WATER-QUALITY DATA FROM THE SAN JUAN AND CHACO RIVERS AND SELECTED ALLUVIAL AQUIFERS, SAN JUAN COUNTY, NEW MEXICO

By Condé R. Thorn

U.S. GEOLOGICAL SURVEY

Open-File Report 93-84

Prepared in cooperation with the

U.S. BUREAU OF RECLAMATION

Albuquerque, New Mexico

1993

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Multiply	By	To obtain
acre	0.004047	square kilometer
cubic foot per second	28.32	liter per second
mile	1.609	kilometer
ton per day	0.0105	kilogram per second

Temperatures can be converted by the equations:

$$°F = (1.8 \times °C) + 32$$

$$°C = (°F - 32)/1.8$$

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ABSTRACT

As a result of the Federal Water Pollution Control Act Amendments of October 1972 (Public Law 92-500), as amended by the Clean Water Act of 1977 (Public Law 95-217) and the Colorado River Basin Salinity Control Act of June 24, 1974 (Public Law 93-320, as amended by Public Law 98-569 on October 30, 1984), an effort has been made to locate areas of salt loading in the Colorado River Basin. This report presents the results of analyses of surface- and ground-water samples collected along the San Juan and Chaco Rivers, San Juan County, New Mexico. Data presented in this report were collected during five sampling efforts beginning in June 1990 and ending in February 1991. This report includes tabulated water-chemistry data; summary statistics; graphs showing daily loads of dissolved solids, chloride, and bromide; and plots showing bromide to chloride ratios. Ground-water data also are included in this report that were collected from three observation wells drilled by the U.S. Geological Survey in 1969, and surface- and ground-water data that were collected by the U.S. Geological Survey and the U.S. Bureau of Reclamation in December 1987.

INTRODUCTION

Salinity control studies on the San Juan River Unit, a part of the Colorado River Water Quality Improvement Program, were authorized as part of the Federal Water Pollution Control Act Amendments of October 1972 (Public Law 92-500), as amended by the Clean Water Act of 1977 (Public Law 95-217) and the Colorado River Basin Salinity Control Act of June 24, 1974 (Public Law 93-320, as amended by Public Law 98-569 on October 30, 1984). Title II of the Salinity Control Act was directed toward salinity control of the Colorado River in the United States upstream from Imperial Dam (on the Arizona-California State line). The Salinity Control Act of 1974 originally authorized the unit for study as part of a basinwide program to enhance and protect the quality of water in the Colorado River for use in the United States (U.S. Bureau of Reclamation, written commun., 1992).

A reconnaissance conducted in 1986 by the U.S. Bureau of Reclamation (BOR) and a synoptic (4-day) sampling effort conducted by the U.S. Geological Survey (USGS) in 1987 along the San Juan and Chaco Rivers in northwestern New Mexico resulted in data that the BOR believes were substantial enough to justify additional sampling. In June 1990, the USGS initiated a sampling program along the San Juan and Chaco Rivers. Surface- and ground-water samples were collected during five sampling periods from June 1990 to February 1991 and analyzed for major ions, selected trace elements, and stable isotopes of sulfur. The intention of this data-collection effort was to gain an understanding of possible salinity contribution to the San Juan River from deep formation waters or from oil-field brines. This report discusses the results of the data-collection effort.

Study Area

The study area is located along the San Juan and Chaco Rivers in San Juan County, northwestern New Mexico (fig. 1). The study area includes the approximate 46-mile reach of the San Juan River, from near Farmington, New Mexico, to about 20 miles downstream from Shiprock, New Mexico; and the reach of the Chaco River from its mouth at the San Juan River upstream for about 25 miles (figs. 1 and 2). There is irrigation on the flood plain and adjacent terraces along most of this reach of the San Juan River and along the La Plata and Animas Rivers, two major tributaries of the San Juan River. About 50,000 acres are also irrigated south of the San Juan River, along Ojo Amarillo and Gallegos Canyons (fig. 1).

The study area contains sedimentary rocks consisting of sandstones, siltstones, shales, and conglomerates of Cretaceous age. An east-facing, northeast-trending, east-dipping Hogback monocline is the main geologic structure in the study area. The west-flowing San Juan River and the north-flowing Chaco River cut through this structure, creating steeply dipping exposures of rocks of the Mesaverde Group. Sand, gravel, and caliche forming pediment and terrace deposits are found along the San Juan River from Farmington to just downstream from Shiprock. The La Plata and Animas Rivers flow south into the San Juan River near the eastern side of the study area. The remainder of the study area is flat to gently rolling grasslands moderately dissected by arroyos.

