed FC are stations operated by Four Corners Power Plant]

Station number	Station name
09339900	East Fork San Juan River above Sand Creek, near Pagosa Springs, Colorado
09341200	Wolf Creek near Pagosa Springs, Colorado
09342500	San Juan River at Pagosa Springs, Colorado
09343000	Rio Blanco near Pagosa Springs, Colorado
09343300	Rio Blanco below Blanco Div. Dam, near Pagosa Springs, Colorado
09343400	Rio Blanco at U.S. Highway 84, near Pagosa Springs, Colorado
09344300	Navajo River above Chromo, Colorado
09344400	Navajo River below Oso Dam, near Chromo, Colorado
09346000	Navajo River above Edith, Colorado
09346400	San Juan River near Carracas, Colorado
09347200	Middle Fork Piedra River near Pagosa Springs, Colorado
09349800	Piedra River near Arboles, Colorado
09352900	Vallecito Creek near Bayfield, Colorado
09354500	Los Pinos River at La Boca, Colorado
09355000	Spring Creek at La Boca, Colorado
09355500	San Juan River near Archuleta, New Mexico
09356565	Canon Largo Wash near Blanco, New Mexico
09357000	San Juan River at Bloomfield, New Mexico
09357100	San Juan River at Hammond Bridge, near Bloomfield, New Mexico
09347205	Middle Fork Piedra River near Dyke, Colorado
09357250	Gallegos Canyon near Farmington, New Mexico
09357300	San Juan River above Animas River at Farmington, New Mexico
09357500	Animas River at Howardsville, Colorado
09358900	Mineral Creek above Silverton, Colorado
09361000	Hermosa Creek near Hermosa, Colorado
09361500	Animas River at Durango, Colorado
09363200	Florida River at Bondad, Colorado
09364500	Animas River at Farmington, New Mexico
09365000	San Juan River at Farmington, New Mexico
09366500	La Plata River at Colorado-New Mexico State line

Table 1. Streamflow and water-quality stations used in this report - Concluded

Station number	Station name
09367500	La Plata River near Farmington, New Mexico
09367540	San Juan River near Fruitland, New Mexico
FC1	San Juan River near Hogback, New Mexico
09367555	Shumway Arroyo near Fruitland, New Mexico
09367561	Shumway Arroyo near Waterflow, New Mexico
09367660	Chaco Wash near Star Lake Trading Post, New Mexico
09367680	Chaco Wash at Chaco Canyon National Monument, New Mexico
09367685	Ah-Shi-Sle-Pah Wash near Kimbeto, New Mexico
09367710	De-Na-Zin Wash near Bisti Trading Post, New Mexico
09367930	Hunter Wash at Bisti Trading Post, New Mexico
09367936	Burnham Wash near Burnham, New Mexico
09367938	Chaco River near Burnham, New Mexico
FC2	Chaco River upstream of power plant
FC3	Morgan Lake
FC4	Ash Pond Effluent
FC5	Chaco River downstream of power plant
09367950	Chaco River near Waterflow, New Mexico
09368000	San Juan River at Shiprock, New Mexico
FC6	San Juan River at Shiprock, New Mexico

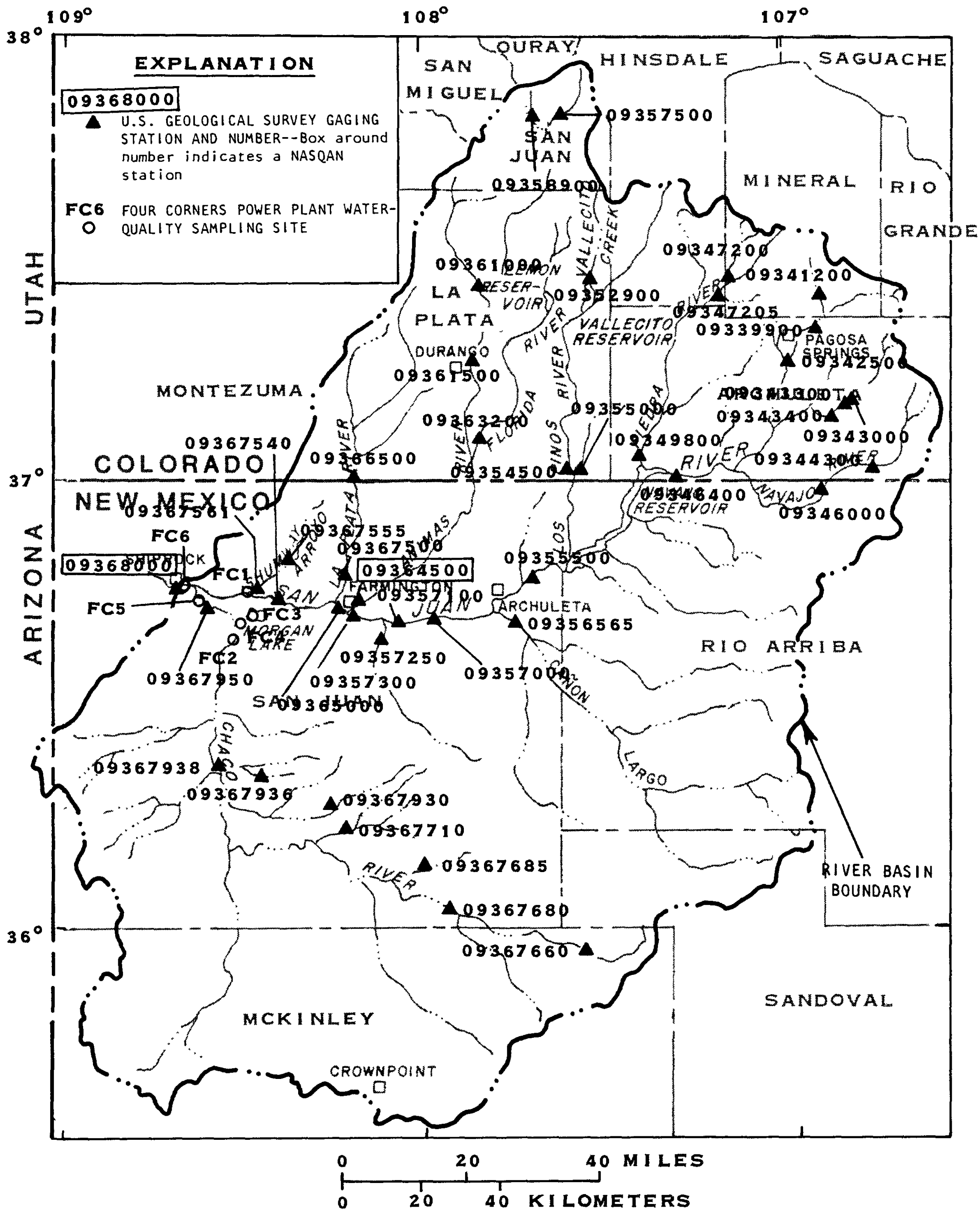


Figure 6.--Location of gaging stations and water-quality sampling sites.

SPATIAL VARIABILITY OF WATER QUALITY

Spatial variation, as used in this report, is the variation in water quality from station to station throughout the basin. Statistics used to summarize the variability of water-quality data collected at 40 stations throughout the study area are: (1) the number of measurements, (2) the date of the first measurement, (3) the date of the last measurement, (4) the mean, (5) the median, (6) the mode, (7) the minimum, and (8) the maximum. Both the mean and the median are measures of central tendency. The median, being the midpoint of the measurements if arranged in order by numerical value, is not affected by extreme values. The mean, being the sum of the measurements divided by the number of measurements, can be greatly affected by extreme values. The mode is the value occurring most frequently in a group of measurements. It represents the condition found most often at a measurement site.

Summary values for streamflow data are given in table 2. Daily values for streamflow data are analyzed rather than instantaneous streamflow data because the larger amount of data in the daily-values file is more representative of the true population. Statistics for values of specific conductance and pH and concentrations of dissolved-orthophosphate phosphorus, dissolved sodium, dissolved sulfate, dissolved iron, dissolved manganese, dissolved radium-226, and suspended sediment are given in tables 3, 4, 5, 6, 7, 8, 9, 10 and 11, respectively.

Dissolved-orthophosphate phosphorus, dissolved-iron and dissolved-manganese data required special treatment because these data are often reported as "less than" the lower limit of detection. An approach was taken to use the many "less than" values that appear in the data, and a simplistic evaluation of the "less than" data was made. If a value is given as less than 10 micrograms per liter, for example, it is known to be between 0 and 10 micrograms per liter. Therefore, the midpoint of the known range was chosen, 5 micrograms per liter, and that midpoint value was used in the calculation of means, medians, modes, minimums and maximums. It is felt that this evaluation of "less than" values introduces the least amount of bias into the data set. To delete the "less than" values from the data set would bias the statistics toward the higher end of the scale. To evaluate the less than 10 values as either 0 or 10 would bias these values toward one end or the other of the known range.

The pH data presented a problem in the calculation of the mean because of the logarithmic scale for pH measurement. Mean values for pH have been omitted.

Streamflow and specific-conductance values, dissolved-sodium, dissolved-sulfate, dissolved-iron, dissolved-manganese, and suspended-sediment concentrations are all highly variable throughout the study area. For example, the ranges of the above-named constituents are: 0.00 through 13,700 cubic feet per second (table 2) for streamflow; 30 through 16,300 microsiemens per centimeter (table 3) for specific conductance; 0.1 through 3,700 milligrams per liter (table 6) for dissolved sodium; 1.7 through 8,300 milligrams per liter (table 7) for dissolved sulfate; 0 through 21,000 micrograms per liter (table 8) for dissolved iron; 0 through 8,800 micrograms per liter (table 9) for dissolved manganese; and 0 through 966,000 milligrams per liter (table 11) for suspended sediment. Concentrations of dissolved-orthophosphate phosphorus and dissolved radium-226 are much more uniform over the basin. For example, the ranges of these constituents are: 0.00 through 2.6 milligrams per liter (table 5) for dissolved-orthophosphate phosphorous, and 0.02 through 0.56 picocurie per liter (table 10) for dissolved radium-226. Considering the logarithmic scale for pH (hydrogen-ion concentration), the variation of 2.4 through 10.4 units (table 4) is very large.

Water-Quality Classification of Streams

The generalized water-quality classification of streams in the San Juan River basin is shown in figure 7. Chemical symbols indicate the water-quality classification at the station 50 percent or more of the time. A detailed accounting of the water-quality classification at each station is given in table 12. A station is included if it had three or more analyses and the cation and anion sums were equal or balanced to within 5 percent of each other. The waters were classified according to the predominant cation and anion. If a cation or anion made up 50 percent or more of the milliequivalents, it was considered the predominant ion. If no one cation or anion made up 50 percent of the milliequivalents, a second cation or anion was then added so that 50 percent or more of the milliequivalents were accounted for, making the water a three or more ionic-composition water.

Most streams in the northeastern part of the basin have calcium bicarbonate water (fig. 7). Streams in the northwestern and western part of the basin have calcium sulfate and sodium sulfate water. The calcium bicarbonate streams in the northeastern part of the basin flow through igneous and sedimentary rocks (fig. 5) and over densely vegetated terrain. Rocks in the southern part of the basin are entirely sedimentary and consist mainly of easily eroded sandstones and shales. Vegetation is sparse. Due to the lower latitude and altitude, much less of the precipitation is in the form of snow and precipitation falls less frequently than in the northern basin. More of the runoff saturates through the porous and easily eroded soils and reflects cation and anion concentrations related to the rock types.

Table 2. Summary values for streamflow data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in cubic feet per second]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09339900	2,557	73-10-01	80-09-30	85	20	10	5.0	1,020
09341200	730	73-10-01	75-09-30	31	5.0	1.9	1.5	348
09342500	2,557	73-10-01	80-09-30	371	80	46	14	4,220
09343300	2,922	73-10-01	81-09-30	30	21	21	1.0	602
09346000	2,922	73-10-01	81-09-30	60	43	32	8.0	435
09346400	2,922	73-10-01	81-09-30	543	179	110	28	5,610
09347200	730	73-10-01	75-09-30	42	12	12	3.5	429
09347205	1,461	77-10-01	81-09-30	53	11	6.0	2.0	568
09349800	2,922	73-10-01	81-09-30	387	99	60	25	4,630
09352900	2,922	73-10-01	81-09-30	132	38	14	6.7	1,240
09354500	2,922	73-10-01	81-09-30	241	111	70	6.1	2,110
09355000	2,922	73-10-01	81-09-30	32	20	67	1.8	329
09355500	2,922	73-10-01	81-09-30	1,160	742	480	246	5,480
09356565	1,461	77-10-01	81-09-30	17	.01	.00	.00	1,380
09357100	1,461	77-10-01	81-09-30	1,250	735	1,780	130	5,390
09357250	1,461	77-10-01	81-09-30	.75	.00	.00	.00	150
09357500	2,922	73-10-01	81-09-30	89	22	14	10	923
09358900	730	73-10-01	75-09-30	20	4.7	1.8	1.5	180
09361000	2,557	73-10-01	80-09-30	130	25	17	7.0	1,880
09361500	2,922	73-10-01	81-09-30	735	258	180	129	7,550
09363200	2,922	73-10-01	81-09-30	72	35	30	5.2	855
09364500	2,922	73-10-01	81-09-30	793	282	220	5.3	8,060
09366500	2,922	73-10-01	81-09-30	39	8.0	10	.00	1,080
09367500	2,922	73-10-01	81-09-30	33	2.0	.00	.00	1,260
09367540	1,096	77-10-01	80-09-30	2,540	1,400	2,120	270	13,700
09367555	2,465	75-01-01	81-09-30	.56	.00	.00	.00	254
09367561	2,576	74-09-12	81-09-30	2.2	1.4	2.0	.00	320
09367660	1,461	77-10-01	81-09-30	.83	.00	.00	.00	61
09367680	2,002	76-04-08	81-09-30	5.0	.00	.00	.00	606
09367685	1,658	77-03-18	81-09-30	1.2	.00	.00	.00	133
09367710	2,100	76-01-01	81-09-30	4.6	.00	.00	.00	657
09367930	2,387	75-03-20	81-09-30	.83	.00	.00	.00	168
09367936	1,461	77-10-01	81-09-30	.29	.00	.00	.00	71
09367938	1,461	77-10-01	81-09-30	28	.00	.00	.00	3,900
09367950	2,161	75-11-01	81-09-30	37	17	20	.00	2,330
09368000	2,922	73-10-01	81-09-30	1,850	1,230	1,200	76	13,700

Table 3. Summary values for specific-conductance data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in microsiemens per centimeter at 25 degrees Celsius]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09339900	46	76-10-04	81-08-31	131	130	130	70	180
09341200	18	74-03-26	75-08-25	48	50	34	30	80
09342500	63	76-10-05	81-08-31	161	140	140	60	430
09343000	13	74-04-16	74-10-02	124	131	175	69	175
09343300	36	74-04-16	75-07-10	111	106	98	68	184
09344300	16	74-04-16	74-10-02	142	152	78	78	193
09346000	76	73-11-26	81-08-31	259	240	240	112	900
09346400	22	80-01-02	81-09-01	315	290	290	100	800
09347200	17	74-03-27	75-08-04	60	62	44	43	80
09347205	42	77-10-11	81-08-31	71	70	70	50	120
09349800	24	80-01-02	81-09-01	324	325	130	110	560
09352900	98	73-10-04	81-08-26	75	75	70	36	120
09354500	22	74-05-03	81-08-25	288	245	180	160	950
09355000	22	74-05-03	81-08-25	643	400	270	260	1,400
09355500	67	73-10-29	81-06-26	282	280	280	180	480
09356565	44	77-12-16	81-09-09	3,350	1,900	1,500	770	11,200
09357100	48	77-12-09	81-09-08	424	409	507	250	940
09357250	15	78-02-03	81-07-26	1,650	1,750	390	390	2,850
09357300	71	73-10-30	79-09-25	495	489	365	282	1,800
09357500	18	74-04-03	75-08-27	224	198	156	105	358
09358900	18	74-04-03	75-08-27	242	198	60	60	529
09361000	49	76-10-29	80-08-29	563	600	750	180	1,200
09361500	66	75-06-08	81-08-19	486	500	680	100	1,000
09363200	61	76-10-29	81-08-25	478	450	380	260	1,200
09364500	81	73-10-30	81-08-27	680	750	800	205	1,120
09365000	246	73-10-01	81-08-27	512	490	440	210	2,050
09366500	46	77-11-29	81-08-24	1,220	1,250	1,210	336	2,000

Table 3. **Summary values for specific-conductance data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico** - **Concluded**

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09367500	43	77-12-12	81-08-28	2,370	2,200	2,000	517	4,850
09367540	47	77-12-14	81-09-08	505	462	450	250	965
09367555	8	76-07-26	78-10-24	793	850	480	480	950
09367561	216	74-08-13	81-09-03	6,740	6,570	6,000	500	16,300
09367660	65	77-11-07	81-09-16	583	393	320	102	6,700
09367680	105	76-08-06	81-07-01	464	440	420	185	900
09367685	70	77-07-18	81-09-30	829	698	800	280	2,600
09367710	46	74-08-12	81-07-13	721	686	700	220	1,500
09367930	86	74-10-31	81-09-23	1,060	981	1,000	435	5,010
09367936	20	77-11-06	81-09-23	793	711	690	520	1,420
09367938	36	77-07-20	81-07-02	1,180	812	700	300	8,400
09367950	150	75-11-13	81-09-03	1,950	1,800	2,000	310	10,900
09368000	220	73-10-01	81-09-01	675	638	550	265	2,450
FC1	74	74-01-15	80-10-15	514	506	615	234	709
FC2	13	74-08-15	79-11-15	1,630	946	610	610	6,560
FC3	77	73-10-15	80-10-15	1,510	1,550	1,050	980	1,920
FC4	65	74-01-15	80-10-15	3,350	3,190	3,090	2,040	11,800
FC5	70	73-10-15	80-10-15	2,410	2,140	980	980	8,000
FC6	71	74-04-15	80-10-15	616	590	278	278	1,100

Table 4. Summary values for pH data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Median, mode, minimum, and maximum values are given in standard units]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	8.1	8.5	7.3	8.6
09343000	4	74-04-23	74-07-03	7.8	7.8	7.7	8.1
09343300	4	74-04-23	74-07-03	7.8	7.8	7.7	8.1
09344300	4	74-04-23	74-07-03	7.8	7.5	7.5	8.0
09346000	10	73-11-26	74-09-19	8.0	8.0	7.8	8.8
09347200	18	74-03-27	75-08-25	8.2	8.3	7.3	8.8
09352900	95	73-10-04	81-08-26	7.8	7.8	6.4	8.6
09355500	67	73-10-29	81-06-26	8.2	8.2	7.2	9.5
09356565	44	77-12-16	81-09-09	8.0	8.4	6.8	8.7
09357100	48	77-12-09	81-09-08	8.3	8.1	7.6	8.9
09357250	15	78-02-03	81-07-26	8.5	8.5	6.9	9.1
09357300	70	73-10-30	79-09-25	8.2	8.0	7.3	9.0
09357500	17	74-04-03	75-08-27	7.7	7.2	7.2	8.3
09358900	16	74-04-03	75-08-27	7.8	7.6	5.8	8.5
09364500	81	73-10-30	81-08-27	8.2	8.3	7.7	8.9
09365000	237	73-10-01	81-08-27	8.0	7.8	7.1	8.9
09366500	46	77-11-29	81-08-24	8.1	7.9	7.1	9.1
09367500	43	77-12-12	81-08-28	8.3	8.2	7.8	8.6
09367540	47	77-12-14	81-09-08	8.2	8.0	7.8	8.8
09367555	8	76-07-26	78-10-24	7.2	7.1	7.0	7.6
09367561	186	74-08-13	81-09-03	7.4	7.2	2.4	10.4
09367660	65	77-11-07	81-09-16	7.5	7.2	7.0	8.8
09367680	103	76-08-06	81-07-01	7.5	7.5	6.3	8.5
09367685	70	77-07-18	81-09-30	7.6	7.3	6.6	8.5
09367710	39	74-08-12	81-07-13	7.8	7.6	6.5	8.5
09367930	74	75-07-11	81-09-23	7.7	7.6	6.8	9.8
09367936	20	77-11-06	81-09-23	8.1	8.1	7.3	9.3
09367938	36	77-07-20	81-07-02	8.3	8.3	6.7	8.9
09367950	148	75-11-13	81-09-03	7.7	7.3	6.8	8.6
09368000	195	73-10-01	81-09-01	8.1	8.0	7.0	9.0
FC1	74	74-01-15	80-10-15	8.2	8.0	7.4	8.7
FC2	13	74-08-15	79-11-15	8.2	7.9	7.9	8.4
FC3	77	73-10-15	80-10-15	8.4	8.4	4.5	8.8
FC4	65	74-01-15	80-10-15	8.3	8.4	6.6	9.2
FC5	70	73-10-15	80-10-15	8.3	8.3	7.7	8.8
FC6	71	74-04-15	80-10-15	8.3	8.3	7.8	8.7

Table 5. Summary values for dissolved-orthophosphate phosphorus data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in milligrams per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	0.03	0.02	0.02	0.01	0.10
09343000	7	74-04-23	74-09-19	.04	.04	.03	.03	.06
09343300	7	74-04-23	74-09-19	.03	.03	.03	.01	.05
09344300	7	74-04-23	74-09-19	.23	.05	.05	.02	1.2
09346000	10	73-11-26	74-09-19	.05	.05	.05	.02	.08
09347200	18	74-03-27	75-08-25	.04	.04	.03	.01	.06
09352900	64	73-10-04	80-10-08	.05	.01	.01	.00	2.6
09355500	67	73-10-29	81-06-26	.02	.01	.01	.00	.24
09357300	48	74-09-26	79-09-25	.01	.01	.01	.01	.05
09357500	18	74-04-03	75-08-27	.01	.01	.01	.01	.12
09358900	18	74-04-03	75-08-27	.01	.01	.01	.01	.03
09364500	74	73-10-30	80-09-03	.02	.01	.01	.00	.08
09365000	72	73-10-30	81-08-27	.04	.03	.01	.01	.18
09367561	59	74-08-13	80-09-02	.15	.08	.04	.01	1.0
09367680	29	76-08-06	80-02-15	.06	.06	.06	.01	.16
09367710	8	74-08-12	78-11-15	.06	.06	.06	.01	.12
09367930	11	76-05-07	78-11-15	.05	.04	.04	.02	.13
09367950	35	75-11-13	80-08-05	.02	.01	.01	.00	.09
09368000	131	73-10-30	80-09-29	.03	.03	.02	.00	.20

Table 6. Summary values for dissolved-sodium data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in milligrams per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	2.9	2.6	2.1	1.7	5.5
09343000	7	74-04-23	74-09-19	6.5	6.6	3.5	3.5	8.5
09343300	7	74-04-23	74-09-19	6.7	6.9	6.9	3.6	9.1
09344300	7	74-04-23	74-09-19	5.5	5.4	3.3	3.3	7.6
09346000	10	73-11-26	74-09-19	9.8	9.9	8.1	6.5	12
09347200	18	74-03-27	75-08-25	3.8	3.8	2.6	2.3	5.5
09352900	99	73-10-04	81-08-26	1.3	1.1	1.1	0.1	3.5
09355500	67	73-10-29	81-06-26	15	14	14	8.3	24
09356565	23	77-12-16	81-09-09	1,000	770	1,700	160	2,800
09357100	45	77-12-09	81-09-08	35	31	20	14	120
09357250	14	78-02-03	81-07-02	320	360	390	89	540
09357300	71	73-10-30	79-09-25	42	39	24	14	270
09357500	18	74-04-03	75-08-27	1.9	1.8	1.2	1.0	3.3
09358900	18	74-04-03	75-08-27	2.8	2.0	1.1	0.9	6.0
09364500	80	73-10-30	81-08-27	35	40	46	5.0	75
09365000	243	73-10-01	81-08-27	40	36	39	7.2	300
09366500	45	77-11-29	81-08-24	52	58	48	11	76
09367500	40	77-12-12	81-08-28	270	220	160	23	700
09367540	46	77-12-14	81-09-08	38	32	26	9.5	130
09367561	83	74-08-13	81-09-03	1,300	1,300	1,300	160	3,700
09367660	6	78-05-08	81-03-04	67	64	44	44	100
09367680	33	76-08-06	81-07-01	82	85	62	37	150
09367685	5	78-02-08	81-03-16	140	130	130	98	180
09367710	14	74-08-12	81-07-13	140	140	130	95	200
09367930	22	75-07-11	81-03-11	180	180	110	91	340
09367936	4	78-05-02	80-09-10	150	150	140	140	170
09367938	18	78-02-07	81-07-02	130	140	130	34	250
09367950	50	75-11-13	81-09-03	240	240	230	130	710
09368000	218	73-10-01	81-09-01	56	49	40	12	240
FC1	21	78-10-15	80-10-15	38	30	20	9.5	90
FC3	21	78-10-15	80-10-15	140	140	170	97	190
FC4	15	78-10-15	79-12-15	270	260	180	50	600

Table 7. Summary values for dissolved-sulfate data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in milligrams per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	4.7	4.3	4.6	2.6	7.6
09343000	7	74-04-23	74-09-19	6.5	6.1	5.0	5.0	8.9
09343300	7	74-04-23	74-09-19	6.5	6.6	5.1	5.1	8.9
09344300	7	74-04-23	74-09-19	28	33	14	14	36
09346000	10	73-11-26	74-09-19	45	45	27	27	59
09347200	18	74-03-27	75-08-25	5.4	5.2	4.8	3.2	7.3
09352900	98	73-10-04	81-08-26	9.8	9.0	12	1.7	36
09355500	67	73-10-29	81-06-26	52	50	47	27	100
09356565	22	77-12-16	81-09-09	2,400	1,900	3,600	300	6,000
09357100	44	77-12-09	81-09-08	110	110	120	50	320
09357250	14	78-02-03	81-07-02	580	580	65	65	1,300
09357300	71	73-10-30	79-09-25	140	130	160	48	700
09357500	18	74-04-03	75-08-27	75	68	130	33	130
09358900	18	74-04-03	75-08-27	100	78	120	25	250
09364500	80	73-10-30	81-08-27	180	200	220	36	390
09365000	243	73-10-01	81-08-27	140	130	150	44	770
09366500	45	77-11-29	81-08-24	500	540	610	82	820
09367500	40	77-12-12	81-08-28	1,000	860	160	160	2,500
09367540	46	77-12-14	81-09-08	140	120	120	50	400
09367561	83	74-08-13	81-09-03	3,800	3,800	3,400	390	8,300
09367660	6	78-05-08	81-03-04	71	74	4.7	4.7	130
09367680	34	76-08-06	81-07-01	71	58	57	30	200
09367685	5	78-02-08	81-03-16	180	180	100	100	250
09367710	13	74-08-12	81-07-13	140	140	150	80	200
09367930	22	75-07-11	81-03-11	280	220	110	52	710
09367936	4	78-05-02	80-09-10	170	200	21	21	280
09367938	19	78-02-07	81-07-02	150	150	180	74	300
09367950	49	75-11-13	81-09-03	900	870	1,200	240	2,800
09368000	218	73-10-01	81-09-01	210	190	130	58	1,100
FC1	74	74-01-15	80-10-15	150	160	170	50	280
FC2	10	74-08-15	79-04-15	820	370	70	70	3,400
FC3	77	73-10-15	80-10-15	560	560	570	350	850
FC4	65	74-01-15	80-10-15	1,900	1,900	1,600	1,100	2,600
FC5	70	73-10-15	80-10-15	1,300	1,100	450	360	5,000
FC6	71	74-04-15	80-10-15	190	190	120	58	450