Energy-resource production activities are the major economic resource in San Juan County. These activities include oil and gas production, gas processing, coal mining, oil refining, and electric-power generating (fig. 3).

Sampling Methods

Data for the calculation of stream discharge were measured with a pygmy current meter, and depth-integrated surface-water samples were collected using a DH-75 sampler. Streamflow-data and water-sample collection efforts were made in accordance with USGS standards as outlined in Carter and Davidian (1968) and Edwards and Glysson (1988). For streams that had shallow depths and velocities too low for a current meter, a portable Parshall flume was used to obtain a discharge measurement (Kilpatrick and Schneider, 1983); a water sample was obtained by hand dipping a sample bottle into the stream several times until the required volume was accumulated. Ground-water samples were collected from shallow wells completed in alluvium. Three casing volumes of water were removed from wells prior to sample collection. Field procedures used in the collection and processing of ground-water samples are outlined in Wood (1981).

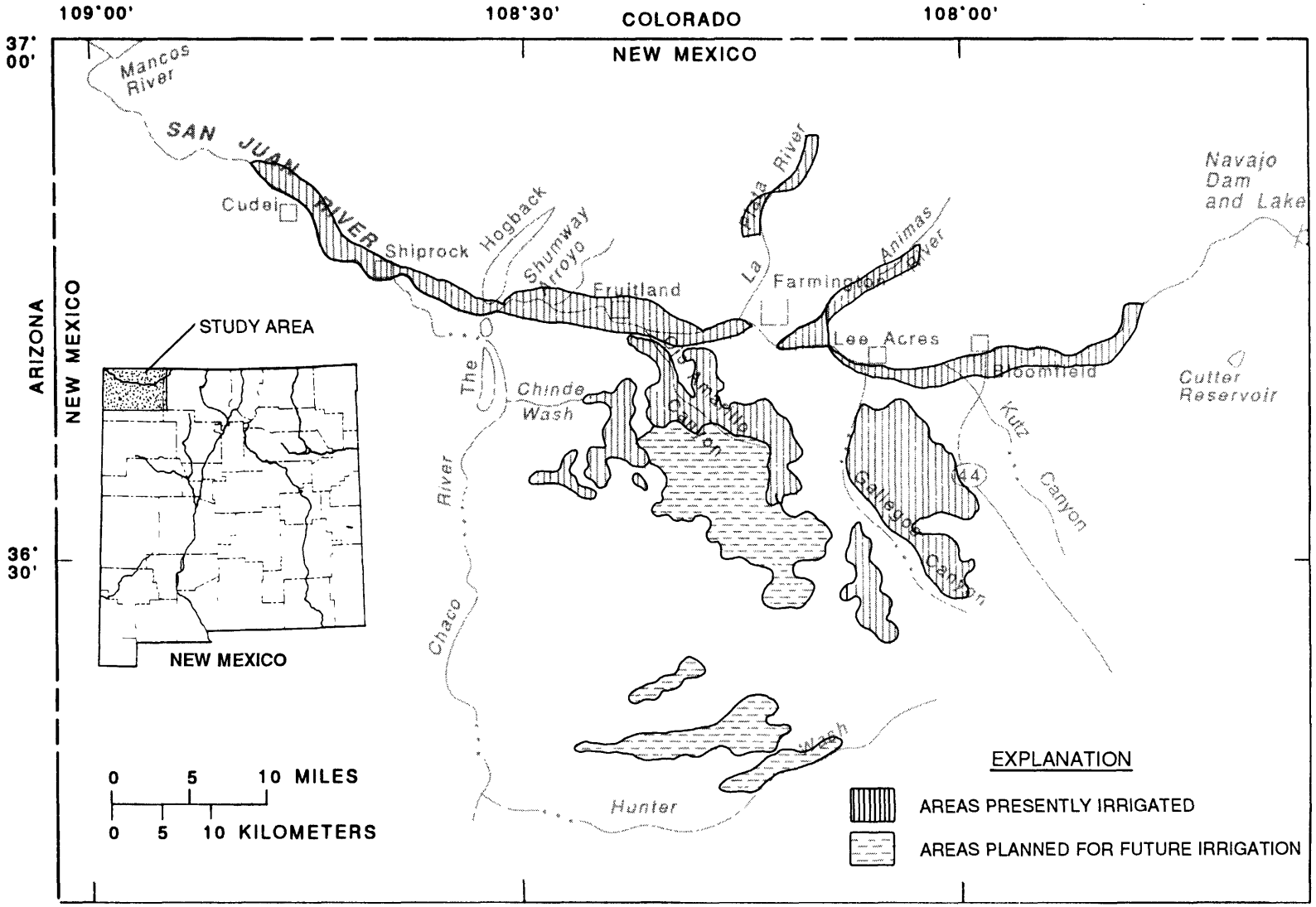

Figure 1.--Location of study area and approximate location of irrigation projects, San Juan County, New Mexico (modified from P. J. Blanchard, U.S. Geological Survey, written commun., 1991).