Table 8. Summary values for dissolved-iron data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in micrograms per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	17	74-03-26	75-08-25	50	40	30	10	120
09343000	7	74-04-23	74-09-19	20	20	20	10	50
09343300	7	74-04-23	74-09-19	20	20	20	10	50
09344300	7	74-04-23	74-09-19	50	20	20	20	200
09346000	10	73-11-26	74-09-19	30	20	20	10	50
09347200	17	74-03-27	75-08-25	60	50	40	20	140
09352900	56	73-10-04	81-05-27	30	20	20	10	340
09355500	67	73-10-29	81-06-26	10	10	10	10	50
09356565	27	77-12-16	81-09-09	110	40	40	10	970
09357100	45	77-12-09	81-09-08	30	20	20	10	280
09357250	15	78-02-03	81-07-26	160	80	40	10	780
09357300	48	74-09-26	79-09-25	20	20	10	0	210
09357500	18	74-04-03	75-08-27	40	30	20	10	80
09358900	18	74-04-03	75-08-27	170	80	50	20	520
09364500	78	73-10-30	81-08-27	20	10	10	10	160
09365000	137	73-10-30	81-08-27	40	10	10	10	1,400
09366500	45	77-11-29	81-08-24	40	20	20	10	450
09367500	40	77-12-12	81-08-28	40	30	30	10	340
09367540	46	77-12-14	81-09-08	40	20	20	10	320
09367561	82	74-08-13	81-09-03	680	30	30	10	16,000
09367660	6	78-05-08	81-03-04	370	290	120	120	1,000
09367680	64	76-08-06	81-07-01	540	80	40	10	21,000
09367685	15	78-01-12	81-04-15	730	410	30	30	2,600
09367710	18	74-08-12	81-07-13	370	260	80	20	1,400
09367930	23	76-01-29	81-03-11	1,300	60	40	10	16,000
09367936	4	78-05-02	80-09-10	550	200	100	100	1,700
09367938	19	78-02-07	81-07-02	430	200	60	10	2,200
09367950	71	75-11-13	81-09-03	30	20	10	0	340
09368000	153	73-10-30	81-09-01	20	10	10	10	710

Table 9. Summary values for dissolved-manganese data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in micrograms per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	6	10	10	5	20
09347200	18	74-03-27	75-08-25	5	10	10	5	10
09352900	55	73-10-04	81-05-27	9	10	10	2	50
09355500	23	73-10-29	81-06-26	7	10	10	2	30
09356565	11	78-05-02	81-09-09	1,200	180	10	0	4,400
09357100	24	77-12-09	81-09-08	17	10	10	4	52
09357250	5	79-08-10	81-07-26	430	10	10	0	2,100
09357500	18	74-04-03	75-08-27	360	300	280	130	850
09358900	18	74-04-03	75-08-27	360	340	630	70	630
09364500	23	73-10-30	81-08-27	51	40	10	10	180
09365000	15	74-04-02	81-05-05	21	10	10	0	70
09366500	15	77-11-29	81-08-24	31	13	10	2	110
09367500	20	77-12-12	81-08-28	250	200	20	0	960
09367540	24	77-12-14	81-09-08	16	10	10	4	90
09367561	60	74-12-18	81-09-03	480	440	10	3	2,800
09367680	44	77-02-12	81-07-01	230	10	10	0	8,800
09367685	13	78-01-12	81-04-15	21	10	10	0	80
09367710	11	76-07-13	81-07-13	5	10	10	0	10
09367930	12	76-08-19	81-03-11	83	10	10	0	930
09367938	8	78-05-08	81-07-02	11	10	20	2	20
09367950	49	75-12-11	81-09-03	12	10	10	0	90
09368000	31	74-09-26	81-09-01	80	7	10	4	2,100
FC1	65	74-02-15	80-10-15	0	0	0	0	6
FC3	59	73-10-15	80-10-15	0	0	0	0	0
FC4	59	74-01-15	79-12-15	1	0	0	0	4

Table 10. Summary values for dissolved-radium-226 data (radon method) in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in picocuries per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09352900	9	73-10-04	81-05-27	0.06	0.06	0.06	0.04	0.11
09355500	7	78-02-21	81-04-06	0.11	0.09	0.05	0.05	0.22
09364500	8	73-10-30	80-09-30	0.09	0.08	0.08	0.07	0.14
09365000	3	79-11-29	81-04-08	0.06	0.06	0.05	0.05	0.07
09367561	12	74-12-18	81-08-04	0.12	0.10	0.07	0.03	0.26
09367680	11	77-02-14	80-02-15	0.14	0.08	0.06	0.02	0.56
09367950	12	77-11-29	81-07-10	0.12	0.10	0.10	0.04	0.18
09368000	16	73-10-30	81-05-06	0.08	0.08	0.06	0.03	0.11

Table 11. Summary values for suspended-sediment data in the drainage basin upstream from the San Juan River at Shiprock, New Mexico

[Mean, median, mode, minimum, and maximum values are given in milligrams per liter]

Station number	Number of measurements	Date of first measurement	Date of last measurement	Mean	Median	Mode	Minimum	Maximum
09341200	18	74-03-26	75-08-25	23	8	4	1	185
09343000	12	74-04-16	74-10-02	16	10	3	2	59
09343300	35	74-04-16	75-07-10	904	165	13	2	5,540
09344300	15	74-04-16	74-10-02	41	11	14	2	168
09346000	17	73-11-26	74-10-02	576	44	32	4	4,830
09347200	16	74-03-27	75-08-25	10	4	4	0	63
09352900	82	73-10-04	81-08-26	4	2	1	0	35
09355500	7	77-04-27	81-06-26	9	7	4	4	16
09356565	47	77-12-16	81-09-09	97,300	37,400	42	42	525,000
09357100	67	77-12-09	81-09-21	1,900	383	38	29	44,100
09357250	18	78-02-03	81-07-26	34,600	16,400	1,460	46	123,000
09357500	18	74-04-03	75-08-27	18	4	2	0	229
09358900	18	74-04-03	75-08-27	16	10	6	2	60
09364500	102	74-01-01	81-07-15	2,140	934	34	8	16,700
09365000	19	77-04-27	81-08-27	442	275	36	36	1,450
09366500	41	77-11-29	81-08-24	355	32	8	3	4,780
09367500	54	77-12-12	81-06-29	3,690	728	21	21	35,100
09367540	65	77-12-14	81-09-21	2,490	539	38	25	58,200
09367555	9	76-07-26	78-10-24	224,000	92,700	298	298	966,000
09367561	275	74-10-24	81-09-21	13,800	789	30,900	15	534,000
09367660	70	77-11-07	81-09-16	17,700	15,200	14,800	706	106,000
09367680	587	76-08-06	81-09-18	29,700	23,400	21,400	395	147,000
09367685	109	77-07-18	81-09-30	51,600	50,200	52,500	6,000	220,000
09367710	84	75-07-10	81-07-13	57,000	36,100	10,600	1,410	197,000
09367930	162	74-09-11	81-09-23	55,300	28,800	28,800	2,420	280,000
09367936	22	77-11-06	81-09-23	106,000	75,100	23,900	23,900	559,000
09367938	42	77-07-20	81-07-02	58,800	49,600	2,470	2,470	236,000
09367950	249	75-11-13	81-09-21	40,000	36,700	49,400	3	280,000
09368000	143	73-10-30	81-09-19	9,110	2,270	1,260	42	102,000

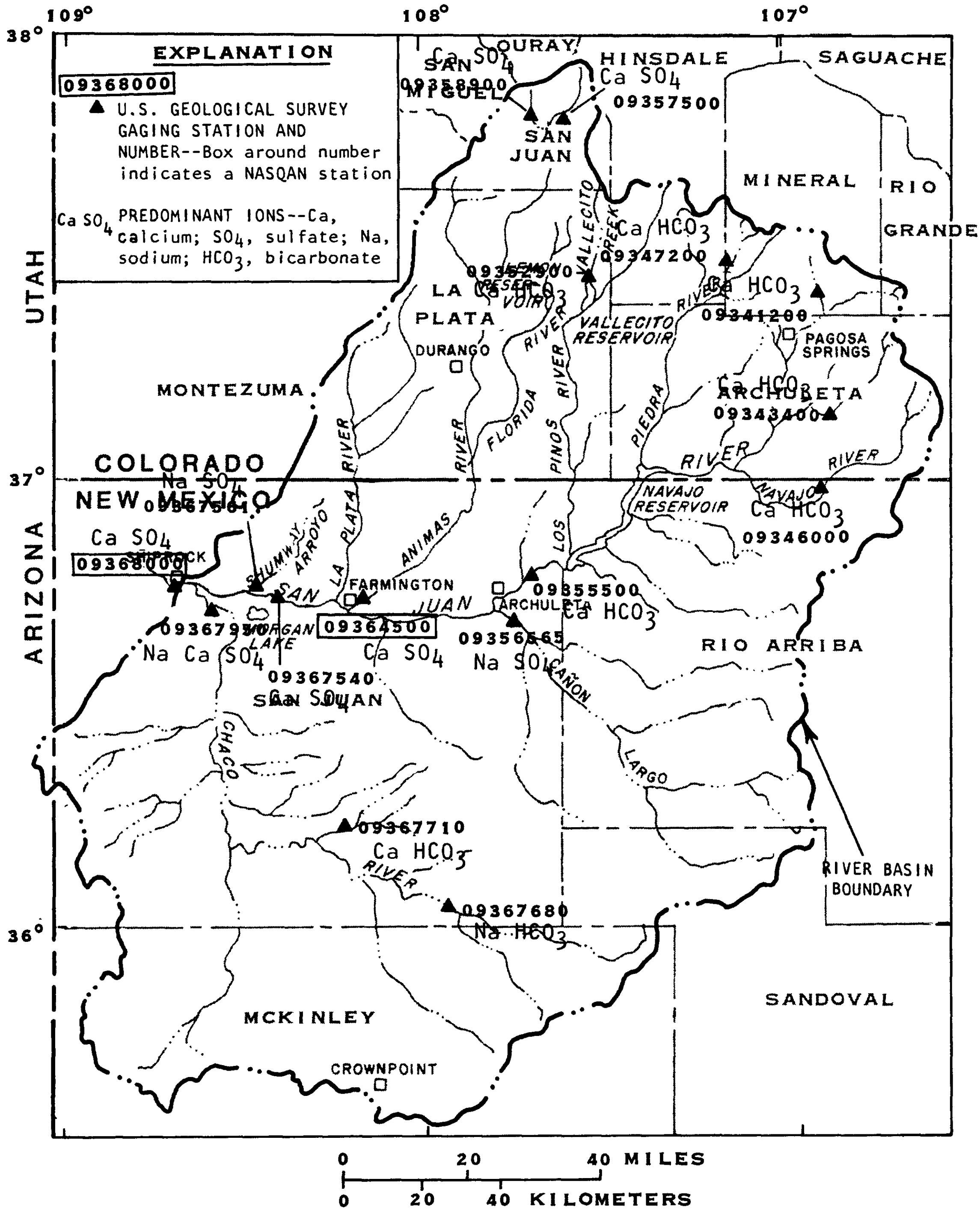


Figure 7.--Predominant ions at selected gaging stations, October 1, 1973 - September 30, 1981.

Table 12. **Water-quality classification of streams in the San Juan River basin upstream from Shiprock, New Mexico**

[Ca, calcium; SO_4, sulfate; Na, sodium; HCO_3, bicarbonate; Cl, chloride; Mg, magnesium]

Station number	Station name	Number of samples	Classification and frequency of occurrence in percentages															
			Ca HCO_3	Ca SO_4	CaNa HCO_3	CaNa SO_4	CaNa SO_4 HCO_3	Ca HCO_3 SO_4	Ca Mg SO_4	Na HCO_3	Na SO_4	Na Ca HCO_3	Na Ca SO_4	Na HCO_3 SO_4	Na SO_4 HCO_3	Na Mg SO_4	Na Cl	Ca SO_4 HCO_3
09341200	Wolf Creek near Pagosa Springs, Colorado	12	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09343000	Rio Blanco near Pagosa Springs, Colorado	7	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09343300	Rio Blanco below Blanco Div. Dam, near Pagosa Springs, Colorado	7	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09343400	Rio Blanco at U.S. Highway 84, near Pagosa Springs, Colorado	5	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09344300	Navajo River above Chromo, Colorado	5	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09346000	Navajo River at Edith, Colorado	9	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09347200	Middle Fork Piedra River near Pagosa Springs, Colorado	12	75	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-
09352900	Vallecito Creek near Bayfield, Colorado	39	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09355500	San Juan River near Archuleta, New Mexico	46	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09356565	Cañon Largo Wash near Blanco, New Mexico	9	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-
09357000	San Juan River at Bloomfield, New Mexico	3	34	-	-	33	-	-	-	-	33	-	-	-	-	-	-	-
09357100	San Juan River at Hammond Bridge, near Bloomfield, New Mexico	32	22	37	3	16	-	-	-	-	3	-	-	-	-	-	-	19
09357300	San Juan River above Animas River at Farmington, New Mexico	49	12	43	-	21	-	6	-	-	6	-	2	-	-	-	-	10
09357500	Animas River at Howardsville, Colorado	15	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 12. Water-quality classification of streams in the San Juan River basin upstream from Shiprock, New Mexico - Concluded

Station number	Station name	Number of samples	Ca HCO_3	Ca SO_4	CaNa HCO_3	CaNa SO_4	CaNa SO_4 HCO_3	Ca HCO_3 SO_4	Ca Mg SO_4	Na HCO_3	Na SO_4	Na Ca HCO_3	Na Ca SO_4	Na HCO_3 SO_4	Na SO_4 HCO_3	Na Mg SO_4	Na Cl	Ca SO_4 HCO_3
			Classification and frequency of occurrence in percentages															
09358900	Mineral Creek above Silverton, Colorado	13	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09364500	Animas River at Farmington, New Mexico	47	9	66	-	-	-	8	-	-	-	-	-	-	-	-	-	17
09365000	San Juan River at Farmington, New Mexico	153	15	51	-	5	-	10	-	-	3	-	3	-	-	-	1	12
09367500	La Plata River near Farmington, New Mexico	27	-	7	-	26	4	-	18	-	15	-	26	-	-	4	-	-
09367540	San Juan River near Fruitland, New Mexico	33	21	52	-	6	-	3	-	-	3	-	-	-	-	-	-	15
09367561	Shumway Arroyo near Waterflow, New Mexico	61	-	-	-	-	-	-	-	-	70	-	20	-	-	10	-	-
09367660	Chaco Wash near Star Lake Trading Post, New Mexico	3	-	-	-	-	-	-	-	34	33	-	-	33	-	-	-	-
09367680	Chaco Wash at Chaco Canyon National Monument, New Mexico	17	-	-	6	-	-	-	-	76	-	12	-	-	-	6	-	-
09367710	De-Na-Zin Wash near Bisti Trading Post, New Mexico	6	83	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-
09367930	Hunter Wash at Bisti Trading Post, New Mexico	10	-	-	-	-	-	-	-	20	80	-	-	-	-	-	-	-
FC3	Morgan Lake	21	-	-	-	5	-	-	-	-	33	-	62	-	-	-	-	-
FC4	Ash pond Effluent	34	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09367950	Chaco River near Waterflow, New Mexico	33	-	12	-	27	-	-	-	-	-	-	61	-	-	-	-	-
09368000	San Juan River at Shiprock, New Mexico	164	2	53	-	27	-	3	-	-	6	-	7	-	-	-	-	2

Metals-mining activities have occurred in the headwaters of the Animas River and probably contribute the sulfate component to the calcium sulfate water passing stations 09358900 and 09357500 (table 12). Further downstream at station 09364500, bicarbonate and sulfate components are present in the water. The La Plata River near Farmington, New Mexico (station 09367500, table 12), contains irrigation-return flow during the growing season, which likely increases the sodium component (sodium is leached from soils). Station 09367561, located on Shumway Arroyo north of the San Juan River near Waterflow, New Mexico, contains sodium sulfate water (table 12). Effluent from a nearby power plant that flows into the arroyo affects the water-quality classification. Station 09367950 is also affected by effluent from a power-plant operation. Upstream of station 09367950, water is classified as calcium bicarbonate and sodium bicarbonate. At station 09367950, water classification is sodium calcium sulfate.

As the San Juan River exits the study area at the Shiprock station, it is a calcium sulfate water 53 percent of the time and a calcium sodium sulfate water 27 percent of the time (table 12). The water is an integration of the many tributaries feeding the San Juan River. However, the station's water classification does not reflect the variety of water classifications at upstream tributaries or the water classification existing at upstream tributaries for a chosen point in time.

Variability of Concentrations or Properties of Selected Water-Quality Constituents

Water-quality data at stations throughout the study area were selected and plotted on maps to show spatial variability. The median value for available data during October 1973 through September 1981 was selected for plotting because it is not biased by extreme values. A median value was plotted at a station only if four or more measurements were made throughout at least 1 year. The data were then considered to be representative for a particular station.

Since the presentation of all water-quality constituents would be too repetitive, eight constituents were chosen. Specific conductance was chosen as a general indicator of dissolved solids. Dissolved sodium was chosen because it is usually a major cation. Dissolved sulfate was chosen because it is usually a major anion. Two metals were chosen: dissolved iron and dissolved manganese. Dissolved-orthophosphate phosphorus was chosen to represent a nutrient constituent. Dissolved radium-226 was chosen to represent radioactive constituents.

Medians of specific conductance vary from 50 to 6,570 microsiemens per centimeter at stations throughout the basin (fig. 8). The smallest values are reported from stations in the northeastern mountainous areas where snowmelt contributes largely to streamflow and the drainage areas consist of igneous-rock formations. The largest value of 6,570 microsiemens per centimeter at Shumway Arroyo near Waterflow is due to a point-source effluent from a power-plant facility less than a mile upstream. On the same tributary 4 miles upstream from the power plant at Shumway Arroyo near Fruitland, the median of specific conductance is 850 microsiemens per centimeter. Another large value of 1,800 microsiemens per centimeter at Chaco River near Waterflow is located about 9 miles downstream of a second power-plant facility. Median values of specific conductance ranging from 393 to 981 microsiemens per centimeter upstream from the Chaco River near Waterflow are considered to be due to the dissolution of salts from the sandy and shaly soils. This area of the basin consists of many canyons and ephemeral channels incised in the surrounding sandstone and shale. Some stations in the north-central and northeastern parts of the basin with specific conductances larger than nearby stations probably are impacted by irrigation-return flow that has elevated specific conductances.

The pattern of variation in median concentrations of dissolved sodium in the basin and the reasons for the variation are very similar to those of specific conductance discussed in the preceding paragraph. Median values of dissolved-sodium concentration vary from 1.1 through 1,300 milligrams per liter (fig. 9). The large value of 770 milligrams per liter at the station on Cañon Largo is probably due to a small saline-water spring that discharges to the normally ephemeral channel of Cañon Largo.

Median concentrations of dissolved sulfate vary throughout the basin in a similar pattern and for the same reasons as specific conductance discussed above. The range in median concentrations of dissolved sulfate is from 4.3 through 3,800 milligrams per liter (fig. 10).

The pattern of dissolved-iron variation in the basin is different from specific conductance, sodium, or sulfate. Dissolved iron varies from less than 10 through 410 micrograms per liter (fig. 11). The largest dissolved-iron concentrations are found in the southeastern section of the basin at stations on the Chaco River and its tributaries. Here, some concentrations are ten times greater than other parts of the basin, or more. In the weathered outcrops of this area, an abundance of iron accumulates as oxide coatings on sand, silt, and clay; as inorganic minerals or organic compounds in the soils; and in plant and animal detritus. Generally, iron is very soluble in acidic water but relatively insoluble in alkaline water. Therefore, the alkalinity of runoff in the area limits the quantity of iron that is dissolved. The larger dissolved-iron concentrations found at some stations may be attributed to ultrafine suspensions of particulate iron compounds, which are difficult to filter from water samples and are analyzed as dissolved iron (Roybal and others, 1983). Dissolved-iron concentrations are largest in areas related to geologic and climatic conditions of large erosion and large sediment concentration in water rather than areas affected by mining, farming, urbanization, and industry.

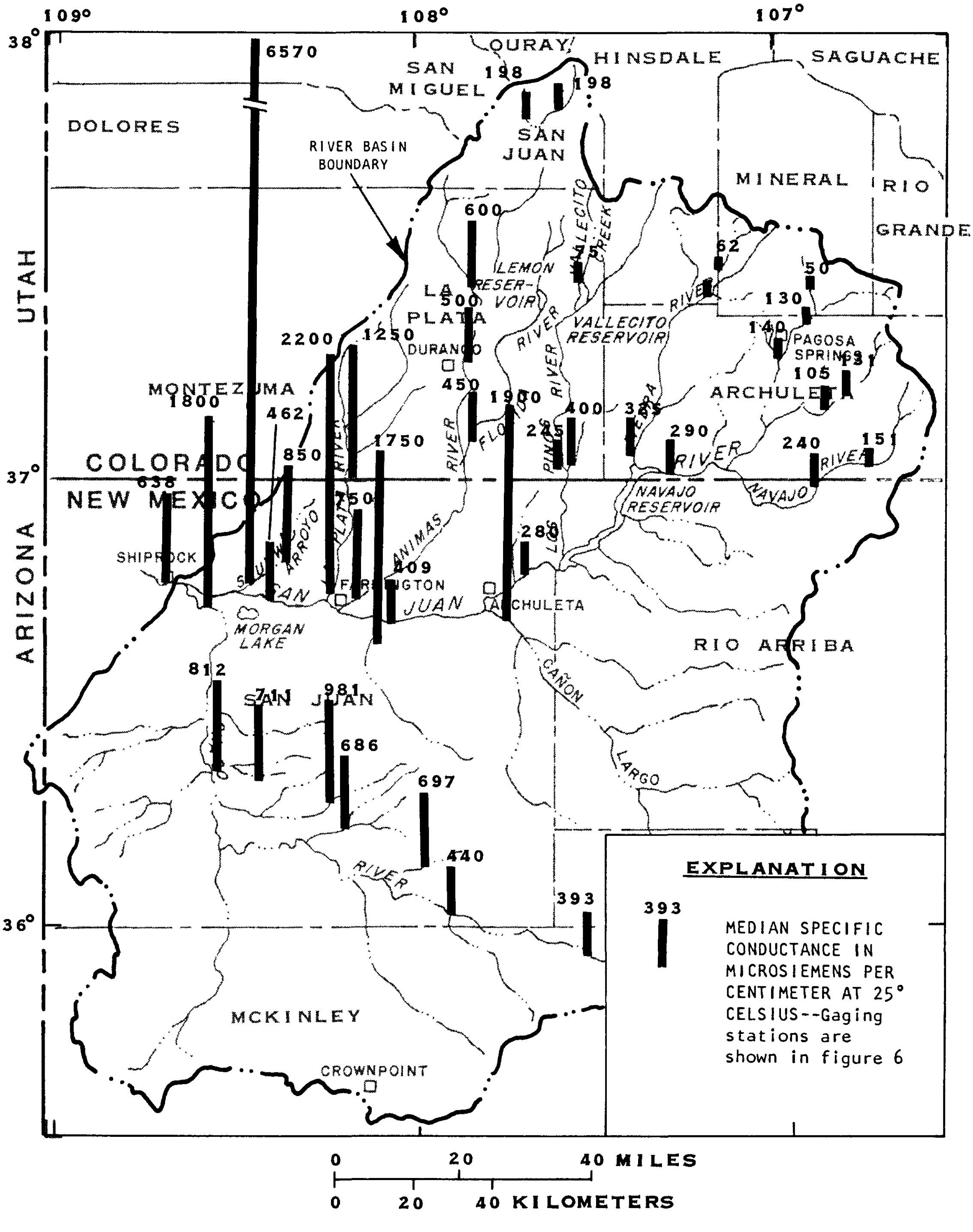


Figure 8.--Variability of median specific conductance, October 1, 1973 - September 30, 1981.

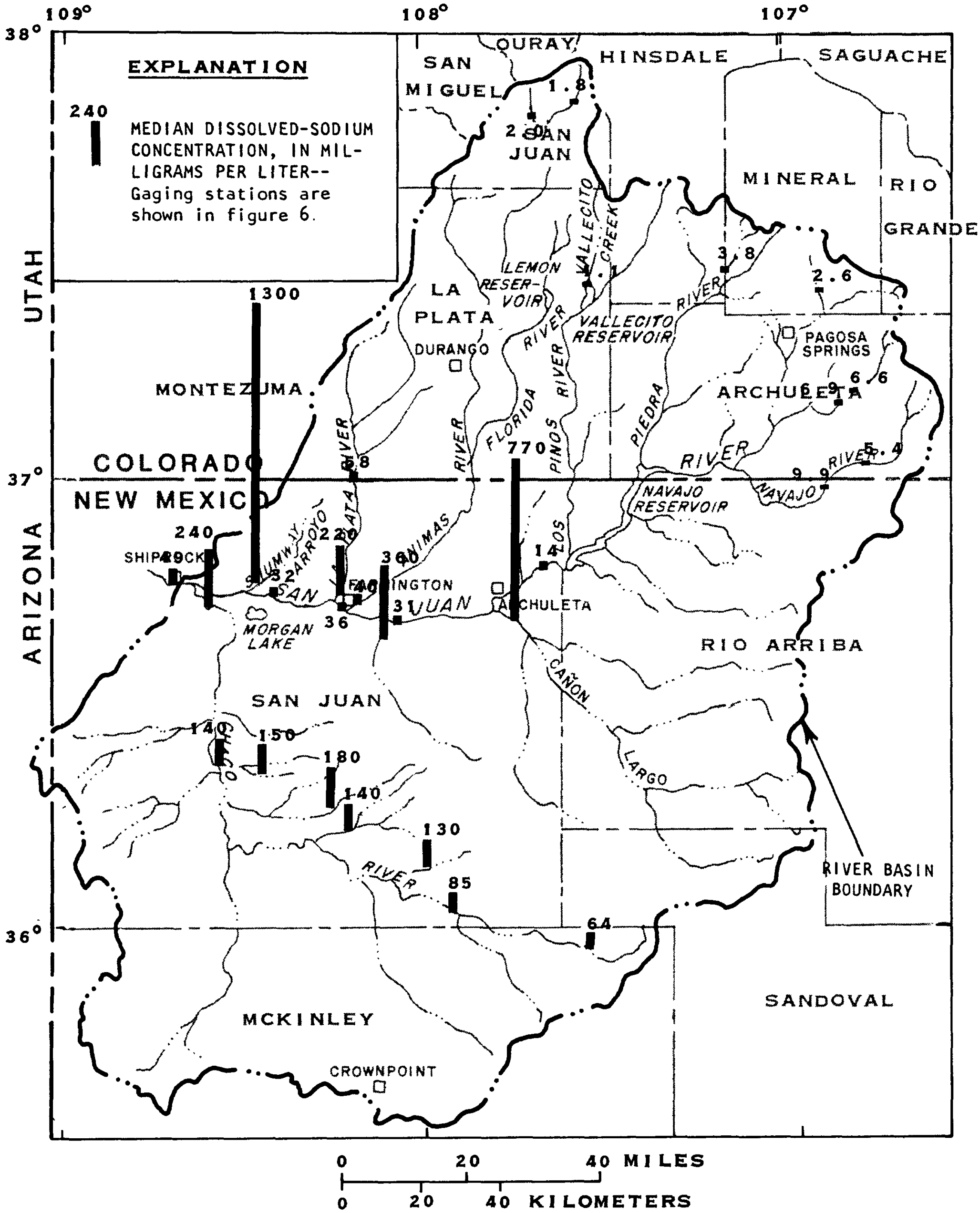


Figure 9.--Variability of median dissolved-sodium concentration, October 1, 1973 - September 30, 1981.