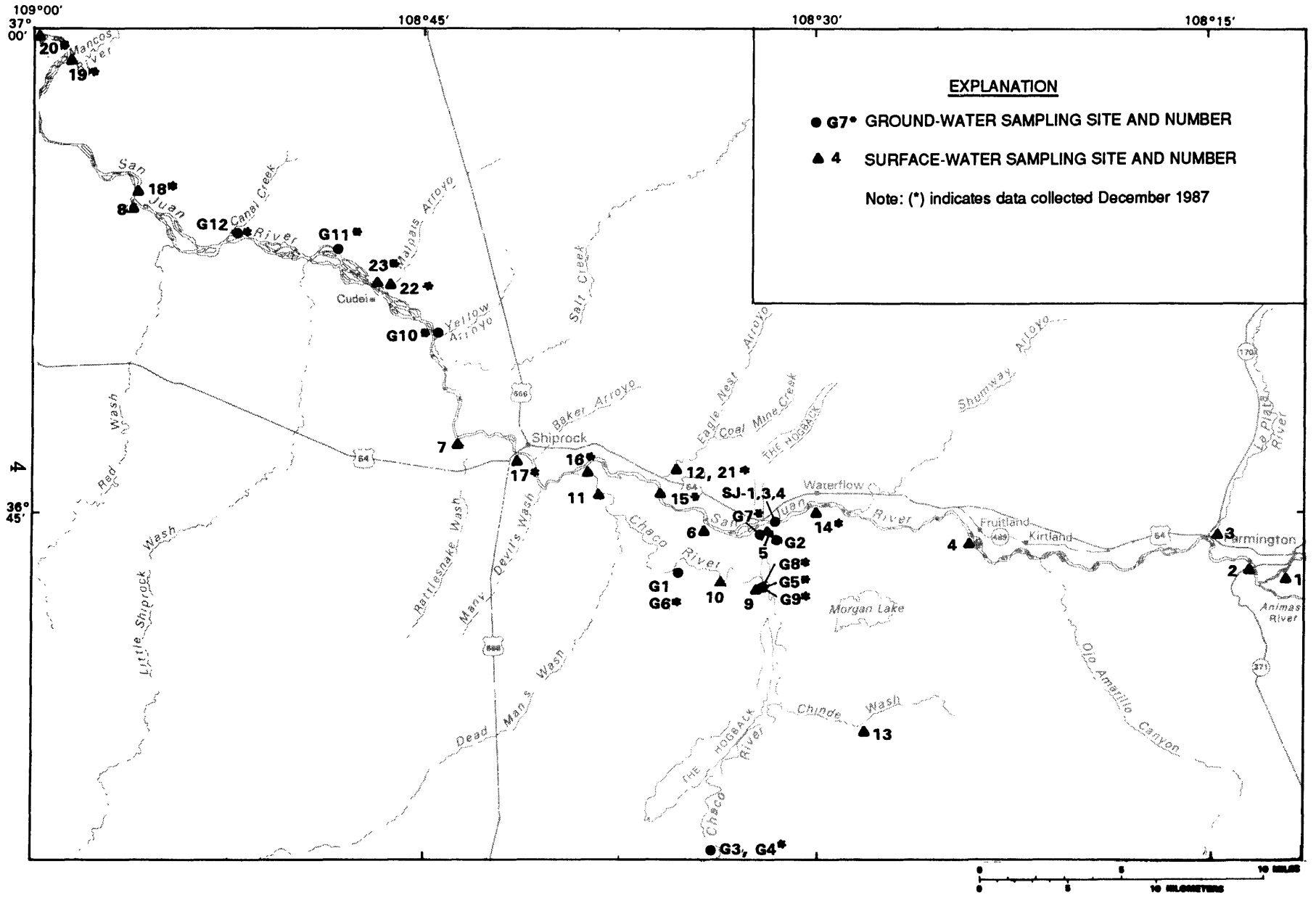

Figure 2.--Location of surface-water and ground-water sampling sites, San Juan County, New Mexico.