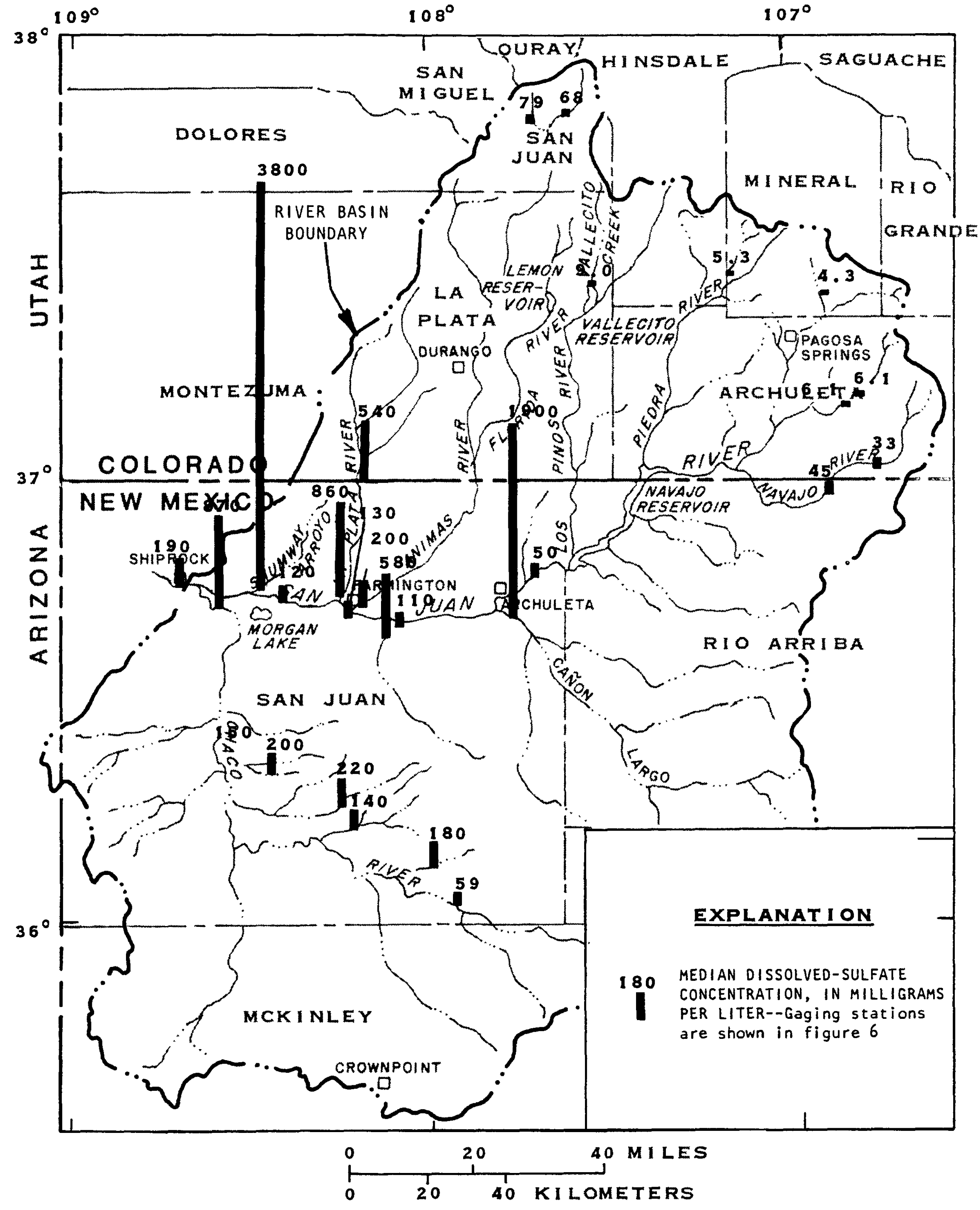


Figure 10.--Variability of median dissolved-sulfate concentration, October 1, 1973 - September 30, 1981.

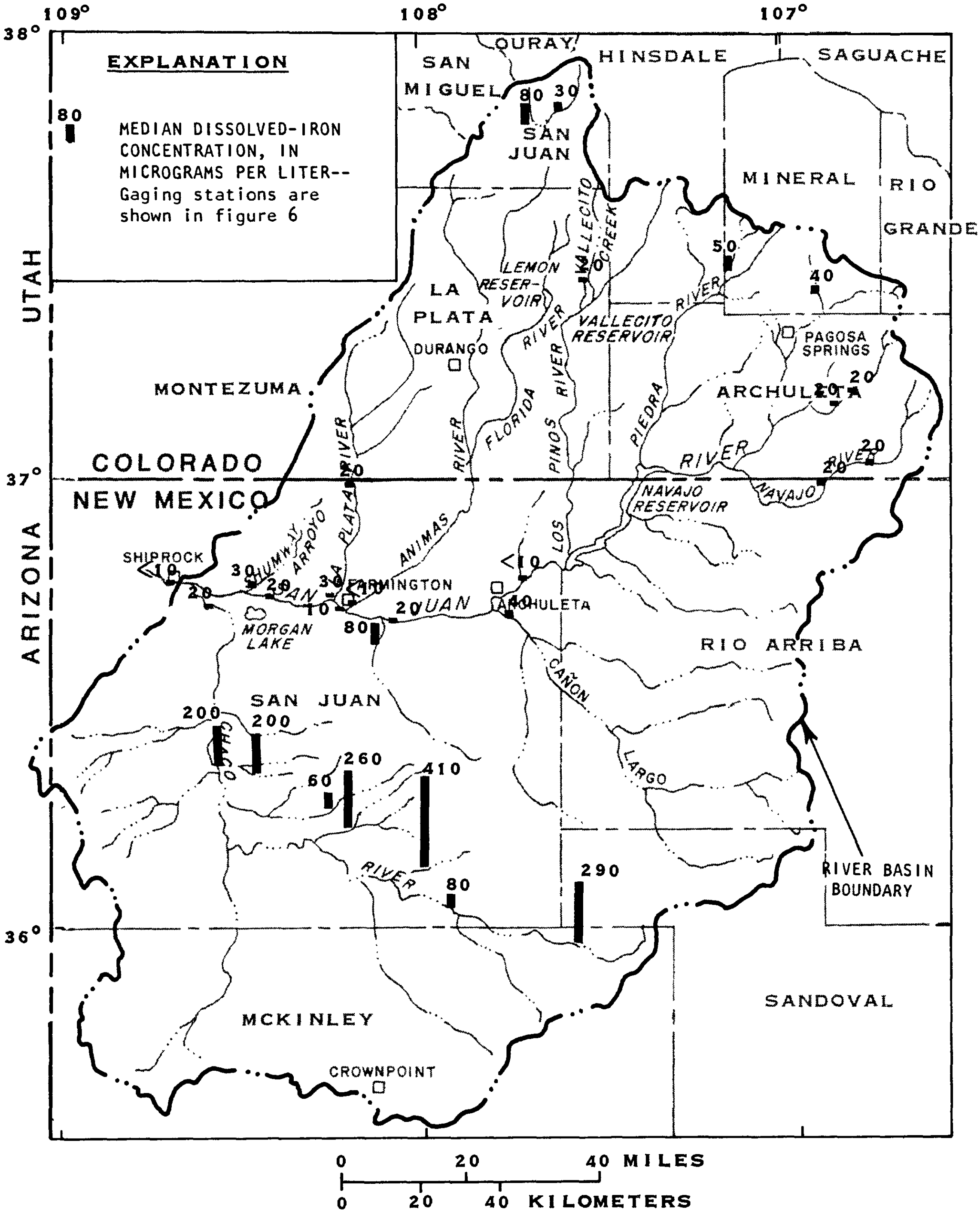


Figure 11.--Variability of median dissolved-iron concentration, October 1, 1973 - September 30, 1981.

Median concentrations of dissolved manganese are shown in figure 12 and range from less than 10 to 430 micrograms per liter. Some of the largest values of dissolved manganese, 300 and 340 micrograms per liter, are associated with the metals-mining area in the northern tip of the basin in the headwaters of the Animas River. The largest median concentration of dissolved manganese, 430 micrograms per liter at Shumway Arroyo near Waterflow, is less than a mile downstream from an electric power-generation facility.

Median concentrations of dissolved-orthophosphate phosphorus throughout the basin are shown in figure 13. The range in these medians is from less than .01 to .08 milligram per liter. The largest value of .08 milligram per liter is the median value for the station Shumway Arroyo near Waterflow, which is just downstream from the electric power-generation facility located north of the San Juan River main stem. Other dissolved-orthophosphate phosphorus values appear to be relatively uniform.

Median concentrations of dissolved radium-226 are similar throughout the basin (fig. 14). Medians range from .06 through .10 picocurie per liter. Dissolved radium-226 has the most uniform median concentration of any constituent discussed. Of these water-quality constituents discussed, the NASQAN station at Shiprock, New Mexico, best represents dissolved-radium-226 conditions throughout the basin, due to the uniformity of this constituent.

Variability of Loads of Selected Water-Quality Constituents

The product of concentration in milligrams per liter (mg/L) multiplied by streamflow in cubic feet per second (ft^3/sec) has the units of mass per unit time ($mg/L \times ft^3/sec \times 28.23\ L/ft^3 = mg/sec$). This is referred to as a load in this report. Loads are additive and the loads at Shiprock are sums of the loads measured in the upstream tributaries plus any unmeasured contribution. Annual loads were calculated from regression equations between streamflow and constituent load for six of the seven constituents discussed in the previous section: specific conductance, dissolved sodium, dissolved sulfate, dissolved iron, dissolved manganese, and dissolved radium-226. Annual loads for dissolved-orthophosphate phosphorus were not calculated because of the poor relationship between streamflow and load.

The first step in the calculation of an annual load for a constituent was to determine the mathematical relationship between streamflow and load as described by Miller (1951). Instantaneous values of streamflow that had a simultaneous value for constituent concentration were multiplied to obtain a load. The instantaneous streamflow and the instantaneous load were graphed with streamflow being the independent variable and load being the dependent variable. A regression equation was determined for the points on the graph and the r^2 value of the regression equation was noted. A large r^2 may result from this regression because streamflow is on both sides of the regression equation (streamflow versus streamflow times concentration).

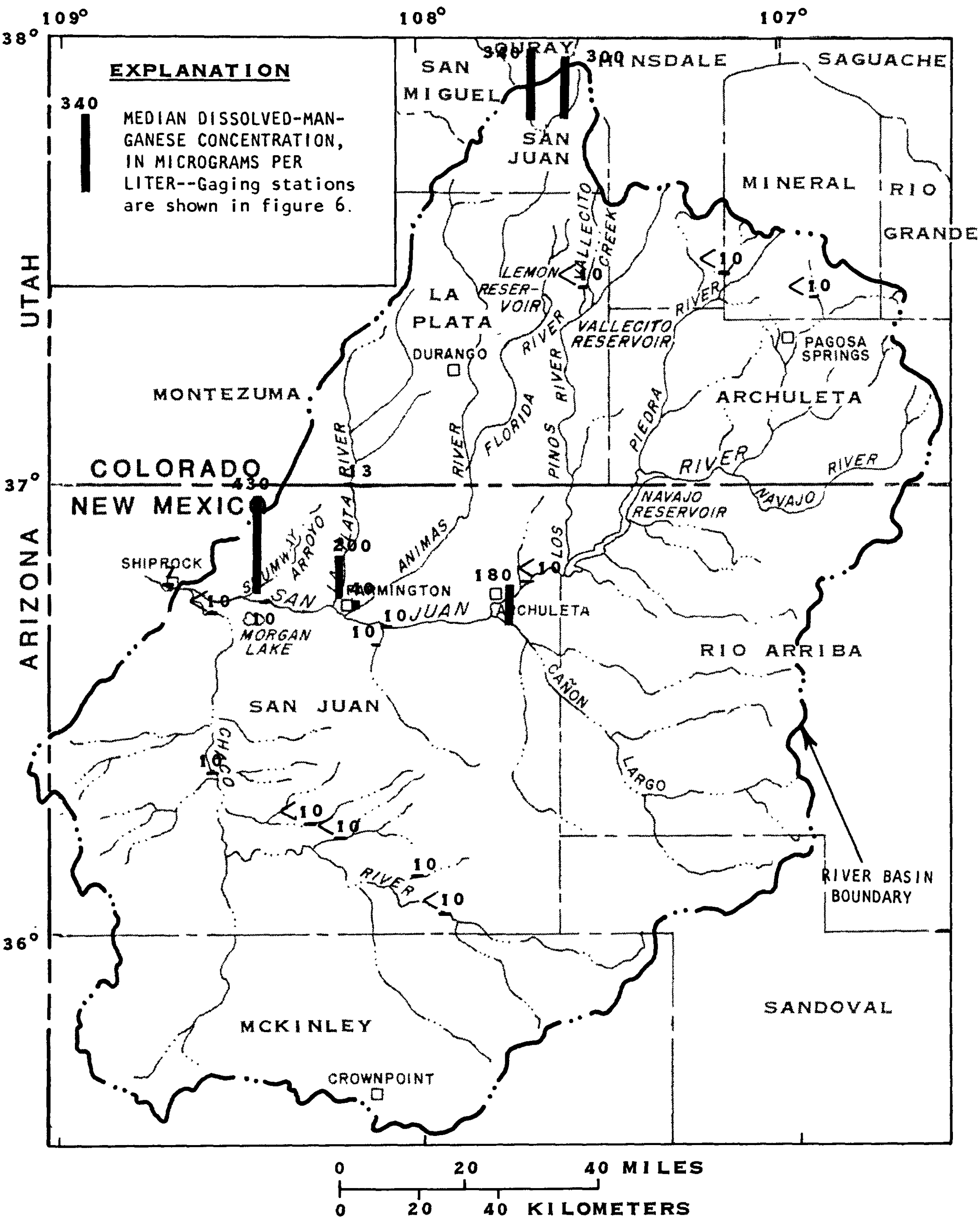


Figure 12.--Variability of median dissolved-manganese concentration, October 1, 1973 - September 30, 1981.

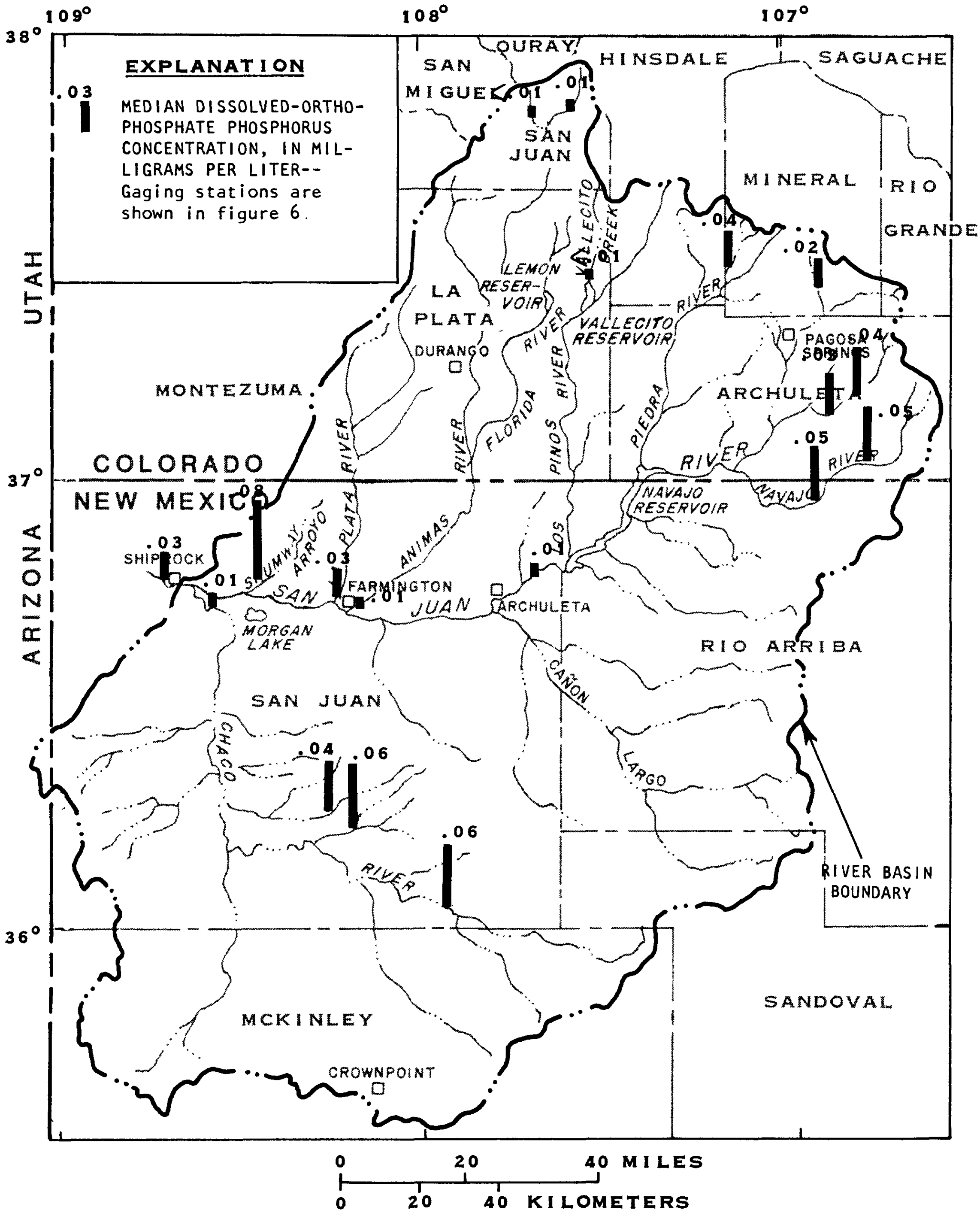


Figure 13.--Variability of median dissolved-orthophosphate phosphorus concentration October 1, 1973 - September 30, 1981.

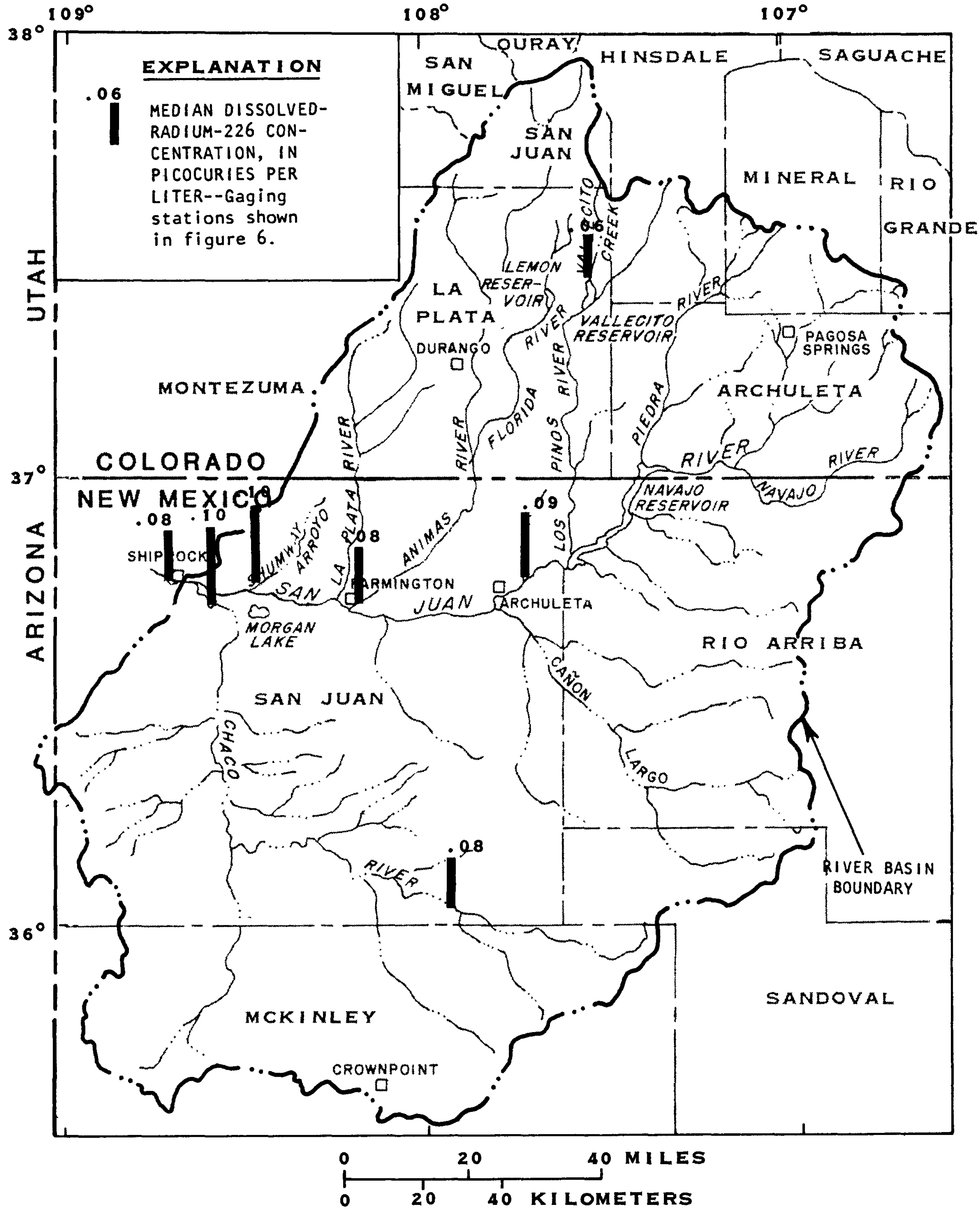


Figure 14.--Variability of median dissolved-radium-226 concentration, October 1, 1973 - September 30, 1981.

As explained by Younger (1979, p. 234), the r^2 value measures the strength of the mathematical relationship, or when multiplied by 100, the percentage of variation in the dependent variable (load in this case) that can be predicted by the mathematical relationship to the independent variable (streamflow in this case). Regression equations were judged to be adequate predictors of the load only if the r^2 value for the equation was equal to .75 or greater. That is, 75 percent or more of the load could be predicted from a known streamflow volume. If the r^2 value was .75 or greater, the daily mean streamflow was used as the independent variable in the regression equation to calculate a daily mean load. The daily mean load was then summed for all the days of the year to calculate an annual load. If the r^2 value was less than .75, no annual load was calculated.

The annual load calculation was further refined if the separation of the streamflow hydrograph into two seasonal periods, yielding two predictive equations, consistently improved the r^2 values. Annual streamflow hydrographs were plotted to determine if there was seasonal variation. At some stations a distinct snowmelt period was very noticeable. At these stations two regression equations were developed to predict daily mean loads for constituents. One regression equation was developed based on streamflow and constituent concentration during the snowmelt period; a second equation was developed based on streamflow and constituent concentration during the rest of the year. Only in the case of station number 09364500, Animas River at Farmington, New Mexico, did the separation of the streamflow hydrograph into two seasonal periods consistently improve the predictive equations. Therefore, a predictive equation for loads during the snowmelt period and loads during the rest of the year was used at this station since it was superior (as judged by the coefficient of determination, r^2) to the predictive equation for loads based on the full year's data. For example, for specific conductance the r^2 values were .96 for both the snowmelt and the rest of the year while the r^2 value was .94 for the whole year. At the other stations within the basin, predictive equations for loads were based on data over the whole year, rather than the year divided into a snowmelt and "rest-of-the-year" season.

Although specific conductance multiplied by streamflow does not represent a true load and the product does not have units of mass per unit time, the product of specific conductance and streamflow is an indirect measurement of the dissolved-solids load. Dissolved solids can be predicted if specific conductance is known (Hem, 1970, p. 99). The product of specific conductance and streamflow is shown in figure 15 at stations where adequate predictive equations could be developed. The variability of the product of specific conductance and streamflow throughout the basin is an indirect measure of the variability of the dissolved-solids load for the basin. At three stations, specific-conductance data were available from both the WATSTORE Daily-Values File and the WATSTORE Water-Quality File (fig. 15). At two stations, the WATSTORE Daily-Values File data gave a yearly product less than the WATSTORE Water-Quality File data. At the third station the Daily-Values File data gave a yearly product equal to the Water-Quality File data. This would lead to the assumption that samples taken monthly or less frequently may result in higher estimates of the loads. About one-third of the specific-conductance-streamflow product that passes the Shiprock, New Mexico, station (table 13) originates upstream of Archuleta, which is 25 percent of the total basin area; one-third originates in the Animas River basin, which is 10.5 percent of the total basin area; one-eighth originates from the Cañon Largo, La Plata and Chaco River basins; and about one-fifth cannot be accounted for and is assumed to originate from small ungaged drainages or to flow to the main stem as overland flow, ground-water inflow, or point sources between the gaging stations at Archuleta and Shiprock. The mean annual product of specific conductance and streamflow per square mile is greatest in the Animas River drainage basin and smallest in the Chaco River and Cañon Largo drainage basins (fig. 16).

The variability of the mean annual dissolved-sodium load throughout the basin is shown in figure 17. The greatest dissolved-sodium load, 14,500,000 kilograms per year, originates from the large upstream drainage area in the northeastern part of the basin. The next largest loads of 6,040,000 and 5,960,000 kilograms per year originate from the Animas River basin and the Chaco River basin, respectively. A mean annual dissolved-sodium load for the entire basin was not computed at the Shiprock station because of the poor r^2 value for the predictive equation; however, it will be greater than the sum of the measured tributary load inflow. The mean annual dissolved-sodium load per square mile is shown in figure 18. On a per-square-mile basis, the largest loads originate from the northern part of the basin and the smallest loads originate from the southern part of the basin.

The variability of the mean annual dissolved-sulfate load (fig. 19) is similar to that of the dissolved-sodium load. No value was calculated for the Shiprock station to determine a total-basin load. The greatest dissolved-sulfate load of 67,800,000 kilograms per year originates from the Animas River basin. The large upstream drainage area in the northeastern part of the basin and the Chaco River contribute the next two greatest dissolved-sulfate loads. On a per-square-mile basis, the greatest loads originate from the Animas River drainage basin (fig. 20).

The mean annual dissolved-radium-226 load was calculated at four stations in the basin (fig. 21). The total load for the basin is 113,000 microcuries per year for the NASQAN station at Shiprock. Of that total, about 58 percent originates from the Animas River basin, which comprises only 10.5 percent of the basin's drainage area (table 14). On a per-square-mile basis, the greatest load originates from the Los Pinos River drainage basin (fig. 22).

Table 13. Percent contribution to the mean annual product of specific conductance and streamflow by subbasin for the San Juan River basin upstream from Shiprock, New Mexico

Subbasin and percentage of total basin area	Percent contribution to total product	
	Using WATSTORE Daily-Values File	Using WATSTORE Water-Quality File
San Juan River basin from Archuleta, New Mexico, upstream, 25 percent		32.5
Cañon Largo basin, 13 percent		2.8
Animas River basin, 10.5 percent	37.2	34.8
La Plata River basin, 4.5 percent		3.3
Shumway Arroyo basin, 0.6 percent	1.0	
Chaco River basin, 34 percent	5.8	6.4

Table 14. Percent contribution to the mean annual dissolved-radium-226 load by subbasin for the San Juan River basin upstream from Shiprock, New Mexico

Subbasin and percentage of total basin area	Percent contribution to total load
Vallecito Creek basin, 0.6 percent	5.1
Animas River basin, 25 percent	57.6
Chaco River basin, 34 percent	2.8

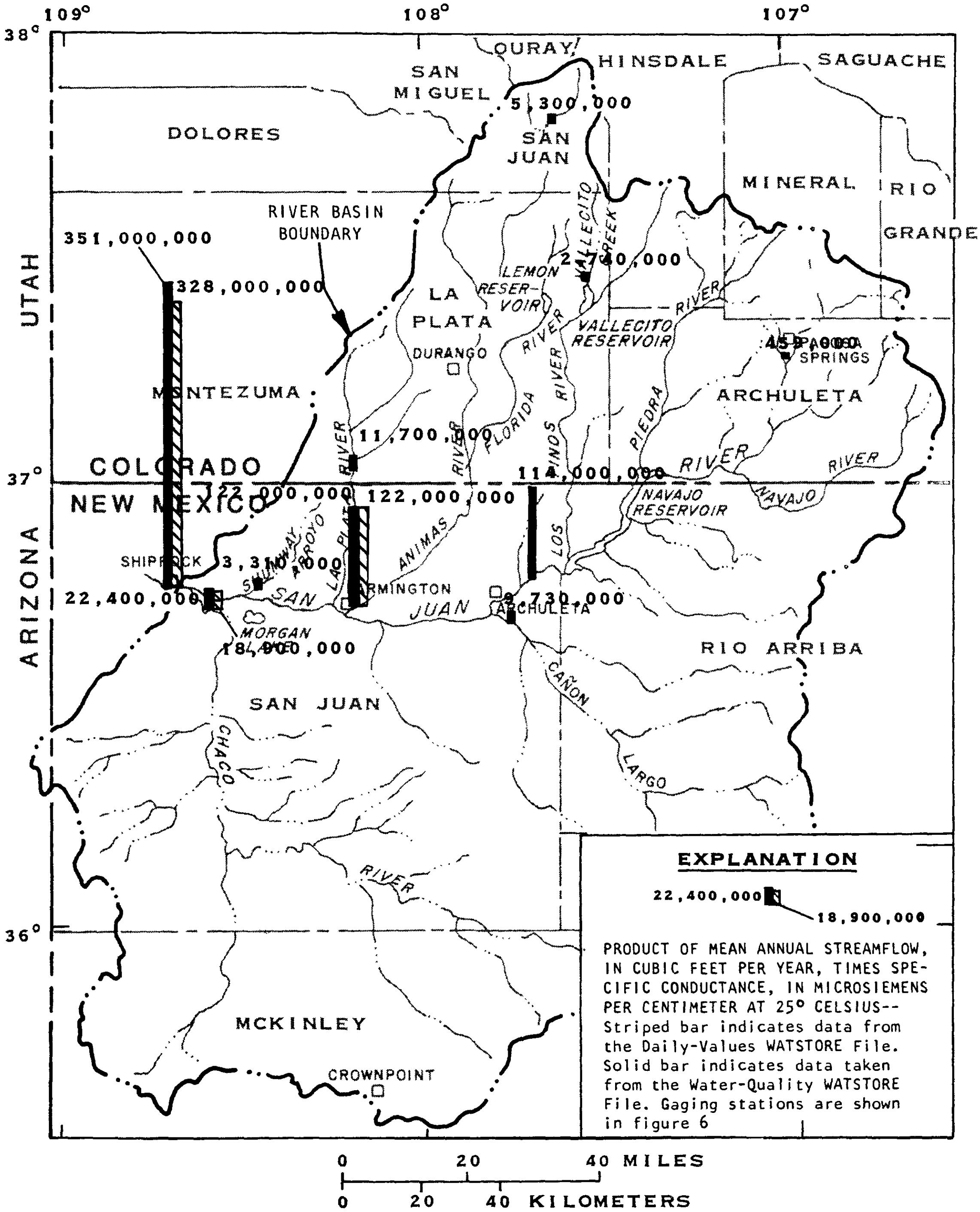


Figure 15.--Variability of the mean annual product of specific conductance and streamflow, October 1, 1973 - September 30, 1981.