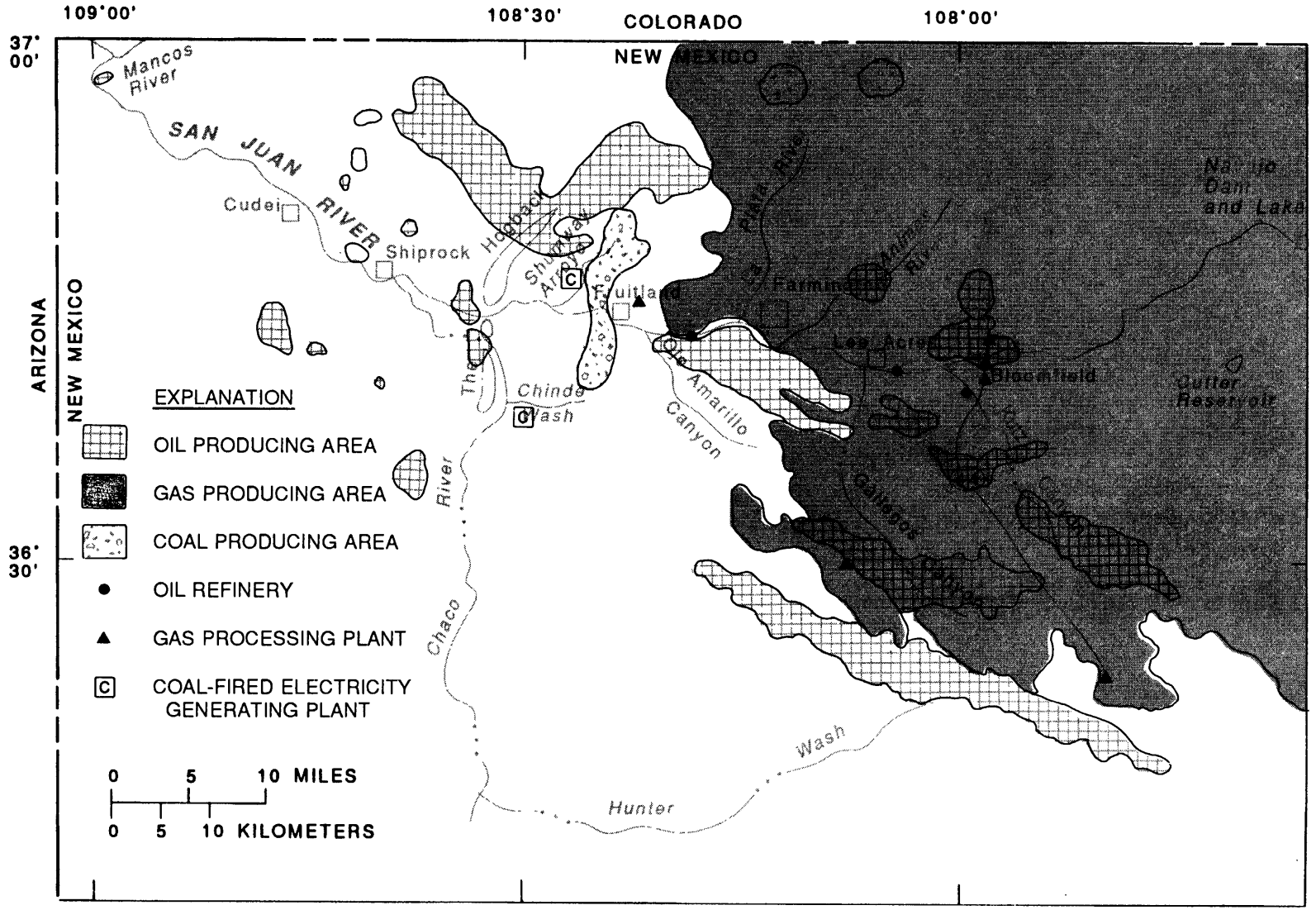

Figure 3.--Location of energy resource areas and production activities, San Juan County, New Mexico (modified from P. J. Blanchard, U.S. Geological Survey, written commun., 1991).

DISCUSSION OF RESULTS

Five sets of samples were collected from June 1990 to February 1991 from 13 surface-water and 3 ground-water sampling sites. The results of all sampling efforts for this study are shown in tables 1 and 2 (tables are all located in the back of the report). Ground-water data from three observation wells that were drilled and sampled in 1969 are also presented in table 2. Surface- and ground-water data from a 4-day synoptic sampling effort conducted in 1987 are shown in table 3.