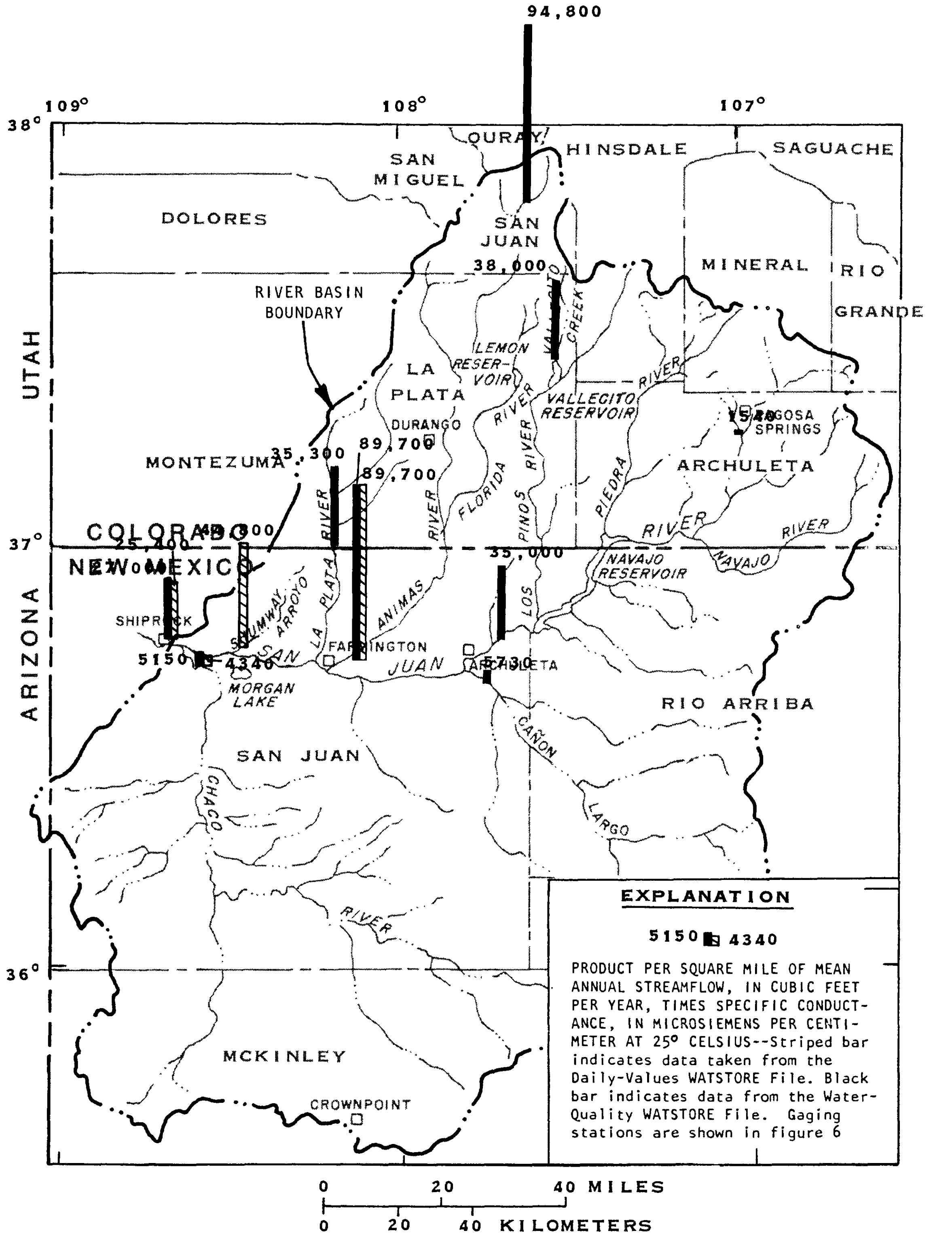


Figure 16.--Variability of the mean annual product of specific conductance and streamflow per square mile of drainage area, October 1, 1973 - September 30, 1981.

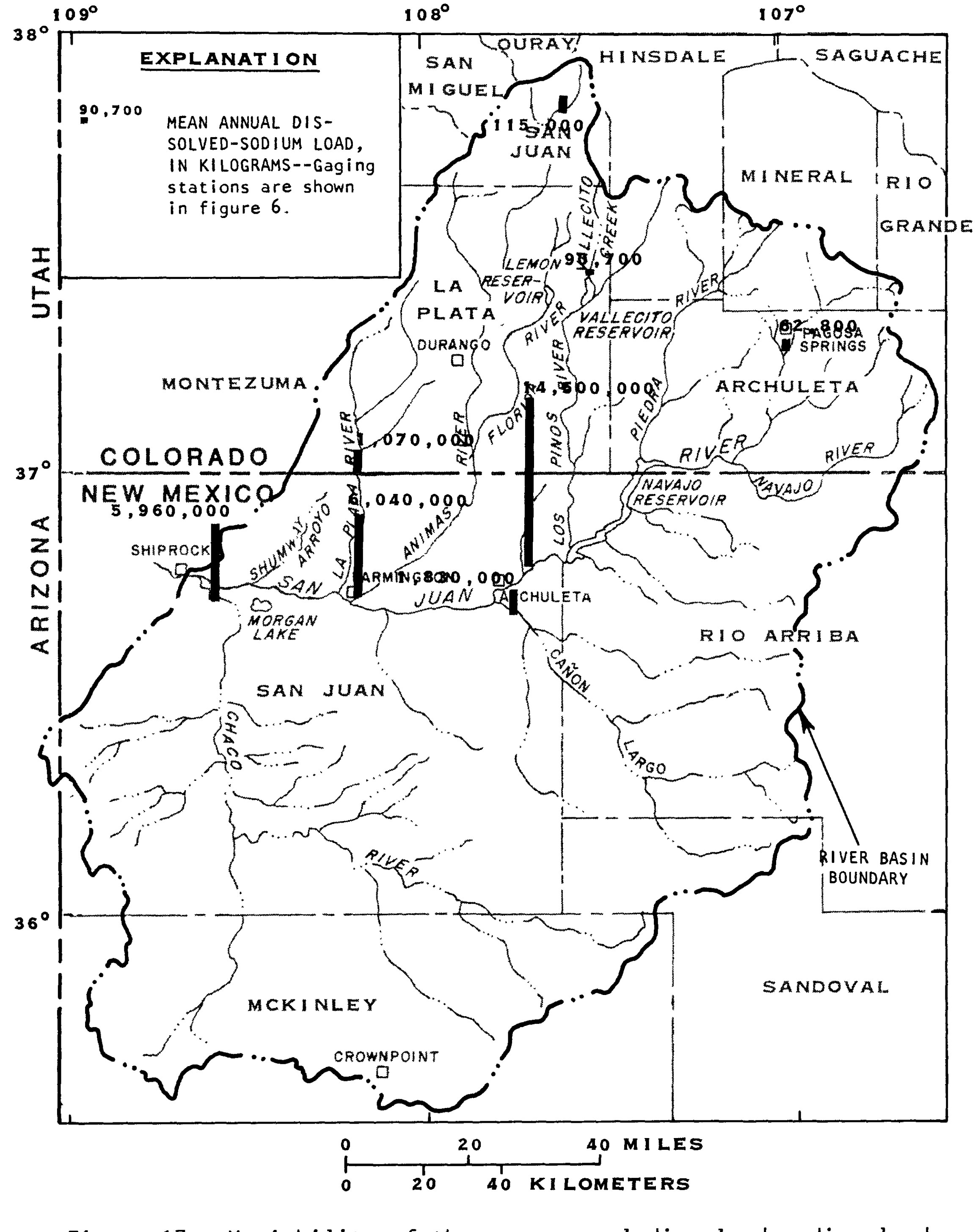


Figure 17.--Variability of the mean annual dissolved-sodium load, October 1, 1973 - September 30, 1981.

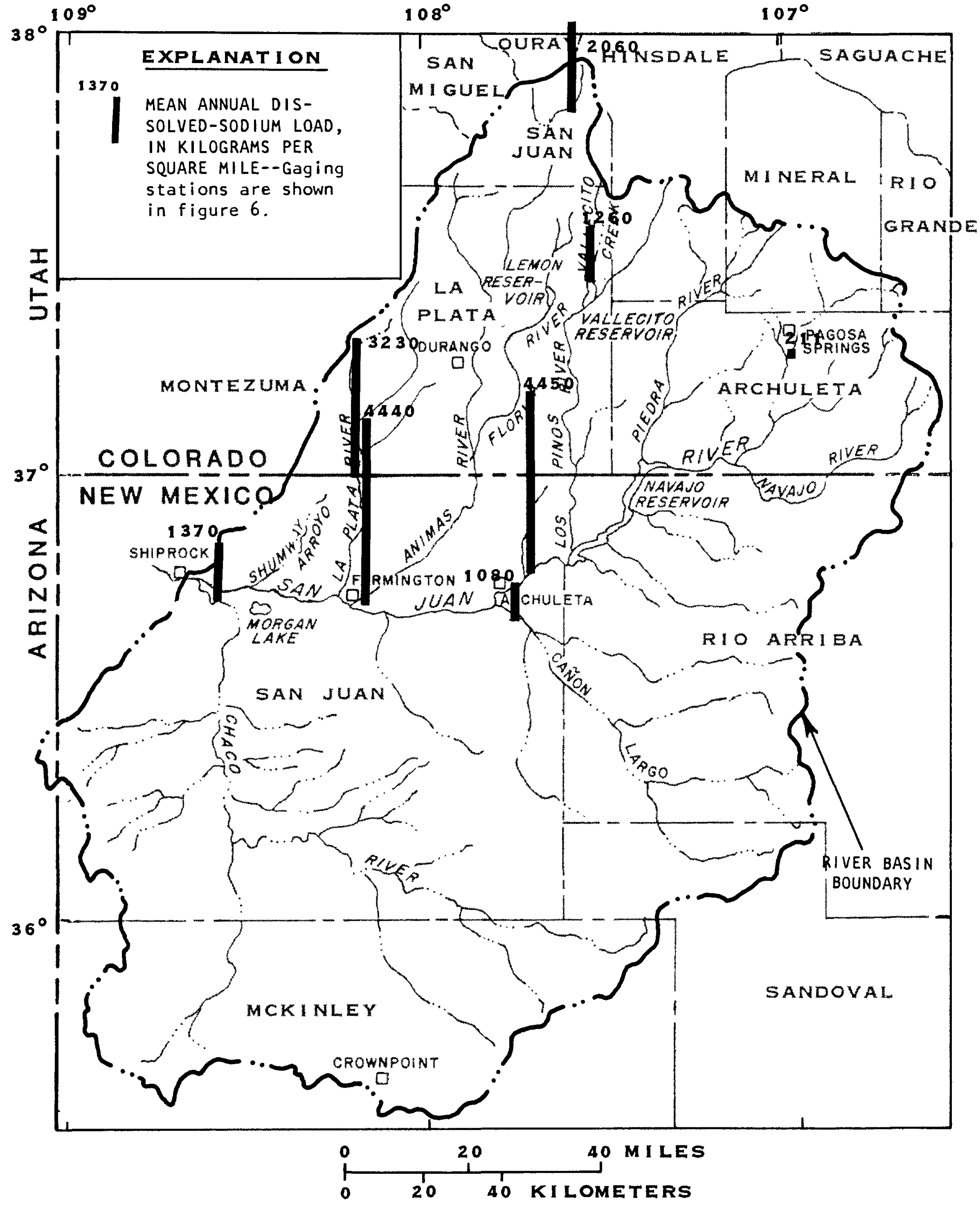


Figure 18.--Variability of the mean annual dissolved-sodium load per square mile of drainage area, October 1, 1973 - September 30, 1981.

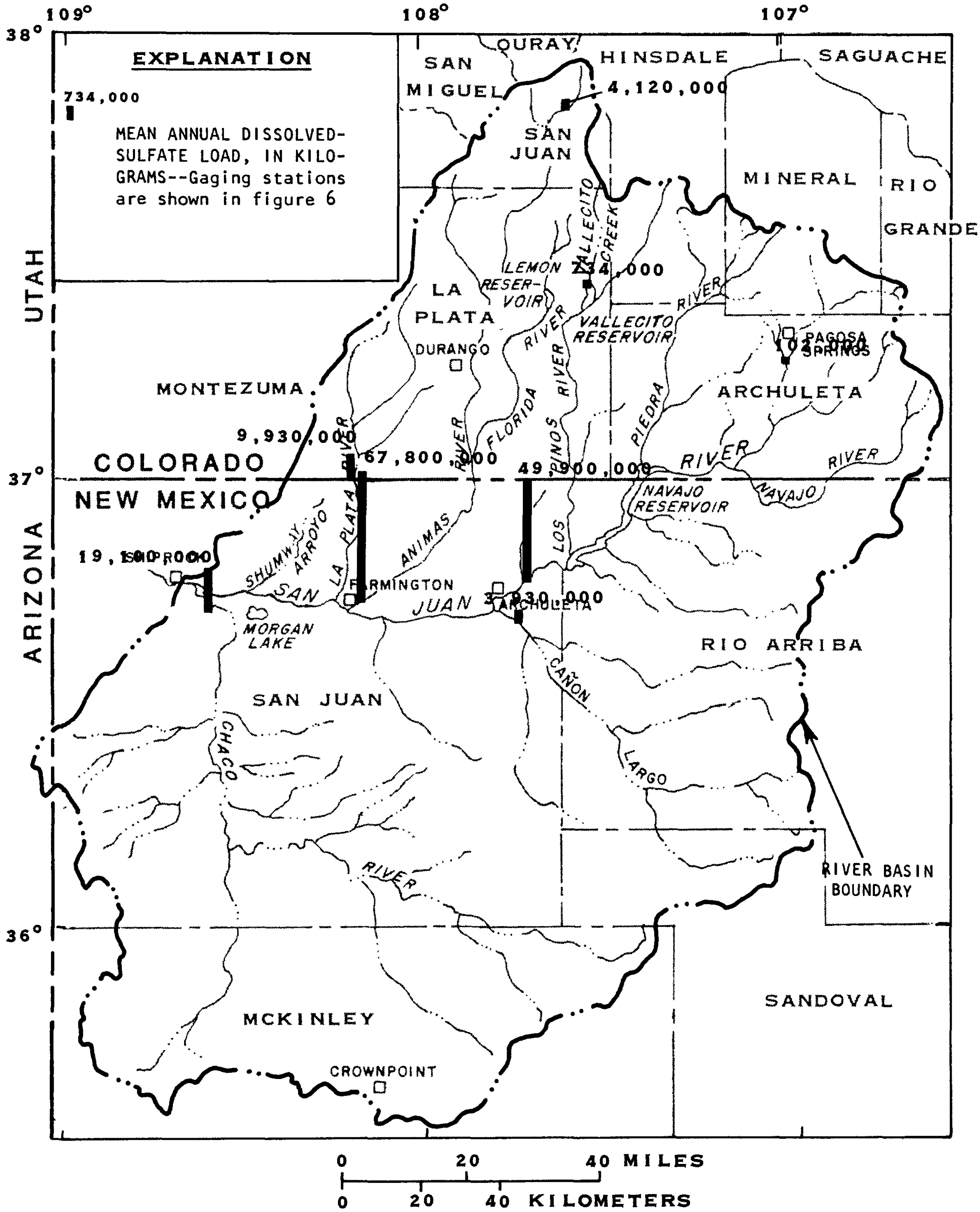


Figure 19.--Variability of the mean annual dissolved-sulfate load, October 1, 1973 - September 30, 1981.

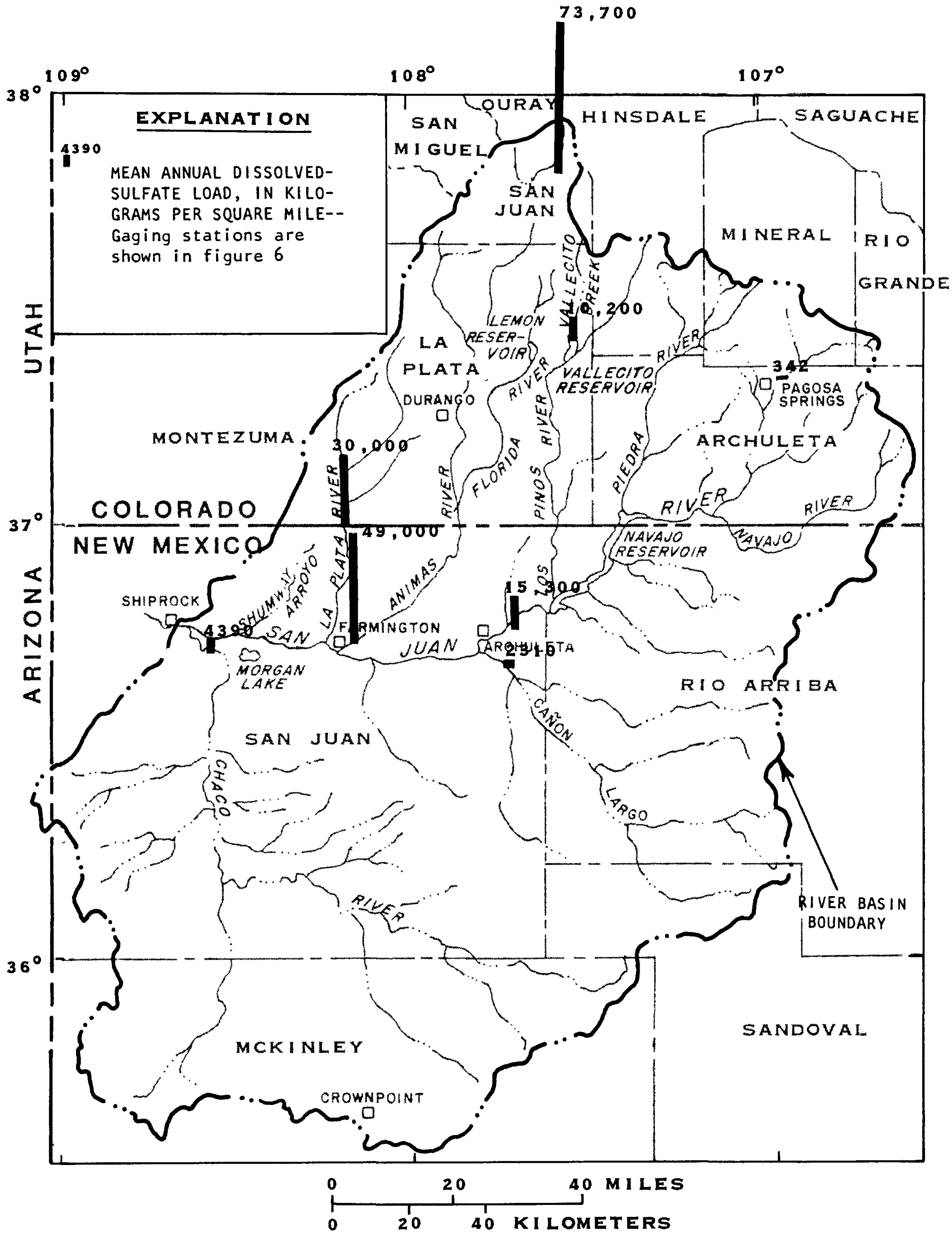


Figure 20.--Variability of the mean annual dissolved-sulfate load per square mile of drainage area, October 1, 1973 - September 30, 1981.

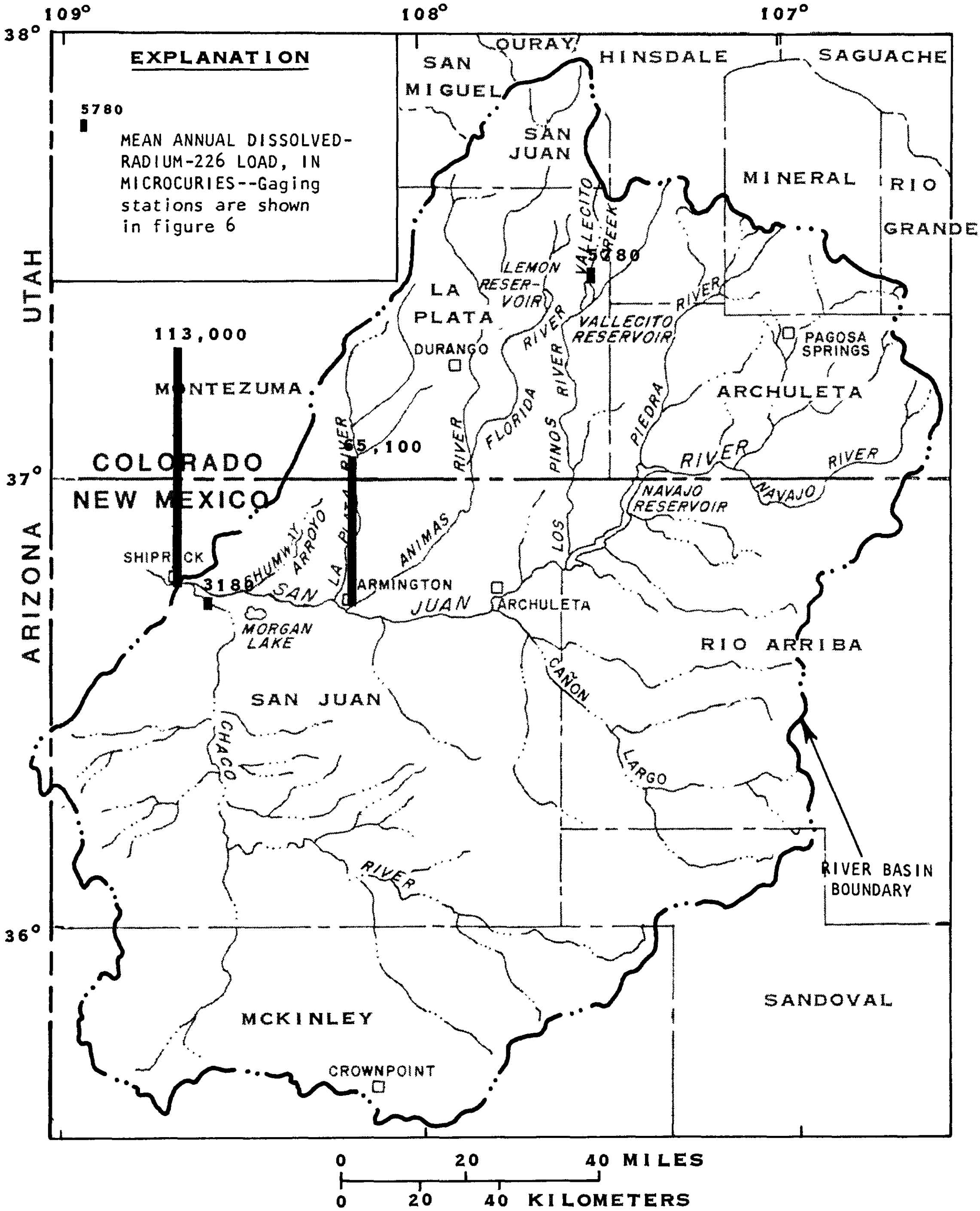


Figure 21.--Variability of the mean annual dissolved-radium-226 load, October 1, 1973 - September 30, 1981.

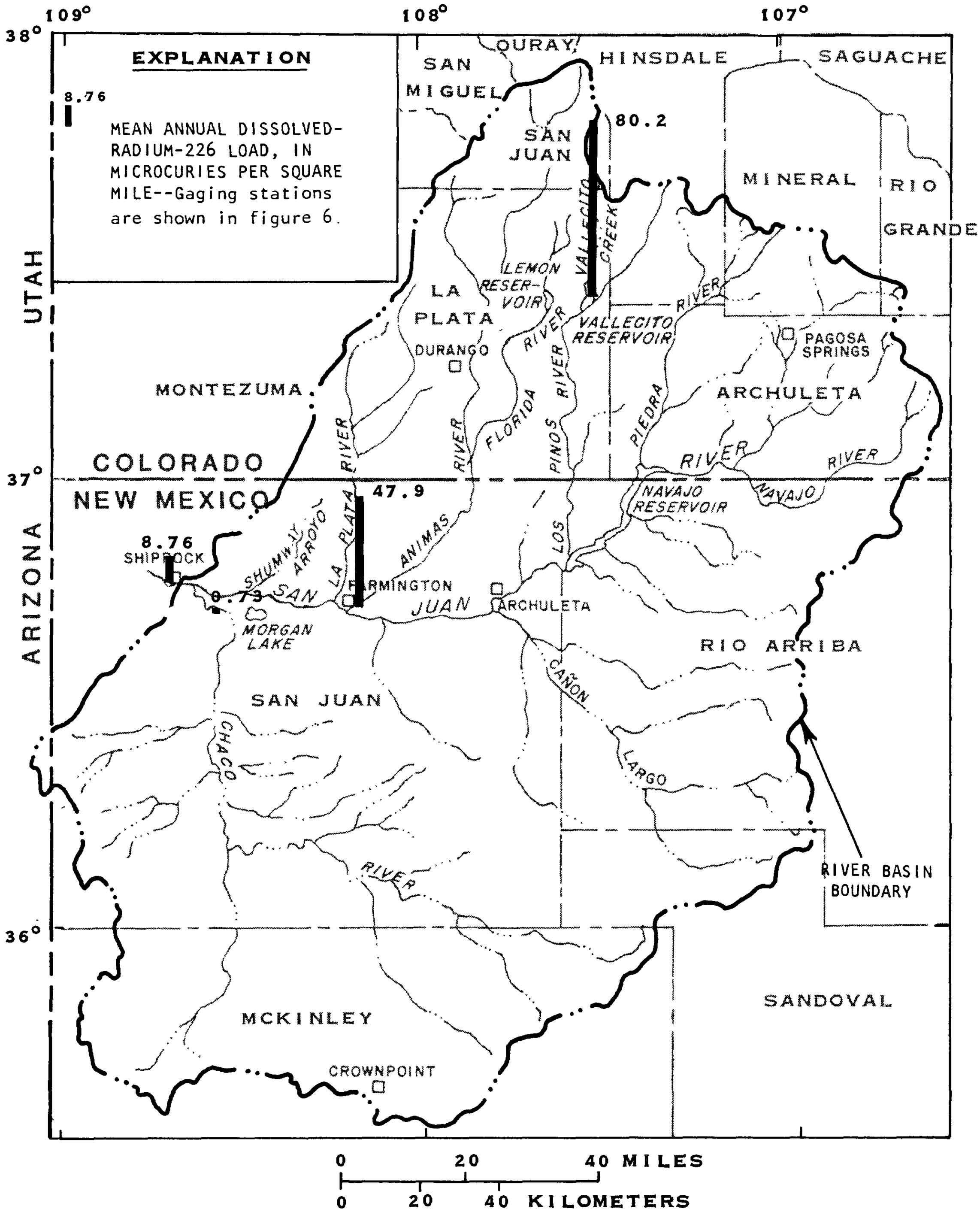


Figure 22.--Variability of the mean annual dissolved-radium-226 load per square mile of drainage area, October 1, 1973 - September 30, 1981.