Most of the reach sampled along the San Juan River is influenced by irrigation. Therefore, complex discharge variations in the San Juan River caused by irrigation withdrawals and returns can have a major effect on the loads carried in the San Juan River. Tributary inputs, particularly those due to intense, localized thunderstorms common to the study area, can also cause large variations in loads in the San Juan River. No correction has been applied to the data to account for the irrigation withdrawals and returns or for tributary input to the San Juan River.

This data-collection effort was intended to define areas that may have been contributing salinity to the San Juan River. Therefore, concentrations of chloride and bromide were analyzed because of their conservative behavior in natural waters and possible indicator of oil-field brines. For further information regarding chloride and bromide as tracers in natural waters the reader is referred to Whittemore (1988).

Daily loads of dissolved solids, chloride, and bromide are shown in figures 4 through 8. These loads were computed by multiplying discharge (in cubic feet per second) by concentration (in milligrams per liter), then multiplying by a conversion factor of 0.002697 to obtain the unit of tons per day. The load computed from the discharge, measured at the time of water-sample collection, is assumed to be representative of the daily load traveling past the sampling site for that day. For example, the chloride concentration in the San Juan River at Farmington in a sample collected at 1730 hours on August 6, 1990, was 9.2 milligrams per liter; the discharge measured for that same day and time was 369 cubic feet per second (table 1). The computed load of chloride for that day was 9.2 tons as shown in figure 5.

Streamflow and dissolved-solids loads for water samples collected from the La Plata River varied widely between sampling periods; those for the Chaco River had smaller variation (fig. 4). Dissolved-solids loads in the San Juan River display variation both in a downstream direction and between periods sampled at a given site. Figures 5 and 6 show the correlation between streamflow and loads of chloride and bromide, respectively, for samples collected along the San Juan River. Loads of chloride and bromide in the Chaco River are shown in figures 7 and 8. A slight variation exists between the sampling sites and periods of sampling on the Chaco River, except in February 1991. In February 1991, streamflow and loads of chloride and bromide were larger at the Chaco River above mouth (site 11) than at the two upstream sites (sites 9 and 10).