Box-and-Whisker Plots

Box-and-whisker plots (Gerig, 1980) show the distribution of water-quality and streamflow data for a chosen period in time. The box-and-whisker plot identifies the mean, median, the 25th and 75th percentiles of the data, adjacent values, and extreme values of the data set. The adjacent and extreme values are calculated as described by Tukey (1977, p. 39-48). Extreme values are subdivided into the terms "outside" values and "far-out" values. Values greater than 1.5 times the interquartile range (difference between the 75th and 25th percentiles) are outside values, and values greater than 3 times the interquartile range are far-out values.

Dissolved-orthophosphate phosphorus, dissolved-iron and dissolved-manganese data contained values reported as less than a given laboratory detection limit, which was subject to change during 1974 to 1981. If a value was given as less than 10 micrograms per liter, for example, it is known to be between 0 and 10 micrograms per liter. In order to simplify matters and avoid bias by either deleting the data or choosing the upper or lower limit as a substitute for the less than value, the midpoint of the known range was chosen, 5 micrograms per liter. That midpoint value replaced the original less than value in the data set. This new data set was then used to produce box-and-whisker plots.

For comparison purposes, the box-and-whisker plots are shown side by side and at the same scale for 23 stations in the study area except figure 23, which shows a box-and-whisker plot for 16 stations (figs. 23-32). It can be seen that streamflow has a large percentage of far-out values (fig. 23). The streamflow box-and-whisker plots have the longest tails of far-out values. This implies that streamflow at most stations is highly variable, also highly skewed and nonnormal. Streamflow from station to station also is quite variable. Streamflow affects water-quality constituents through dilution processes.

Dissolved-iron (fig. 24) and suspended-sediment concentrations (fig. 25) are the water-quality constituents with the most noticeable percentage of far-out values. The central values (25th percentile, mean, median, and 75th percentile) for dissolved iron are poorly defined on the plot due to the scale. Central values for suspended sediment are fairly variable.

Dissolved radium-226 (fig. 26) is the constituent with the least number of far-out and outside values. It also does not vary greatly from station to station.

Specific conductance (fig. 27), pH (fig. 28), dissolved-orthophosphate phosphorus (fig. 29), dissolved sodium (fig. 30), dissolved sulfate (fig. 31), and dissolved manganese (fig. 32) fall between dissolved iron and dissolved radium-226 in variability at a single station. Central values of specific conductance and sulfate are the most variable from station to station of this group of constituents.

Station 09367561, Shumway Arroyo near Waterflow, New Mexico, has the greatest variability of all stations for most constituents and the largest concentration for these constituents. It has the greatest variation in specific conductance, pH, dissolved-orthophosphate phosphorus, dissolved sodium, and dissolved sulfate. This station carries wastewater from a power-generation facility located less than a mile upstream, except in the case of a rainfall event, when it carries a mixture of wastewater and overland runoff. The conclusion could be made that effluent from power-generation facilities adds the largest concentrations of the above-named constituents to the stream system.

The box-and-whisker plots show that large concentrations of the following constituents are transported to the San Juan River main stem from the Cañon Largo tributary, station 09356565: dissolved sodium, dissolved sulfate, dissolved manganese, and suspended sediment. Compared to streamflow in the main stem, flow in this tributary is small, emanating from small seeps and springs except when there is a rainfall event. Then, a mixture of ground-water flow and overland runoff is carried and the streamflow volume is large.

The box-and-whisker plots of sulfate, specific conductance, and pH at stations FC6 and 09368000 represent data collected at the same site by two different organizations. Only in the case of dissolved sulfate do the box-and-whisker plots appear to be very similar. Box-and-whisker plots of specific conductance at these two stations are fairly similar. Box-and-whisker plots of pH are noticeably more compressed for station FC6 than for station 09368000. The compression in pH at FC6 could be due to the fact that data from this station are monthly averages rather than instantaneous values and this could have a leveling effect. At station 09368000, pH measurements were taken at the time of collection.

The box-and-whisker plots display variations in the data better than the summary values of tables 1 through 10. The tables give maximum and minimum values that indicate degrees of variation but do not show the values that are near these extremes or the spread about the central values.

The two NASQAN stations, Animas River at Farmington (09364500) and San Juan River at Shiprock (09368000), have large volumes of streamflow. Of the stations shown in figures 23 through 32, the two NASQAN stations are low in variability; that is, their box-and-whisker plots are compressed. Their constituent concentrations are also at smaller levels in comparison to other stations in the basin. In general, stations with small to ephemeral flows in the downstream end of the basin have the most variable water quality and often have large constituent concentrations. These stations have little influence on water quality in the San Juan River main stem, but they are representative of conditions in the southern part of the basin.

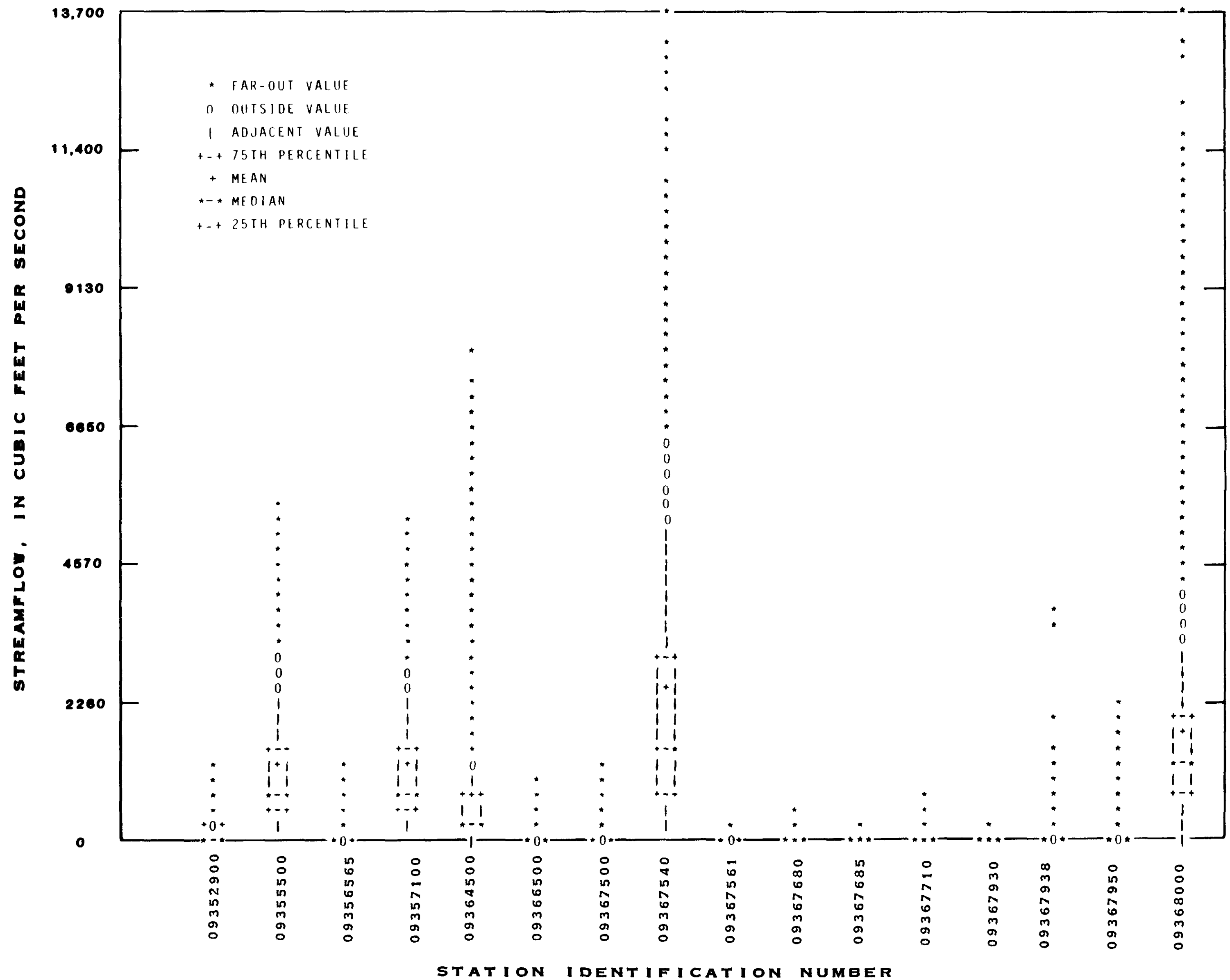


Figure 23.--Box-and-whisker plot of streamflow data, October 1, 1973 - September 30, 1981.

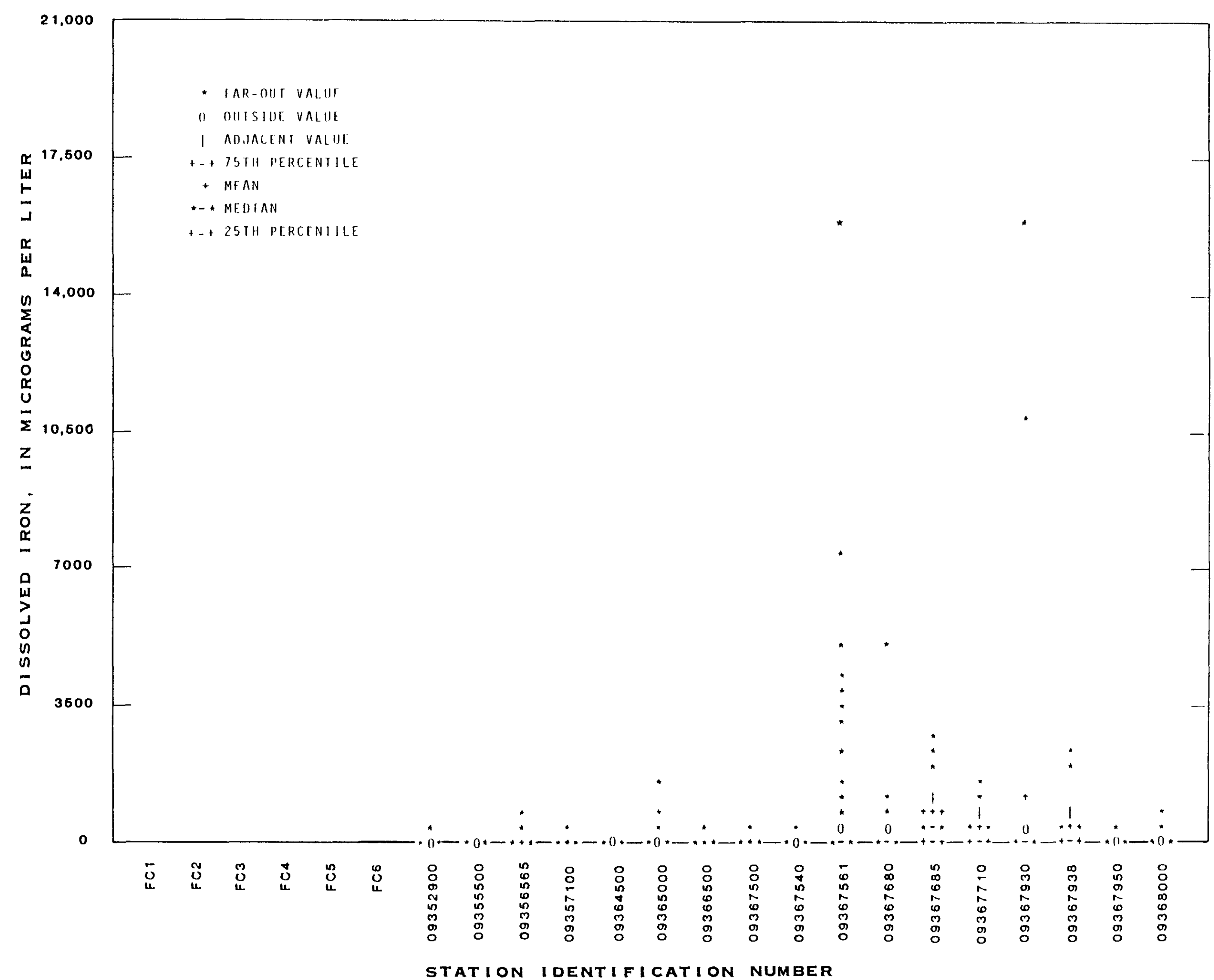


Figure 24.--Box-and-whisker plot of dissolved-iron data, October 1, 1973 - September 30, 1981.

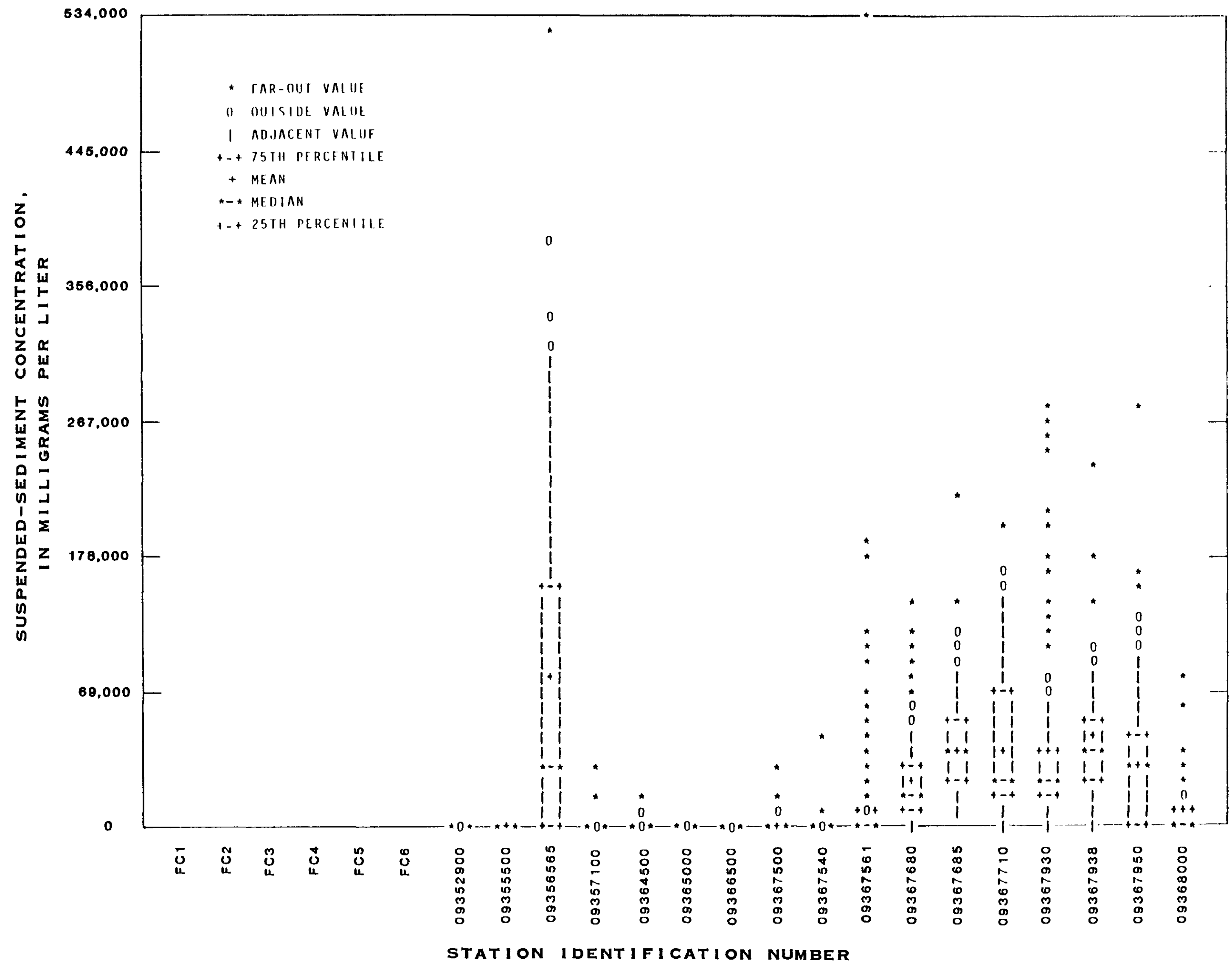


Figure 25.--Box-and-whisker plot of suspended-sediment-concentration data, October 1, 1973 - September 30, 1981.

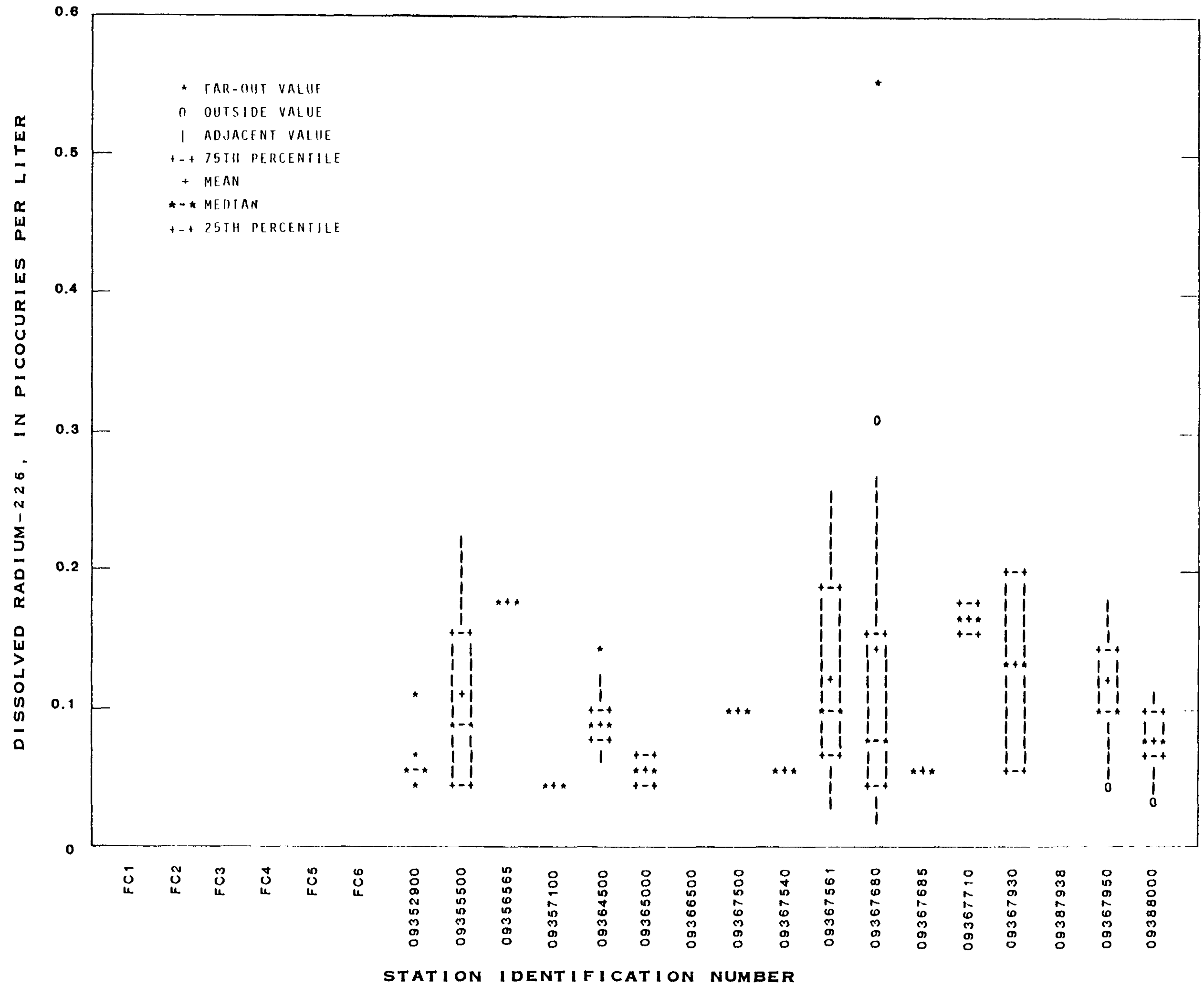


Figure 26.--Box-and-whisker plot of dissolved-radium-226 data, October 1, 1973 - September 30, 1981.

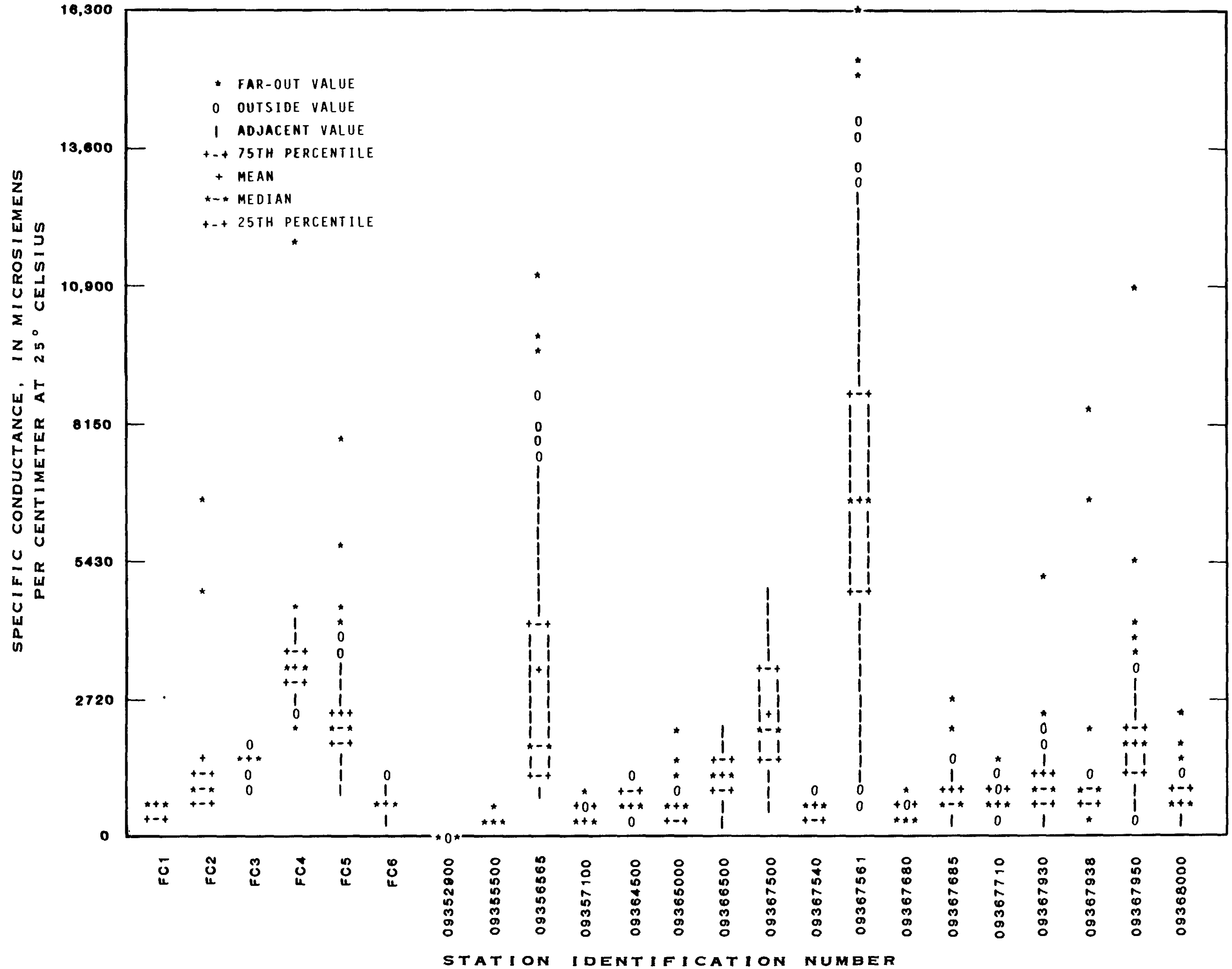


Figure 27.--Box-and-whisker plot of specific-conductance data, October 1, 1973 - September 30, 1981.

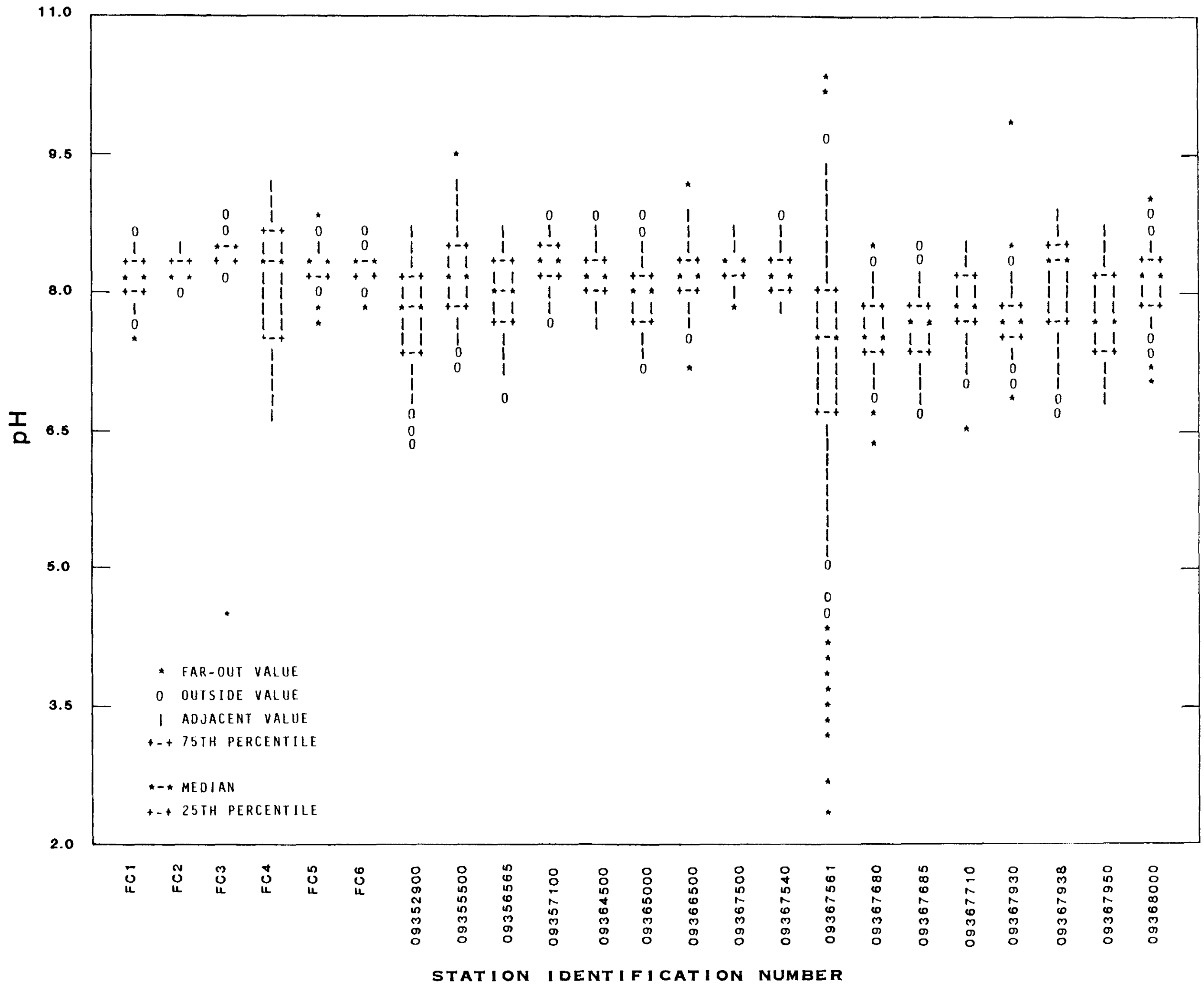


Figure 28.--Box-and-whisker plot of pH data, October 1, 1973 - September 30, 1981.