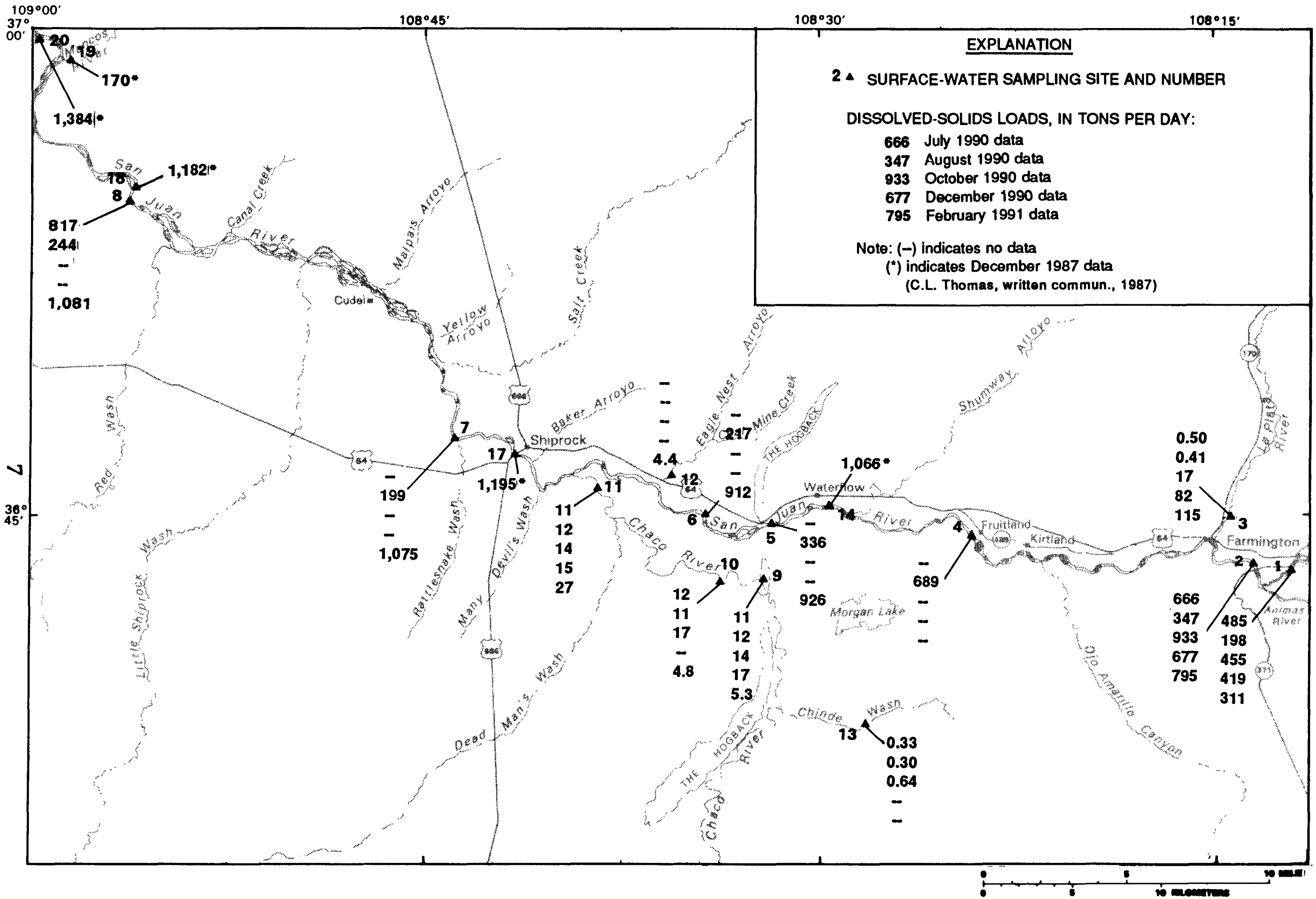

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Figure 4.--Dissolved-solids loads, in tons per day, at surface-water sampling sites, San Juan County, New Mexico.

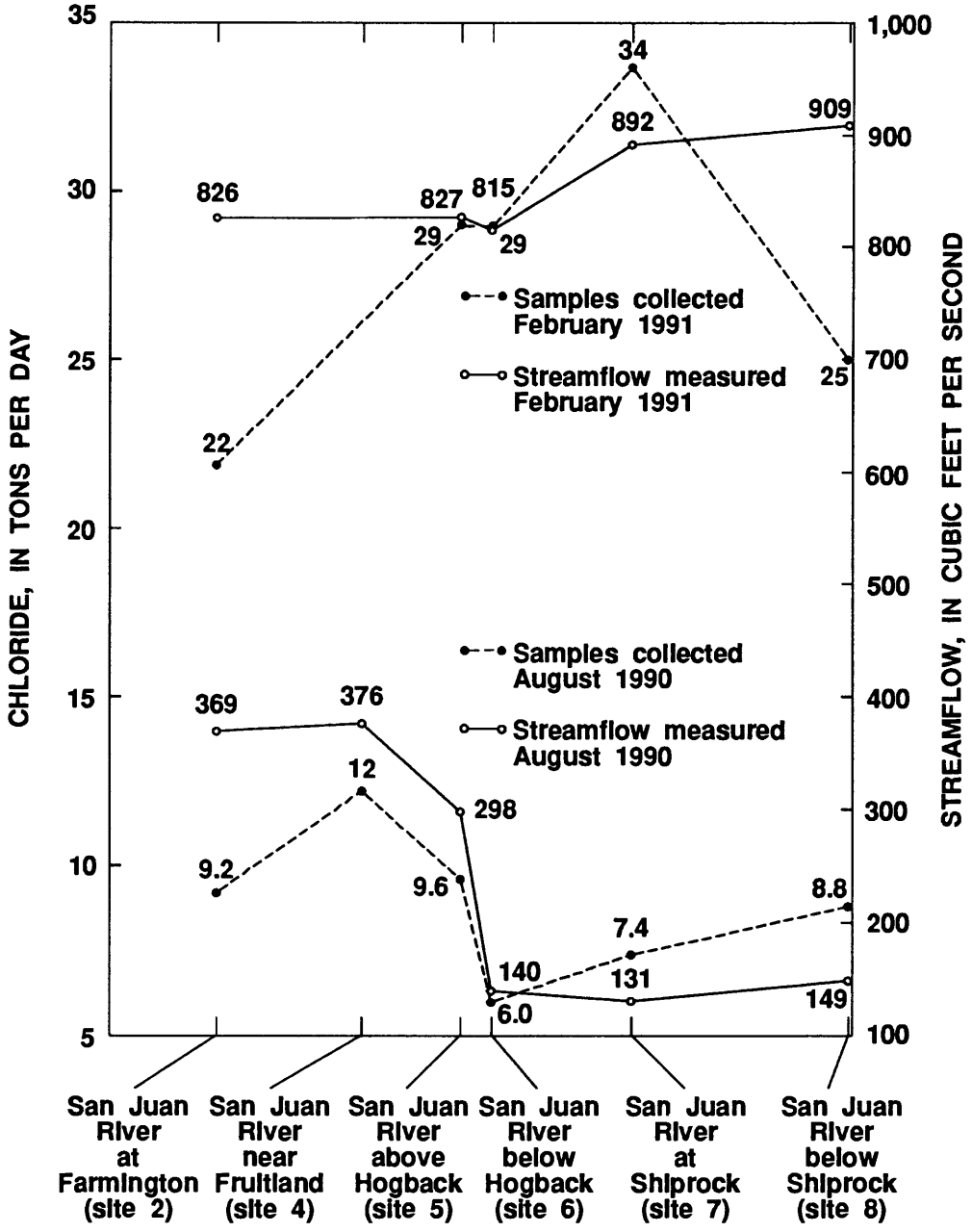

Figure 5.--Daily loads of chloride in the San Juan River, San Juan County, New Mexico.

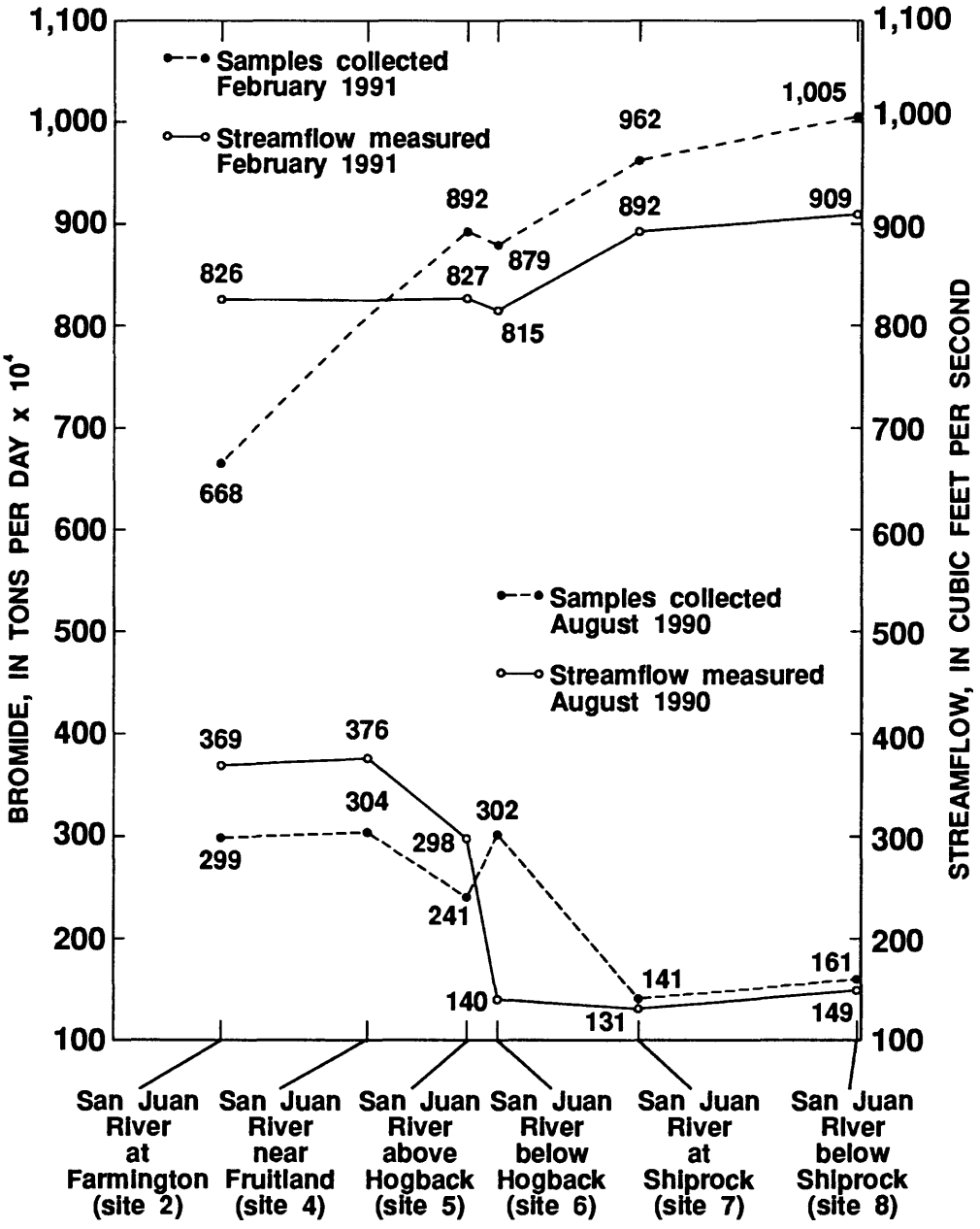

Figure 6.--Daily loads of bromide in the San Juan River, San Juan County, New Mexico.