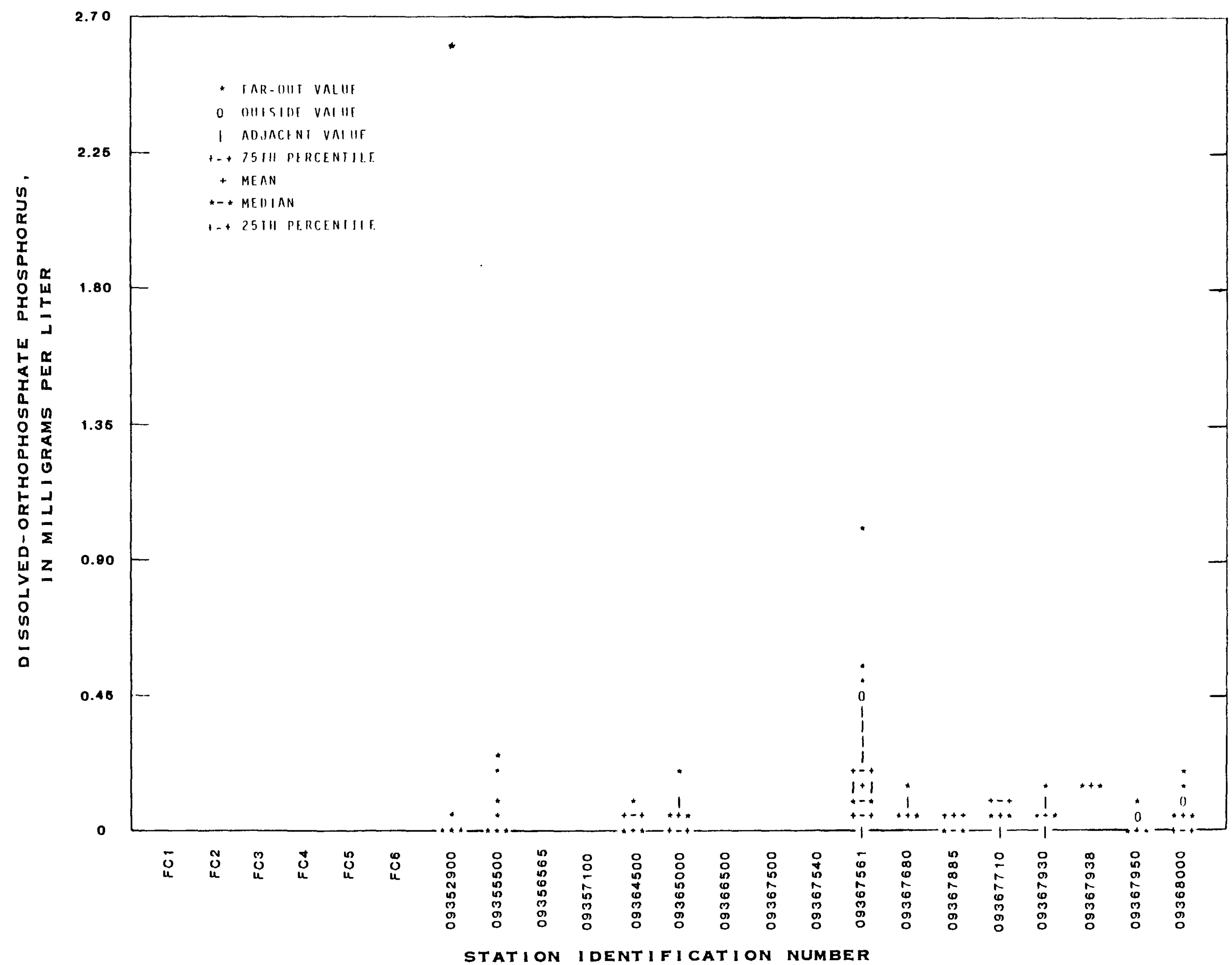


Figure 29.--Box-and-whisker plot of dissolved-orthophosphate phosphorus data, October 1, 1973 - September 30, 1981.

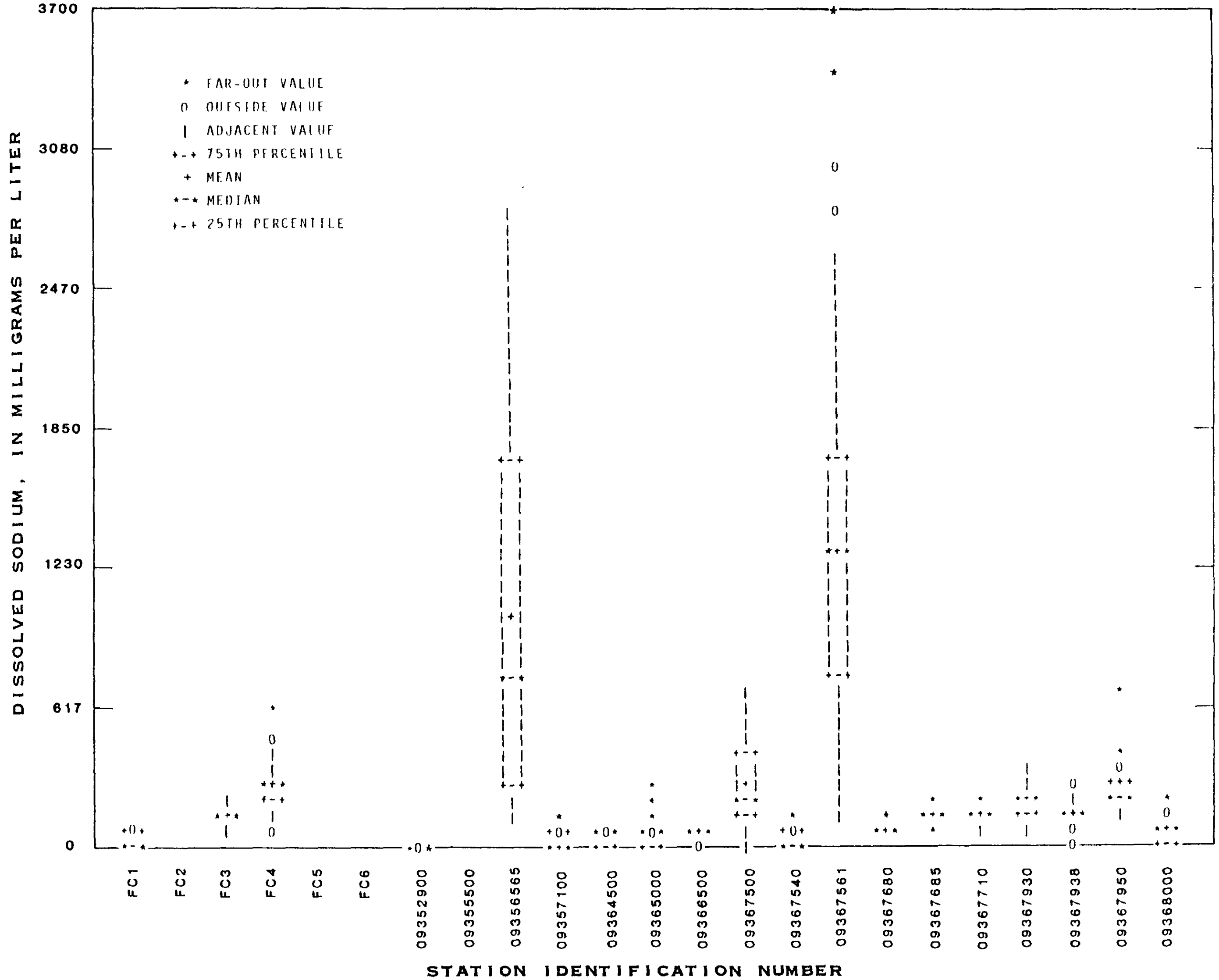


Figure 30.--Box-and-whisker plot of dissolved-sodium data, October 1, 1973 - September 30, 1981.

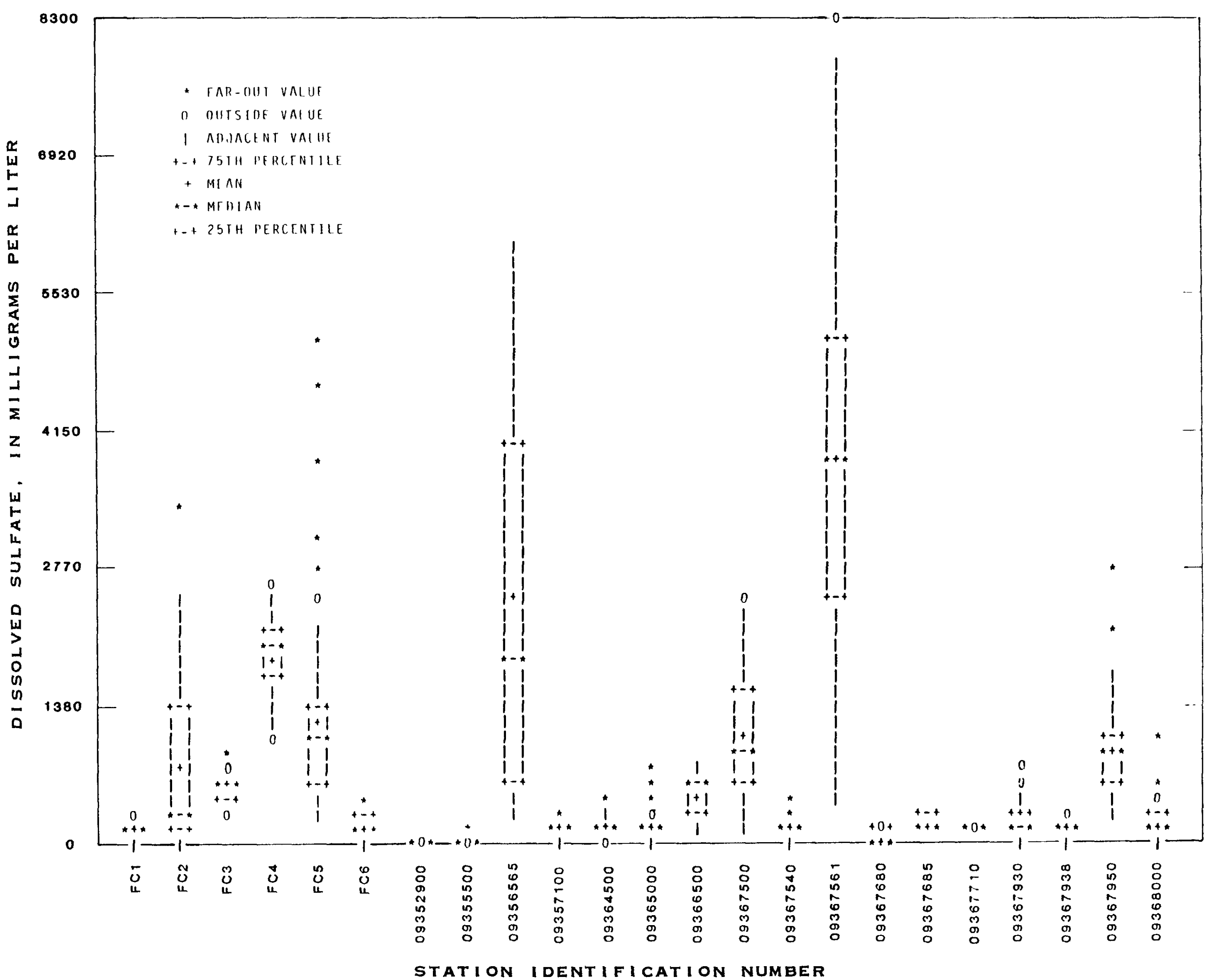


Figure 31.--Box-and-whisker plot of dissolved-sulfate data, October 1, 1973 - September 30, 1981.

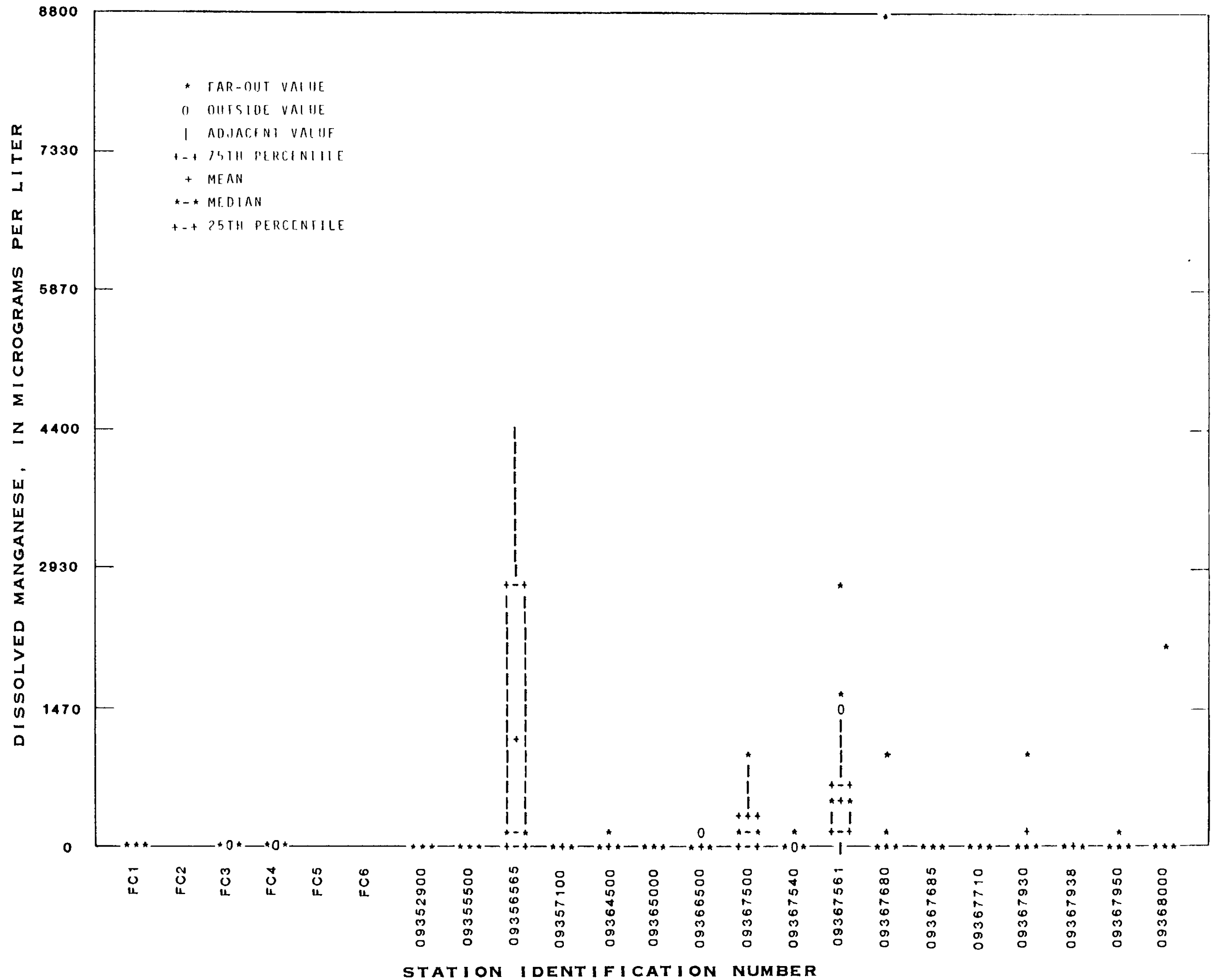


Figure 32.--Box-and-whisker plot of dissolved-manganese data, October 1, 1973 - September 30, 1981.

TEMPORAL VARIABILITY OF WATER QUALITY

Is the water quality in the San Juan River basin getting better or worse? The answer depends on how one chooses to define "better" and "worse." An objective of this study is to define whether the water quality is changing over time and, if so, how it is changing over time.

The time period of interest for this study is October 1, 1973, through September 30, 1981. The primary stations of interest are the NASQAN stations, San Juan River at Shiprock, New Mexico, and Animas River at Farmington, New Mexico. Also of interest is whether other stations within the basin correlate with the NASQAN stations.

Two analytical techniques were applied to the data. The first is a statistical technique that analyzes for a monotonic trend in monthly or seasonal data. This technique is referred to as the "Seasonal Kendall test for trend magnitude" (Crawford and others, 1983). The second is a graphical technique that displays data values over time and is referred to as time-series plotting.

Seasonal Kendall Test for Trend Magnitude

The Seasonal Kendall test for trend magnitude was performed for data at 36 stations within the study area. Constituents tested include specific conductance, pH, dissolved-orthophosphate phosphorus, dissolved sodium, dissolved sulfate, dissolved iron, dissolved manganese, dissolved radium-226, and suspended sediment. Not all of the constituents were tested at each station. Only those constituents that were collected regularly for 3 or more years were selected for testing. At eight stations, the only constituent with sufficient data for testing was specific conductance.

A trend was judged to exist if the test was significant at the 5-percent probability level. The hypothesis tested was that there was no trend from October 1, 1973, through September 30, 1981. The hypothesis was declared true (that is, a trend does not exist) if the calculated probability exceeded a given value called the significance level. The significance level chosen for this study was 0.05 (5 percent). The hypothesis was declared false (a trend exists) if the calculated probability was less than 0.05. Using the 5-percent level of significance, a station will appear to have trend when it truly does not have trend once in 20 trials by chance alone. Therefore, in using the 5-percent level of significance, an error will occur once in 20 trials on the average.

Trends were detected at 14 stations. Trends detected at the 14 stations and a trend summary for the NASQAN stations are given in table 15.

Of the 14 stations where trends were detected, 5 stations are downstream from coal-mining and power-generation facilities. Water-quality measurements taken at these stations may be reflecting changes in coal- or power-production rates over the indicated years and changes in water-discharge practices. The five stations are 09367561, 09367950, FC3, FC4, and FC5 in table 15 and figure 6. Station 09367561 is less than a mile downstream from one coal-mining and power-generation facility; stations 09367950, FC1, FC3, FC4, and FC5 are 9 to 10 miles downstream from a second coal-mining and power-generation facility. The largest increasing trends in specific conductance, dissolved sodium, dissolved sulfate, and dissolved iron and the largest decreasing trend in pH took place at station 09367561. This trend is believed to be associated with wastewaters from the power-generation facility. During 1974 through 1981 this facility gradually increased coal and power production and installed air scrubbers that require the use of water that consequently may have changed the water-quality characteristics of wastewater discharges from the facility. The quantity of flow at this station is small and the trends detected here were not detected at the NASQAN station, 09368000, 18 miles downstream. At the four other stations affected by wastewater flow from the second power-generation facility, the largest decreases in specific conductance, dissolved sodium and dissolved sulfate were detected. A small decrease in pH also was detected for this station. At this facility production remained steady during 1974 through 1981, but efforts to reduce wastewater discharges may account for the decreasing trends.

At other stations in the study area, one showed an increase in suspended sediment; one a decrease in suspended sediment; one an increase in dissolved iron; one a decrease in dissolved iron; three a decrease in pH; one an increase in dissolved-orthophosphate phosphorus; one an increase in dissolved sulfate; and one a small decrease in specific conductance and dissolved sodium. These trends may be due to new or increased disturbances in the drainage area, such as expanded metals mining, changes in agricultural practices, or increased urbanization. None of the trends detected above are attributable to any single cause.

At the two NASQAN stations, Animas River at Farmington and San Juan River at Shiprock, which appear in boldface type in table 15, a decrease in suspended sediment of 78 mg/L per year occurred at the Farmington station and no trends occurred at the Shiprock station. The decrease in suspended sediment is assumed to result from the retention of sediments in upstream reservoirs and efforts to decrease erosion from farmed lands through improved farm management. Also of some influence may be the land-use change from farms to resort properties in this part of the basin. The NASQAN station 09368000, San Juan River at Shiprock, which is the most downstream station in the study area, is an integration of trends over the upstream basin. No trends were detected at 09368000. At upstream sites there were both increasing and decreasing trends for several constituents and they likely cancelled each other. The Four Corners data-collection site at the same location, FC6, showed a decreasing trend in pH of .04 unit. The most consistent trend in the basin was the decrease in pH at six stations. Three stations are downstream from coal-mine and power-generation activities.

Table 15. Results of Seasonal Kendall test for trend magnitude

[NASQAN stations in boldface type; mg/L, milligrams per liter; μg/L, micrograms per liter; S/cm, microsiemens per centimeter at 25 °Celsius]

Station name and number	Trend	Water years that trend was detected
Vallecito Creek near Bayfield, Colorado, 09352900	Decrease in pH of 0.08 unit per year Increase in suspended sediment of 0.2 mg/L per year	1974-81
Cañon Largo Wash near Blanco, New Mexico, 09356565	Increase in dissolved iron of 20 μg/L per year	1978-81
San Juan River at Hammond Bridge, near Bloomfield, New Mexico, 09357100	Decrease in suspended sediment of 218 mg/L per year	1978-81
San Juan River above Animas River at Farmington, New Mexico, 09357300	Decrease in dissolved iron of 2 μg/L per year	1974-79
Animas River at Farmington, New Mexico, 09364500	**Decrease in suspended sediment of 78 mg/L per year**	**1974-81**
San Juan River at Farmington, New Mexico, 09365000	Increase in dissolved-orthophosphate phosphorus of .01 mg/L per year	1974-81
La Plata River at Colorado-New Mexico State line, 09366500	Increase in dissolved sulfate of 55 mg/L per year	1978-81
Shumway Arroyo near Waterflow, New Mexico, 09367561	Increase in specific conductance of 367 μS/cm per year Decrease in pH of .38 unit per year Increase in dissolved sodium of 160 mg/L per year Increase in dissolved sulfate of 200 mg/L per year Increase in dissolved iron of 20 μg/L per year	1974-81

Table 15. Results of Seasonal Kendall test for trend magnitude - Concluded

Station name and number	Trend	Water years that trend was detected
Chaco River near Waterflow, New Mexico, 09367950	Decrease in specific conductance of 230 μS/cm per year Decrease in dissolved sodium of 16 mg/L per year Decrease in dissolved sulfate of 120 mg/L per year	1976-81
San Juan River at Shiprock, New Mexico, 09368000	**No trends**	**1974-81**
San Juan River near Hogback, FC1	Decrease in specific conductance of 11 μS/cm per year Decrease in pH of 0.06 unit per year Decrease in dissolved sodium of 11 mg/L per year	1974-81
Morgan Lake, FC3	Decrease in specific conductance of 95 μS/cm per year Decrease in sodium of 30 mg/L per year Decrease in sulfate of 45 mg/L per year	1974-81
Ash pond Effluent, FC4	Decrease in specific conductance of 120 μS/cm per year Decrease in pH of .12 unit per year Decrease in sulfate of 66 mg/L per year	1974-81
Chaco River downstream of FC5	Decrease in specific conductance of 300 μS/cm per year Decrease in pH of .02 unit per year Decrease in dissolved sulfate of 190 mg/L per year	1974-81
San Juan River at Shiprock, New Mexico, FC6	Decrease in pH of .04 unit per year	1974-81

Time-Series Plots

Time-series plots show changes over a period of time for some constituents of interest. Time-series plots were prepared for 1974 through 1981 water-year water-quality data at 36 stations within the study area. Constituents graphed include specific conductance, pH, dissolved-orthophosphate phosphorus, dissolved sodium, dissolved sulfate, dissolved iron, dissolved manganese, dissolved radium-226, and suspended sediment. Any trends detected by the Seasonal Kendall test for trend magnitude may be able to be verified by the time-series plots. From the large number of plots, only selected plots representing some typical conditions and some trends (figs. 33-43) are presented in this report.

Some of the plots showed seasonal variation (figs. 33, 35, and 37). These plots are for stations located north of the San Juan River main stem, located on perennial, high-altitude streams. Concentrations of dissolved chemical constituents are smallest during snowmelt runoff in the spring and largest during late summer when streamflow is small.

The following conclusions were made after visual examination of the time-series plots. The determination of whether trends exist may be difficult for many of the plots because of seasonal variation at some stations and sparsity of data. At other stations with plots of extremely large and small values, such as suspended-sediment concentration, the pattern of the smaller values is hidden and trends are difficult to detect. Only at stations 09367950 (fig. 39), FC1 (fig. 42), and FC3 (fig. 43) are sequences with successive, consistent increasing or decreasing members (monotonic trend) readily discernible in the plots. At station 09357100 (fig. 34) a step decrease in specific conductance took place between October 1, 1978, and October 1, 1979.

The time-series plots at the two NASQAN stations, 09364500 and 09368000 (figs. 35, 36, 40, and 41), for specific conductance, dissolved sodium, and dissolved sulfate show correspondence, particularly for the periods of small concentrations. The other constituents do not correspond very well. Station 09364500 has more distinct seasonal variation. Most of the constituent values are within the same order of magnitude for the two stations, with the exception of dissolved-orthophosphate phosphorus and suspended-sediment concentrations. Specific conductance, dissolved sodium, and dissolved sulfate appear to be the most stable constituents. The other constituents are more transitory in nature and consequently more changeable at each site through time.

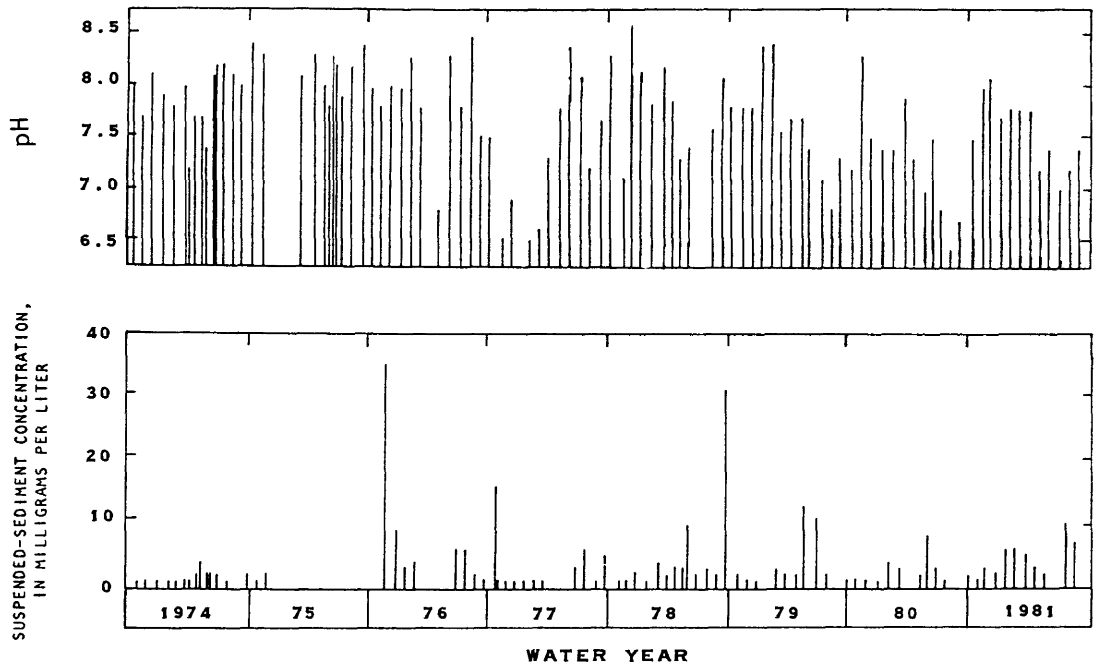


Figure 33.--Time-series plots of pH and suspended-sediment concentration, October 1, 1973 - September 30, 1981, at Vallecito Creek near Bayfield, Colorado (station 09352900).

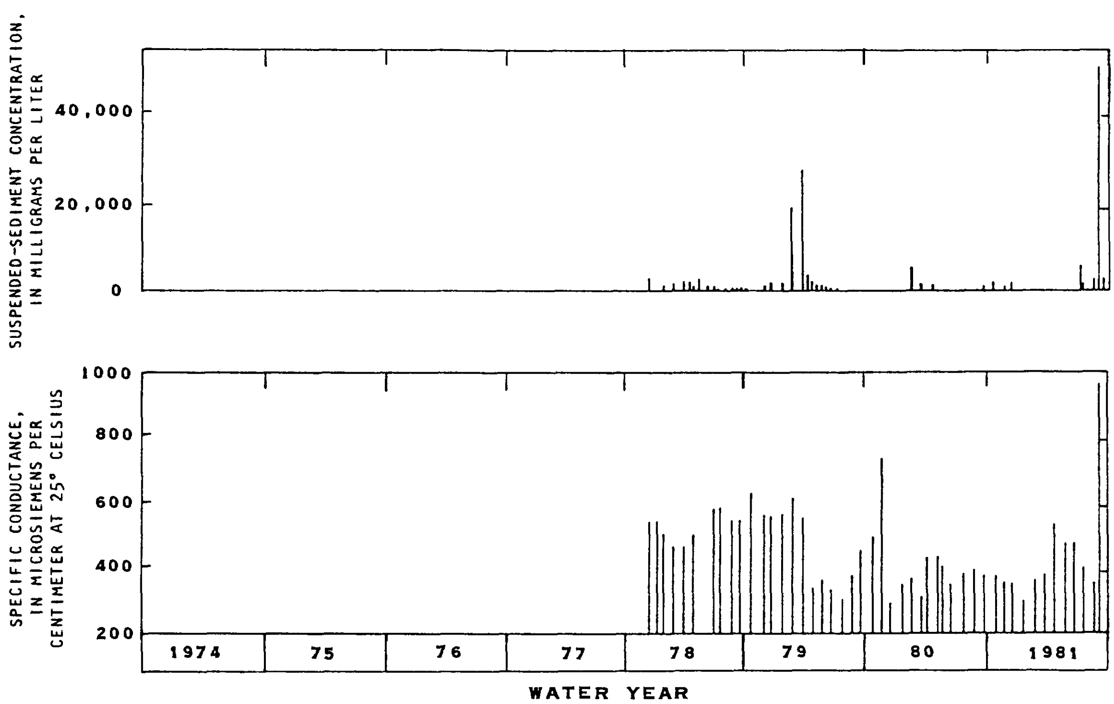


Figure 34.--Time-series plots of suspended-sediment concentration and specific conductance, October 1, 1973 - September 30, 1981, at San Juan River at Hammond Bridge near Bloomfield, New Mexico (station 09357100).

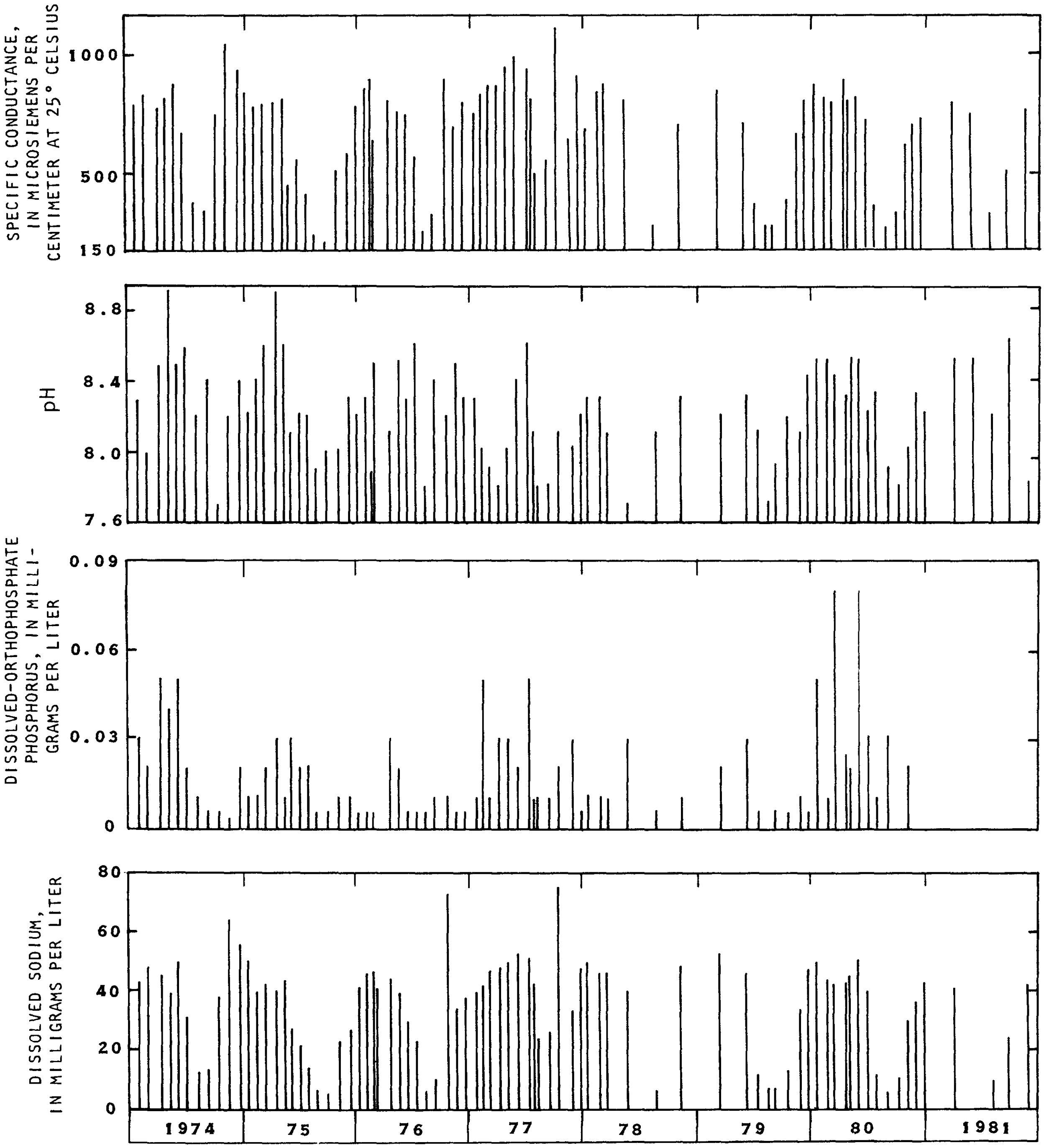


Figure 35.--Time-series plots of specific conductance, pH, dissolved-orthophosphate phosphorus concentration, and dissolved-sodium concentration, October 1, 1973 - September 30, 1981, at Animas River at Farmington, New Mexico (station 09364500).

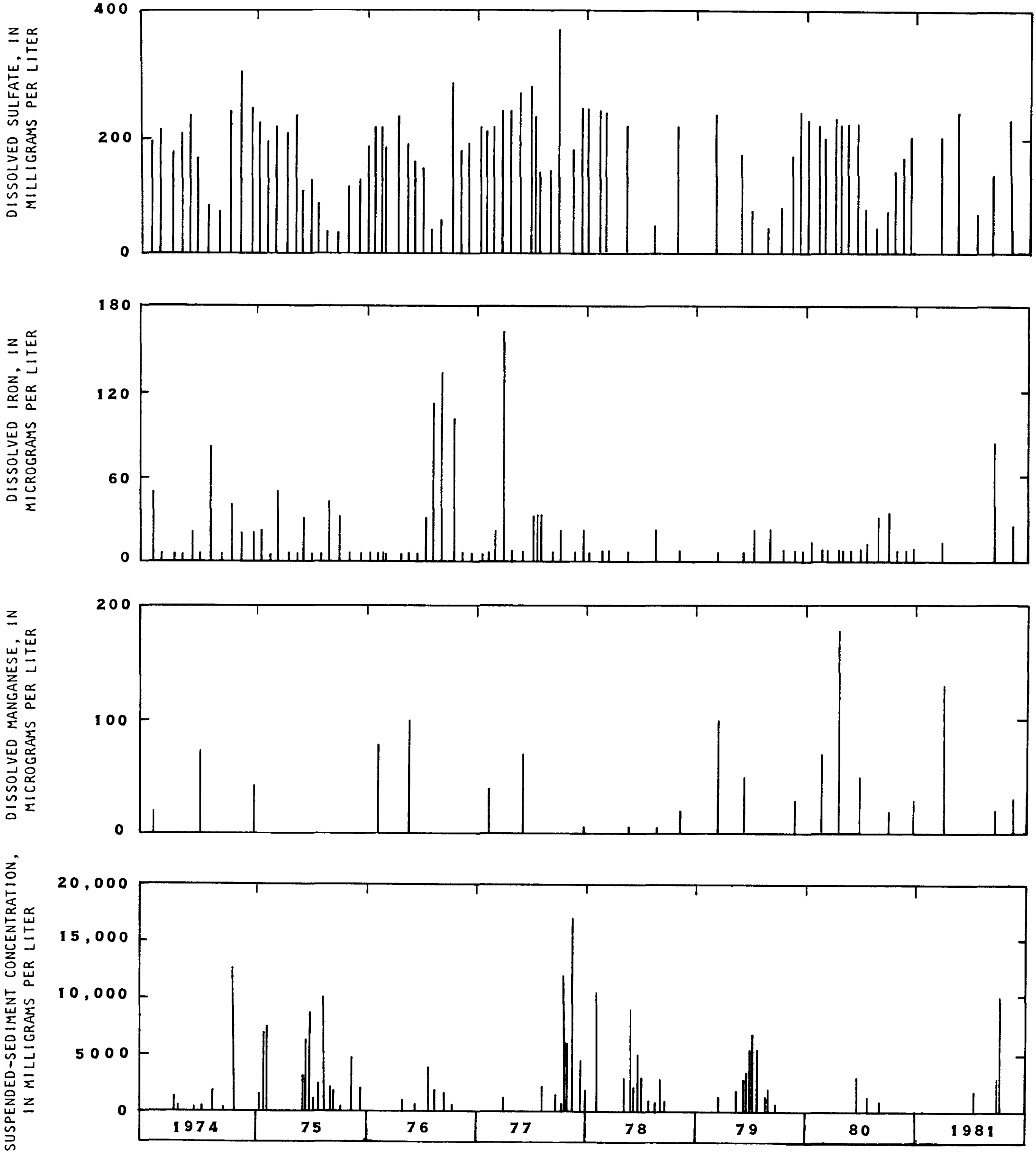


Figure 36.--Time-series plots of dissolved-sulfate, dissolved-iron, dissolved-manganese, and suspended-sediment concentrations, October 1, 1973 - September 30, 1981, at Animas River at Farmington, New Mexico (station 09364500).

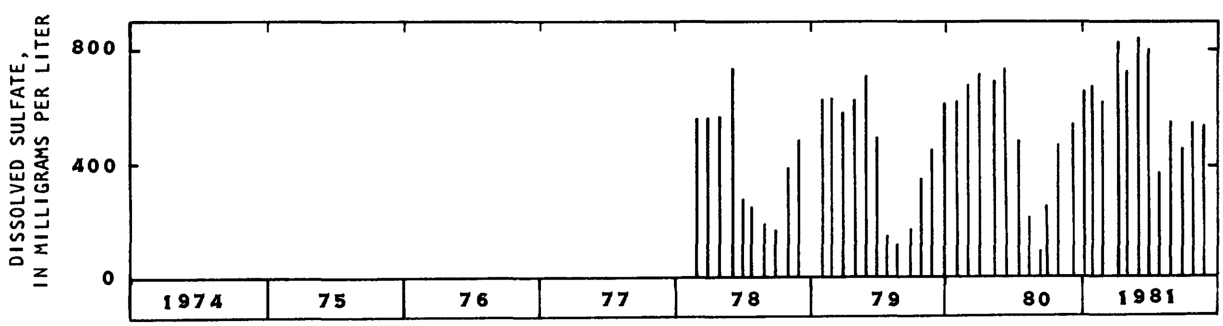


Figure 37.--Time-series plot of dissolved-sulfate concentration, October 1, 1973 - September 30, 1981, at La Plata River at Colorado - New Mexico State line (station 09366500).

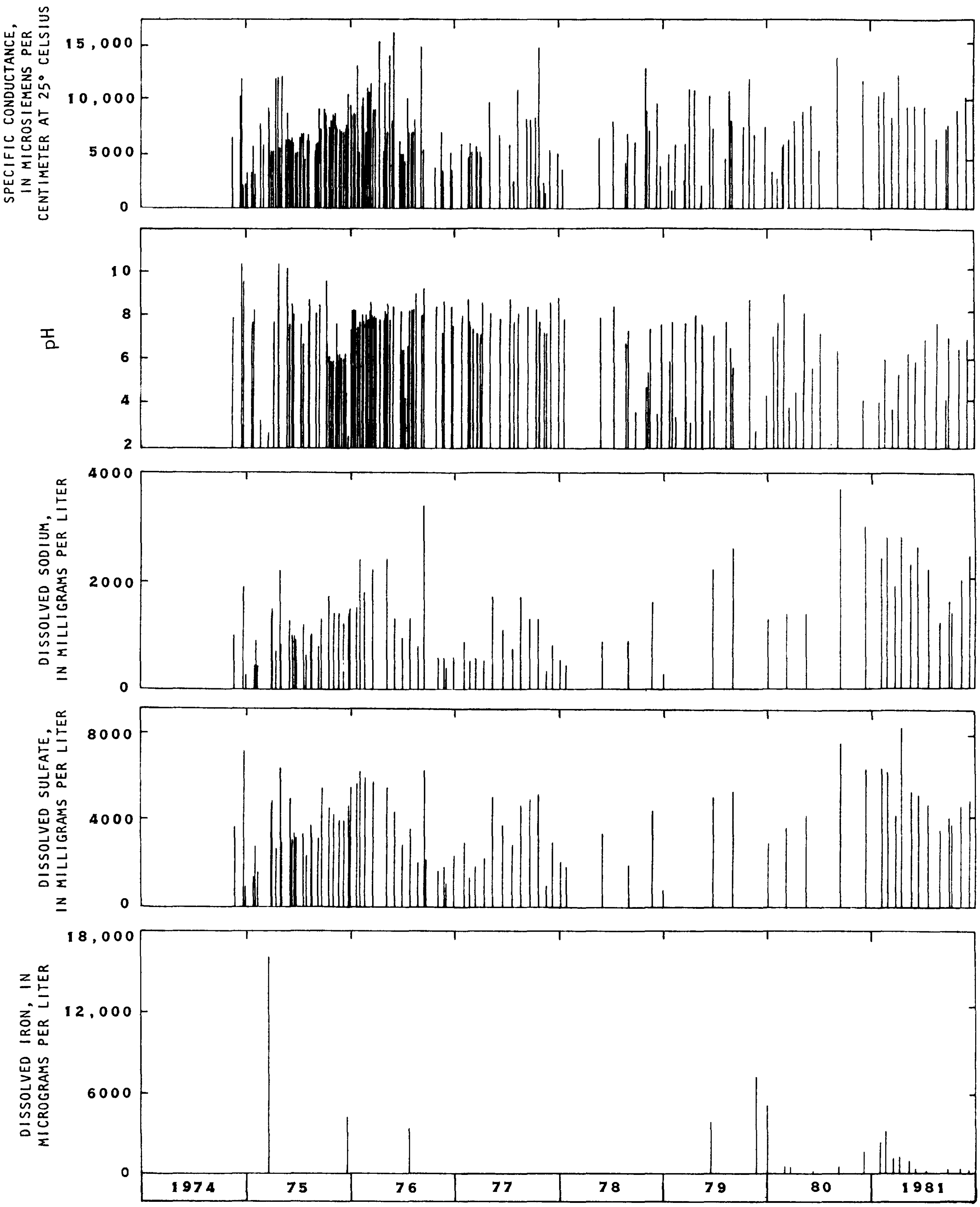


Figure 38.--Time-series plots of specific conductance, pH, and dissolved-sodium, dissolved-sulfate, and dissolved-iron concentrations, October 1, 1973 - September 30, 1981, at Shumway Arroyo near Waterflow, New Mexico (station 09367561).

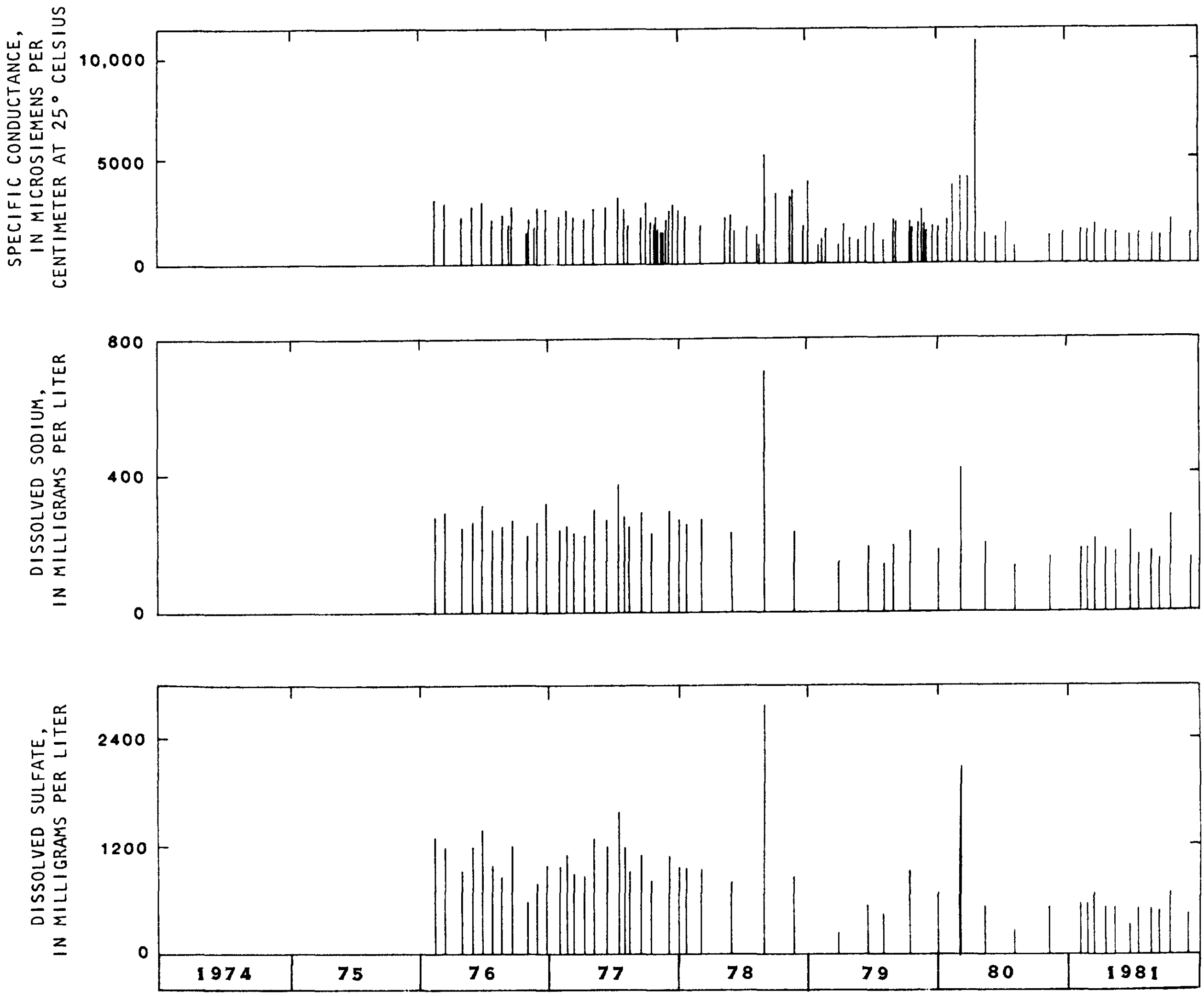


Figure 39.--Time-series plots of specific conductance and dissolved-sodium and dissolved-sulfate concentrations, October 1, 1973 - September 30, 1981, at Chaco River near Waterflow, New Mexico (station 09367950).

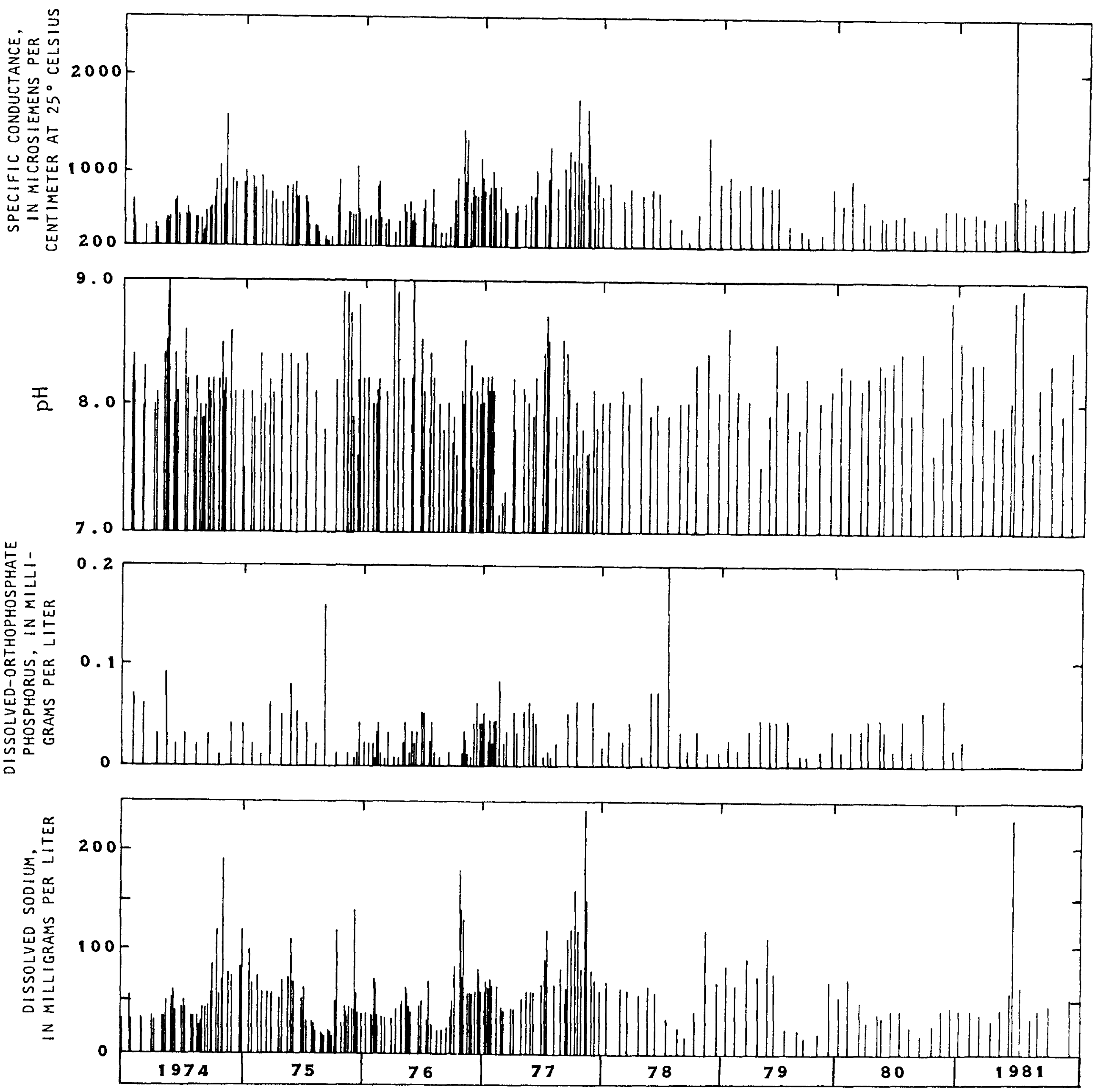


Figure 40.--Time-series plots of specific conductance, pH, and dissolved-orthophosphate phosphorus and dissolved-sodium concentrations, October 1, 1973 - September 30, 1981, at San Juan River at Shiprock, New Mexico (station 09368000).

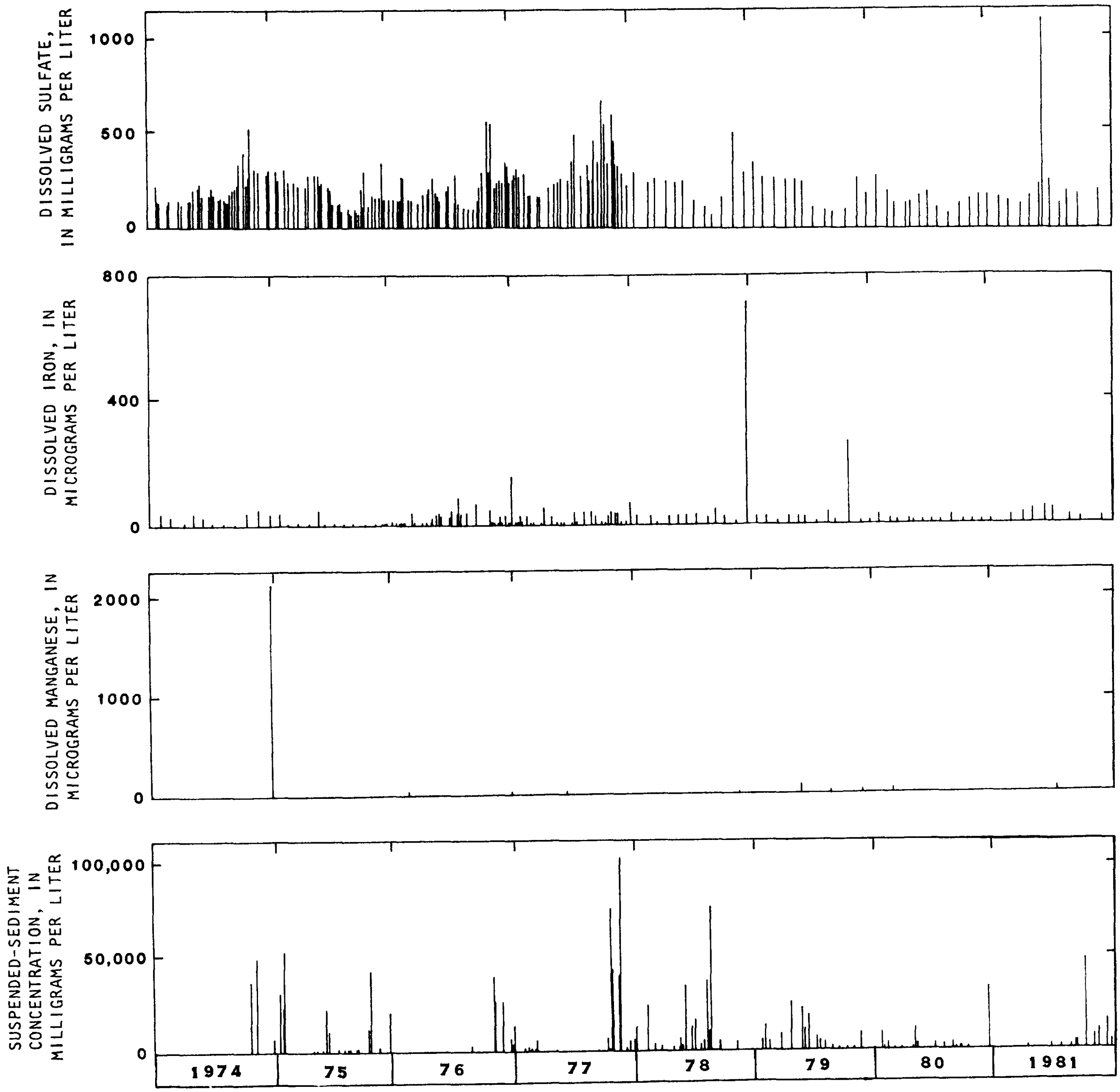


Figure 41.--Time-series plots of dissolved-sulfate, dissolved-iron, dissolved-manganese, and suspended-sediment concentrations, October 1, 1973 - September 30, 1981, at San Juan River at Shiprock, New Mexico (station 09368000).

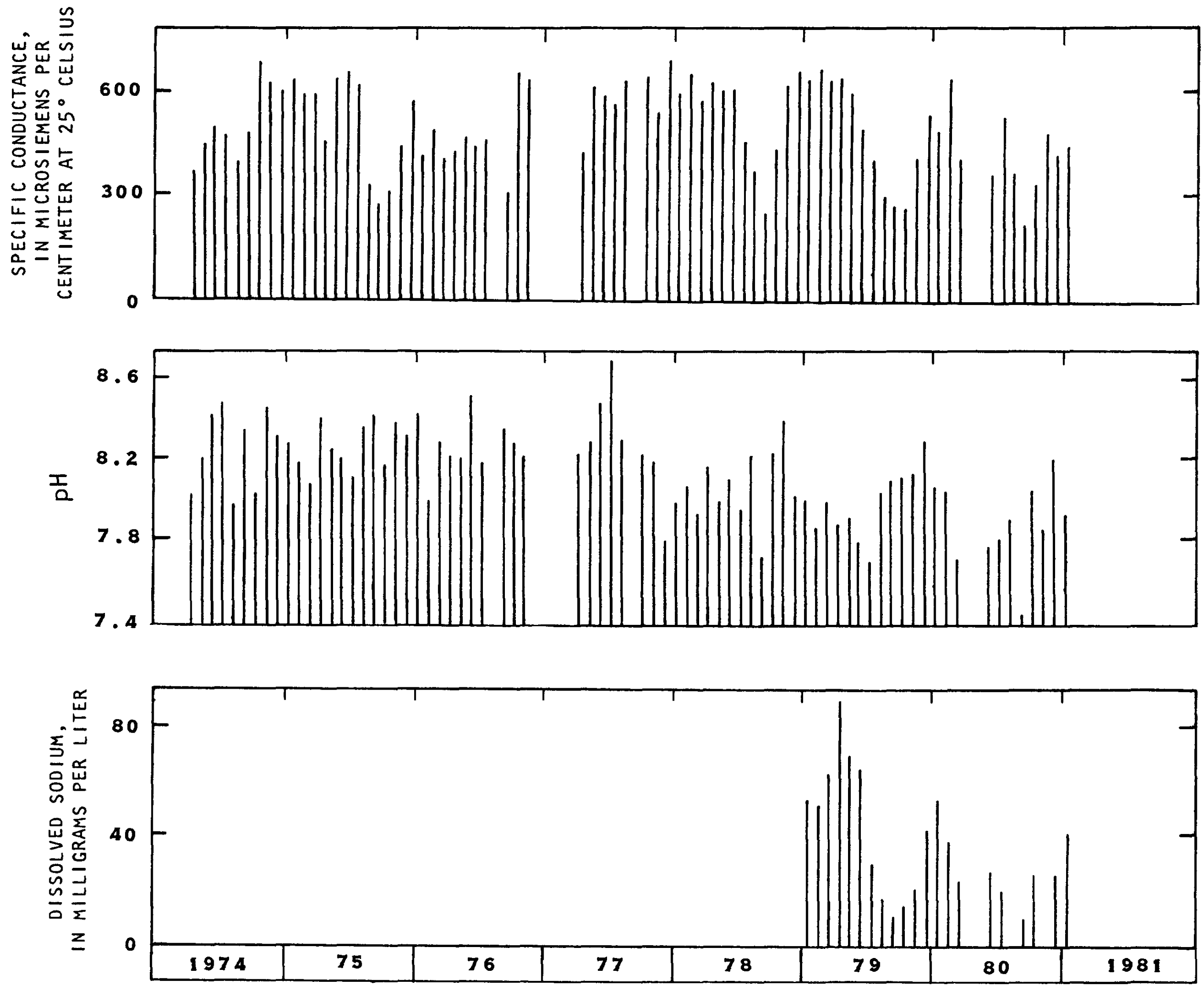


Figure 42.--Time-series plots of specific conductance, pH, and dissolved-sodium concentration, October 1, 1973 - September 30, 1981, at San Juan River intake to Morgan Lake, New Mexico (station FC1).

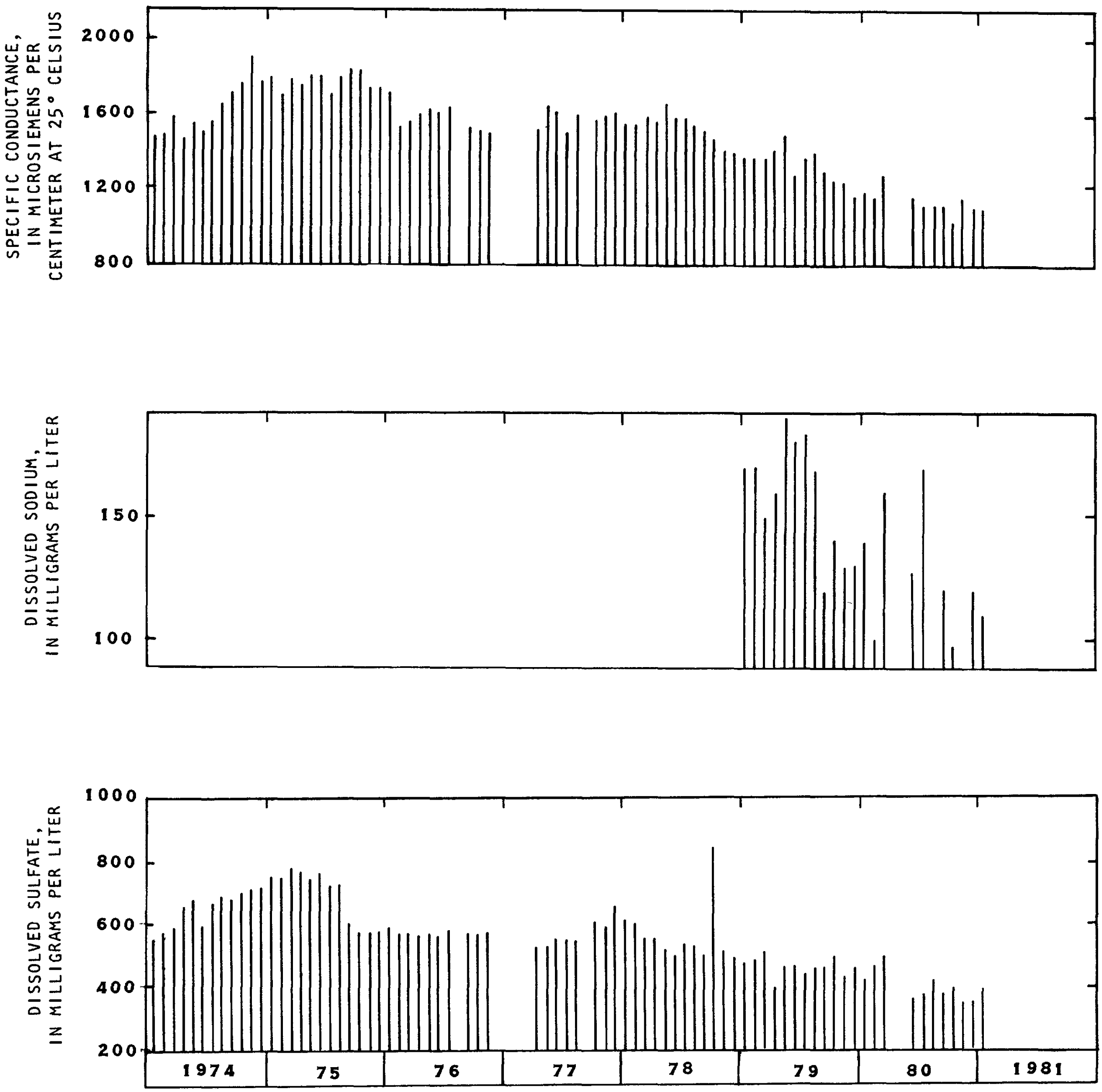


Figure 43.--Time-series plots of specific conductance and dissolved-sodium and dissolved-sulfate concentrations, October 1, 1973 - September 30, 1981, at Morgan Lake, New Mexico (station FC3).

ADEQUACY OF NASQAN DATA TO REPRESENT WATER QUALITY THROUGHOUT THE BASIN

Water quality is variable throughout the San Juan River basin from Shiprock, New Mexico, upstream. Water-quality types found within the basin include: calcium sulfate, sodium sulfate, calcium bicarbonate, and sodium bicarbonate (fig. 7). The median values of specific conductance and median concentrations of dissolved sodium, dissolved sulfate, dissolved iron, dissolved manganese, and dissolved-orthophosphate phosphorus (figs. 8-13) vary throughout the basin. The median concentration of dissolved radium-226 is fairly stable (fig. 14).

These variations are due to climate, geology, land-use, and water-use conditions. The northern part of the basin is high in altitude and mountainous. Rainfall and snowfall occur frequently and streams are perennial. Igneous, metamorphic, and sedimentary rocks outcrop here. The igneous and metamorphic rocks generally are less porous, less permeable, and more resistant to erosion. Runoff from this surface geology contains small concentrations of dissolved solids. In the southern part of the basin, altitudes are lower and the topography is dominated by mesas, hogbacks, washes, draws, canyons, badlands, and sand dunes. Rainfall and snowfall are sparse and streamflow is ephemeral. Sedimentary shales and sandstones are the predominant geologic deposits, and the land is sparsely vegetated. Runoff from this part of the basin generally contains larger concentrations of dissolved solids than runoff from the northern part of the basin.

A criterion was chosen to determine the ability of the NASQAN stations (San Juan River at Shiprock and Animas River at Farmington) to represent water quality at selected upstream stations. If the mean, median, and mode of a constituent in tables 2 through 11 were within plus or minus 25 percent of the same constituent's value at the downstream NASQAN station, then the NASQAN station was judged to be representative of the upstream station. Trends detected at the selected stations are shown in figure 44 and listed in table 16 for comparison with trends detected at the NASQAN stations. The NASQAN stations do not represent water quality at other specific points throughout the basin. No single station could represent water quality throughout this basin. The climate, geology, and land use are not uniform, and these conditions affect water-quality variation.

The NASQAN stations represent water quality at the station site. In the case of NASQAN station 09368000, San Juan River at Shiprock, New Mexico, the station represents the integration of water quality from the entire upstream basin. This integration of water quality is important. Assume that there is a persistent and large-load, water-quality change upstream; the change will also occur at the NASQAN site. The NASQAN-site water-quality analysis would signal an observer that conditions have changed somewhere in the basin upstream of the NASQAN site. The observer may want more detailed information on the change and may do some upstream sampling to determine the origin of the change.

If the upstream water-quality change was not persistent or large in load, then the NASQAN station would not accurately reflect that change. Situations in which an upstream change in water quality would not also occur at the NASQAN site would be the following: (1) The change occurring upstream is transitory in nature and has stabilized to downstream conditions within the upstream-to-downstream travel time; (2) the change occurring upstream is a one-time or infrequent occurrence and the sampling time at the downstream station does not correspond with the time when the affected water is passing by; and (3) the change occurring upstream involves a small volume of streamflow and is diluted to the point of being unnoticeable at the downstream site.

The NASQAN station's data provide accurate information on how much water quality is changing over time. The information can be used to judge whether water quality is deteriorating, remaining the same, or improving. However, this is true only for water quality at the NASQAN site. The NASQAN station cannot accurately reflect what is occurring simultaneously in the remainder of the basin. Again, it is an integration of the entire basin. When a change occurring upstream is persistent and involves a large volume of streamflow, the change also will be detected downstream at the NASQAN site.

A water-quality, streamflow model would be necessary to accurately reflect what is occurring simultaneously at any point in the entire basin. The NASQAN station's data would provide the control data needed to calibrate and verify the model's results. Stations at the mouths of all tributaries and at selected locations perhaps every 20 to 30 miles along the main stem would need to be sampled frequently during approximately a 72-hour period for different streamflow and seasonal conditions. Present sampling at the NASQAN station could be supplemented with simultaneous sampling at tributaries and selected sites along the main stem over about a 72-hour period. A different streamflow and seasonal condition needs to be selected for sampling each year.

In order to define any changes in the seasonal variation of water quality, monthly or more frequent sampling of specific conductance needs to be continued at the NASQAN stations. Quarterly to bimonthly sampling is desirable for other constituents. Water quality that has been well defined at a few stations would be preferred to water quality that has been poorly defined at many stations.

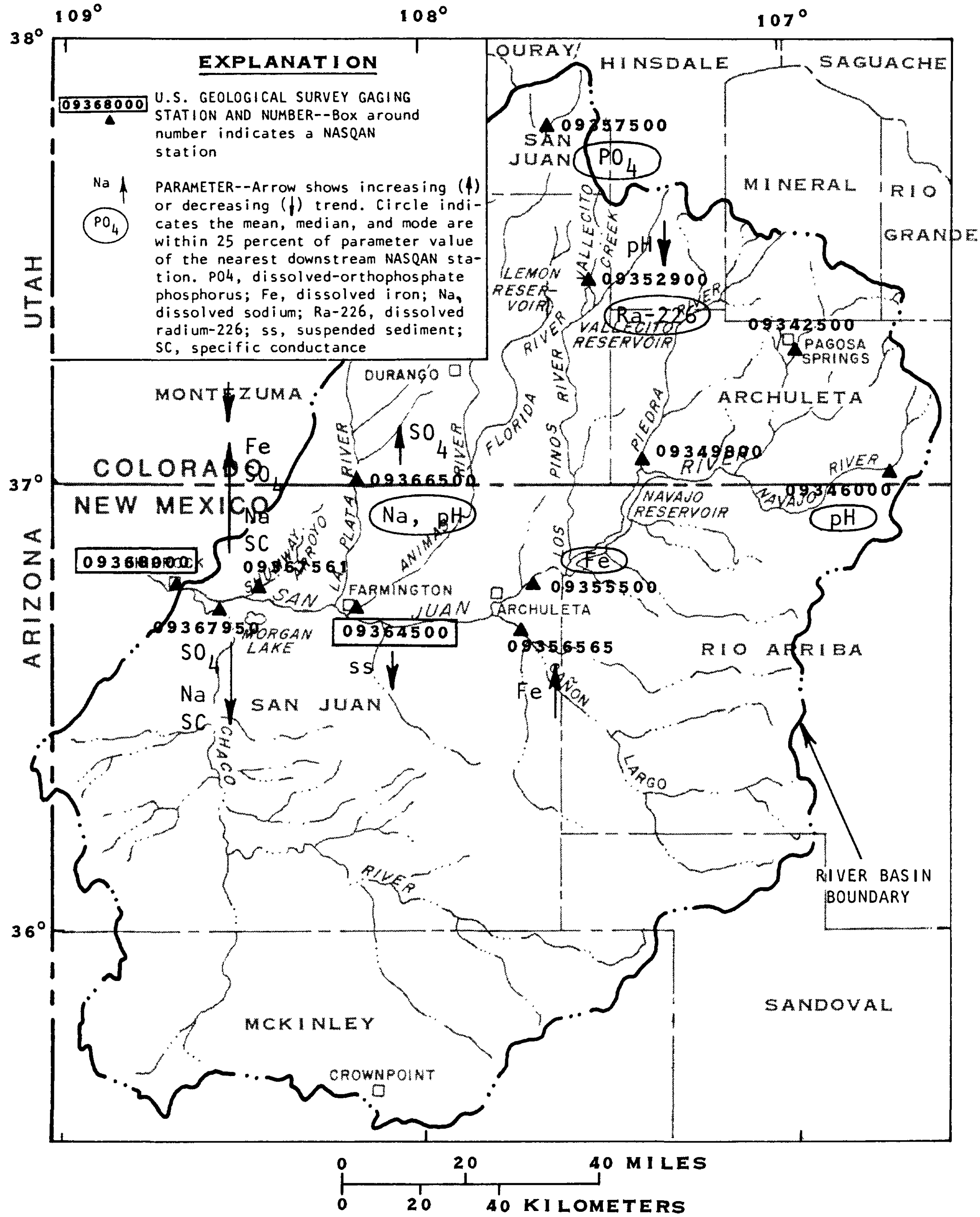


Figure 44.--Trends in water-quality parameters at selected U.S. Geological Survey stations and ability of the NASQAN stations to represent water quality at upstream stations.

Table 16. Trends detected and a criterion describing the adequacy of NASQAN stations to represent water quality at selected stations in the San Juan River basin upstream from Shiprock, New Mexico

Station number	Parameter tested	Trend detected	Mean, median, and mode of the parameter tested are within 25 percent of the parameter value at the downstream NASQAN station
09342500	Specific conductance	None	No
	Dissolved sodium	--	--
	Dissolved sulfate	--	--
	Dissolved iron	--	--
	Dissolved manganese	--	--
	Dissolved-orthophosphate phosphorus	--	--
	Dissolved radium-226	--	--
	pH	--	--
	Streamflow	None	No
	Suspended sediment	--	--
09346000	Specific conductance	None	No
	Dissolved sodium	None	No
	Dissolved sulfate	None	No
	Dissolved iron	None	No
	Dissolved manganese	--	--
	Dissolved-orthophosphate phosphorus	None	No
	Dissolved radium-226	--	--
	pH	None	Yes
	Streamflow	None	No
	Suspended sediment	None	No
09349800	Specific conductance	None	No
	Dissolved sodium	--	--
	Dissolved sulfate	--	--
	Dissolved iron	--	--
	Dissolved manganese	--	--
	Dissolved-orthophosphate phosphorus	--	--
	Dissolved radium-226	--	--
	pH	--	--
	Streamflow	None	No
	Suspended sediment	--	--

Table 16. Trends detected and a criterion describing the adequacy of NASQAN stations to represent water quality at selected stations in the San Juan River basin upstream from Shiprock, New Mexico - Continued

Station number	Parameter tested	Trend detected	Mean, median, and mode of the parameter tested are within 25 percent of the parameter value at the downstream NASQAN station
09352900	Specific conductance	None	No
	Dissolved sodium	None	No
	Dissolved sulfate	None	No
	Dissolved iron	None	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	None	No
	Dissolved radium-226	None	Yes
	pH	Decrease	No
	Streamflow	None	No
	Suspended sediment	Increase	No
09355500	Specific conductance	None	No
	Dissolved sodium	None	No
	Dissolved sulfate	None	No
	Dissolved iron	None	Yes
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	None	No
	Dissolved radium-226	None	No
	pH	None	No
	Streamflow	None	No
	Suspended sediment	None	No
09356565	Specific conductance	None	No
	Dissolved sodium	None	No
	Dissolved sulfate	None	No
	Dissolved iron	Increase	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	--	--
	Dissolved radium-226	None	No
	pH	None	No
	Streamflow	None	No
	Suspended sediment	None	No

Table 16. Trends detected and a criterion describing the adequacy of NASQAN stations to represent water quality at selected stations in the San Juan River basin upstream from Shiprock, New Mexico - Continued

Station number	Parameter tested	Trend detected	Mean, median, and mode of the parameter tested are within 25 percent of the parameter value at the downstream NASQAN station
09357500	Specific conductance	None	No
	Dissolved sodium	None	No
	Dissolved sulfate	None	No
	Dissolved iron	None	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	None	Yes
	Dissolved radium-226	--	--
	pH	None	No
	Streamflow	None	No
	Suspended sediment	None	No
09364500	Specific conductance	None	NASQAN Station
	Dissolved sodium	None	
	Dissolved sulfate	None	
	Dissolved iron	None	
	Dissolved manganese	None	
	Dissolved-orthophosphate phosphorus	None	
	Dissolved radium-226	None	
	pH	None	
	Streamflow	None	
	Suspended sediment	Decrease	
09366500	Specific conductance	None	No
	Dissolved sodium	None	Yes
	Dissolved sulfate	Increase	No
	Dissolved iron	None	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	--	--
	Dissolved radium-226	--	--
	pH	None	Yes
	Streamflow	None	No
	Suspended sediment	None	No

Table 16. Trends detected and a criterion describing the adequacy of NASQAN stations to represent water quality at selected stations in the San Juan River basin upstream from Shiprock, New Mexico - Concluded

Station number	Parameter tested	Trend detected	Mean, median, and mode of the parameter tested are within 25 percent of the parameter value at the downstream NASQAN station
09367950	Specific conductance	Decrease	No
	Dissolved sodium	Decrease	No
	Dissolved sulfate	Decrease	No
	Dissolved iron	None	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	None	No
	Dissolved radium-226	None	No
	pH	None	No
	Streamflow	None	No
	Suspended sediment	None	No
09368000	Specific conductance	None	NASQAN Station
	Dissolved sodium	None	
	Dissolved sulfate	None	
	Dissolved iron	None	
	Dissolved manganese	None	
	Dissolved-orthophosphate phosphorus	None	
	Dissolved radium-226	None	
	pH	None	
	Streamflow	None	
	Suspended sediment	None	
09367561	Specific conductance	Increase	No
	Dissolved sodium	Increase	No
	Dissolved sulfate	Increase	No
	Dissolved iron	Increase	No
	Dissolved manganese	None	No
	Dissolved-orthophosphate phosphorus	None	No
	Dissolved radium-226	None	No
	pH	Decrease	No
	Streamflow	None	No
	Suspended sediment	None	No

NEED FOR FUTURE STUDY

Topics of interest for continued study are enumerated as follows:

(1) Exploratory data analysis of sampling frequency -- For water-quality constituents collected monthly or more frequently, a monthly, bimonthly, and quarterly subset of the original data set can be used to determine annual concentrations and loads, which will provide a comparison of the influence of data-collection frequency on the determination of annual concentrations and loads.

(2) Correlation of NASQAN stations with upstream stations -- Water-quality concentrations and loads at the NASQAN stations can be plotted on one axis against upstream water-quality concentrations and loads on the other axis to determine if mathematical relations exist; if a good relation exists, even though the NASQAN station does not represent water quality at the upstream station, it could be used to predict water quality at the upstream station after the proper mathematical relation is applied.

(3) Flow-adjusted concentration-Seasonal Kendall test for trend magnitude -- Water-quality-constituent concentrations can be adjusted for flow and then tested by the Seasonal Kendall test to determine if a significant trend exists and if so, its magnitude; this result can be compared with the unadjusted trend results to determine if the flow-adjustment procedure gives different results.

SUMMARY OF RESULTS

The Accounting Unit 140801, upstream from NASQAN site 09368000, is the San Juan River drainage basin upstream from Shiprock, New Mexico. The San Juan River drainage basin upstream from Shiprock includes high mountain cobble streams in the north and ephemeral sand channels in the south. The San Juan River is the second largest tributary of the Colorado River.

Water-quality data from the U.S. Geological Survey WATSTORE files and the New Mexico Environmental Improvement Division's files were analyzed. The analyses were made to describe water-quality variability in streams on both a spatial and temporal basis; to relate water-quality variability to general causes; and to determine whether water-quality data collected at NASQAN stations, San Juan River at Shiprock (09368000) and Animas River at Farmington (09364500), are representative of water quality in the upstream drainage basin.

Streamflow (0.00 to 13,700 cubic feet per second), specific conductance (30 to 16,300 microsiemens per centimeter at 25 °Celsius), pH (2.4 to 10.4 units), dissolved-sodium concentration (0.1 to 3,700 milligrams per liter), dissolved-sulfate concentration (1.7 to 8,300 milligrams per liter), dissolved-iron concentration (0 to 21,000 micrograms per liter), dissolved-manganese concentration (0 to 8,800 micrograms per liter), and suspended-sediment concentration (0 to 966,000 milligrams per liter) are the most variable properties and constituents. Dissolved-orthophosphate phosphorus concentration (0.00 to 2.6 milligrams per liter) and dissolved-radium-226 concentration (0.02 to 0.56 picocurie per liter) are much less variable.

Most streams in the northeastern part of the basin have calcium bicarbonate waters (fig. 7 and table 12). Streams in the northwestern and southern part of the basin have calcium sulfate and sodium sulfate waters. Geology, climate, and land use affect the water quality and consequently, the water-quality classification. In those parts of the study area at high altitudes, much of the precipitation is in the form of snow. Streamflow from snowmelt runoff in this area has largely calcium bicarbonate water. Metals mining may contribute a sulfate component to streamflow in the parts of the basin where the mines are located. Irrigation-return flow likely contributes a sodium component to streamflow in some parts of the basin. Porous sandstones and interbedded shales in the southern part of the basin yield runoff with large dissolved-solids concentration. The San Juan River at Shiprock, NASQAN station 09368000, shows a water-quality classification resulting from integration of the many tributaries feeding the San Juan River. Streamflow at this station contains a calcium sulfate water 53 percent of the time and a calcium sodium sulfate water 27 percent of the time. The station does not reflect the variety of water-quality classifications at upstream tributaries or the water-quality classification existing at upstream tributaries for a chosen point in time. However, it does represent the integration of upstream waters and the outflow to downstream sites.

Median concentrations of water-quality constituents plotted at selected stations throughout the basin (figs. 8-14) show a range for specific conductance of 50 to 6,570 microsiemens per centimeter; dissolved sodium, 1.1 to 1,300 milligrams per liter; dissolved sulfate, 4.3 to 3,800 milligrams per liter; dissolved iron, less than 10 to 410 micrograms per liter; dissolved manganese, less than 10 to 430 micrograms per liter; dissolved-orthophosphate phosphorus, less than 0.01 to .08 milligram per liter; dissolved radium-226, .06 to .10 picocurie per liter. Specific-conductance, sodium, and sulfate variation is similar throughout the basin. The smallest values are reported from stations in the northeastern mountainous areas where snowmelt contributes largely to streamflow. Largest values are located downstream from power-generation facilities. Other fairly large values in the southern part of the basin are influenced by the ground-water-flow component of the streamflow. Irrigation-return flow increases values in the central part of the basin. Dissolved-iron concentration is greatest in the southern part of the basin and may be due in part to dissolution of iron minerals from soils and rocks in that area. Some large concentrations of dissolved manganese are associated with the metals-mining area in the northern tip of the basin. Dissolved-orthophosphate phosphorus and radium-226 concentrations appear to be fairly uniform throughout the basin.

The product of specific conductance and streamflow (fig. 15) indicates that samples taken monthly or less frequently may result in an overestimation of loads. About one-third of the specific-conductance-streamflow product calculated for the drainage basin originates upstream of Archuleta, which is 25 percent of the total basin area; one-third originates in the Animas River basin, which is 10.5 percent of the total basin area; one-eighth originates from the Cañon Largo and La Plata and Chaco River basins, which are 51.5 percent of the total basin area; and about one-fifth cannot be accounted for and is assumed to originate from small ungaged drainages or to flow to the main stem as unidentified sources between the gaging stations at Archuleta and Shiprock (table 13).

Based on box-and-whisker plots, streamflow has the greatest number of far-out values at individual stations. From station to station, streamflow is also highly variable and influences water-quality constituents through dilution. Dissolved-iron and suspended-sediment concentrations are the water-quality constituents with the largest number of far-out values. The central values for dissolved iron are fairly uniform from station to station within the basin. Suspended sediment is much more variable among stations. Dissolved radium-226 is the constituent with the least number of far-out and outside values. It also does not vary greatly from station to station. Specific conductance, pH, dissolved-orthophosphate phosphorus, dissolved sodium, dissolved sulfate, and dissolved manganese fall somewhere between in variability at a single station. Central values of specific conductance and sulfate are the most variable from station to station of this group of properties and constituents.

The wastewater from one of the power-generation facilities in the drainage basin has the greatest water-quality variability of all stations for most constituents. It also contributes the largest concentrations of these constituents to the stream system. Small quantities of flow from the Cañon Largo tributary (station 09356565) add large concentrations of dissolved sodium, dissolved sulfate, dissolved manganese, and suspended sediment to the stream system. This tributary also contributes water with large specific conductance to the stream system.

The small to ephemeral flows at stations in the southern part of the drainage basin have the most variable water quality and commonly have large constituent concentrations. These stations have little influence on water quality in the San Juan River main stem, but they are representative of conditions in the southern part of the basin. The two NASQAN stations have large volumes of streamflow and generally are among the lowest in variability within the study area.

A trend in water quality was detected at 14 out of 36 stations tested (table 15). The time period for trend testing was October 1, 1973, through September 30, 1981. Of those 14 stations, 5 are downstream from point-source discharges from power-generation facilities. Water-quality measurements taken at these stations may be reflecting changes in coal- or power-production rates over the years and changes in water-discharge practices. At other stations in the study area, one showed an increase in suspended sediment, one a decrease in suspended sediment, one an increase in dissolved iron, one a decrease in dissolved iron, three a decrease in pH, one an increase in dissolved-orthophosphate phosphorus, one an increase in dissolved sulfate, and one a decrease in specific conductance and dissolved sodium. At the upstream NASQAN station, Animas River at Farmington, a decrease in suspended-sediment concentration of 78 milligrams per liter per year was detected. At the downstream NASQAN station, San Juan River at Shiprock, no trends were detected. At the stations upstream from San Juan River at Shiprock, there were both increasing and decreasing trends for several constituents, which might cancel each other. The most consistent trend in the basin was the decrease in pH at six stations, three of which are downstream from coal-mine and power-generation activities.

Hydrographs commonly showed seasonal variation in water quality (figs. 33-43). At stations 09367950, FC1, and FC3, monotonic trends are apparent. These stations are associated with point-source discharges of wastewater and represent changes in the wastewater rather than in the natural streamflow. At station 09357100 a step decrease in specific conductance occurred between October 1, 1978, and October 1, 1979 (fig. 34). The hydrographs at the two NASQAN stations, San Juan River at Shiprock and Animas River at Farmington, show correspondence, particularly for periods of small concentrations, for the property of specific conductance and constituents of dissolved sodium and dissolved sulfate.

Water quality is variable throughout the San Juan River basin upstream from Shiprock, New Mexico, due to climatic, geologic, land-use and water-use conditions within the study area. The NASQAN stations represent water quality at the station site, not what is occurring simultaneously elsewhere in the basin. The NASQAN stations have large volumes of flow, which represents an integration of the flow from many upstream tributaries.

The NASQAN data provide accurate information on how water quality is changing over time. If a change occurring upstream is persistent and involves a large volume of streamflow, it likely will also be detected at the downstream NASQAN station. A water-quality, streamflow model would be necessary to accurately reflect what is simultaneously occurring in the entire basin. Present sampling at the NASQAN stations could be supplemented with simultaneous sampling over the upstream drainage basin that would be suitable for input into a model.

Sample frequency needs to be maintained in order to preserve definition of the seasonal variation. Water quality that has been well defined at a few stations would be preferred to water quality that has been poorly defined at many stations.

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