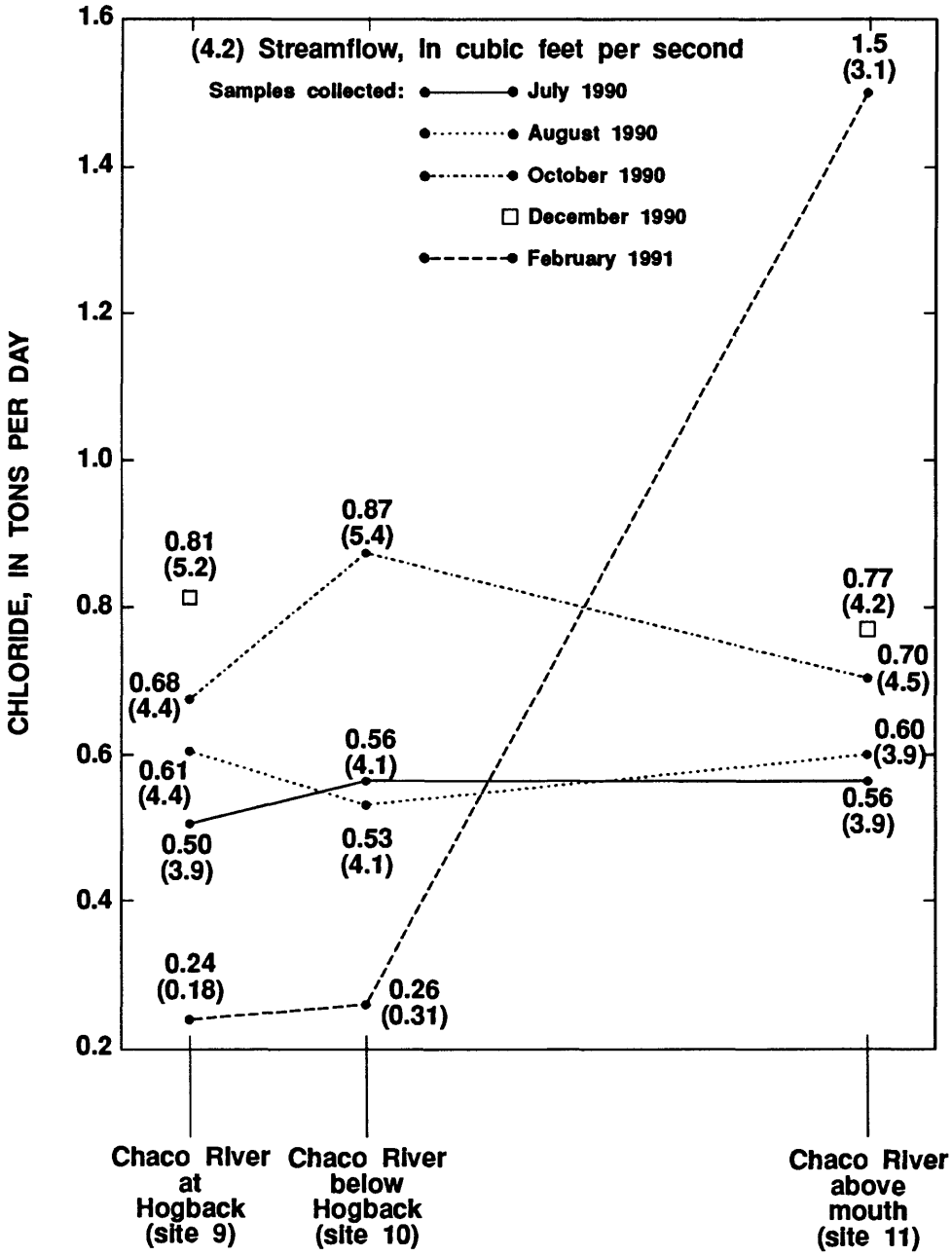

Figure 7.--Daily loads of chloride in the Chaco River, San Juan County, New Mexico.

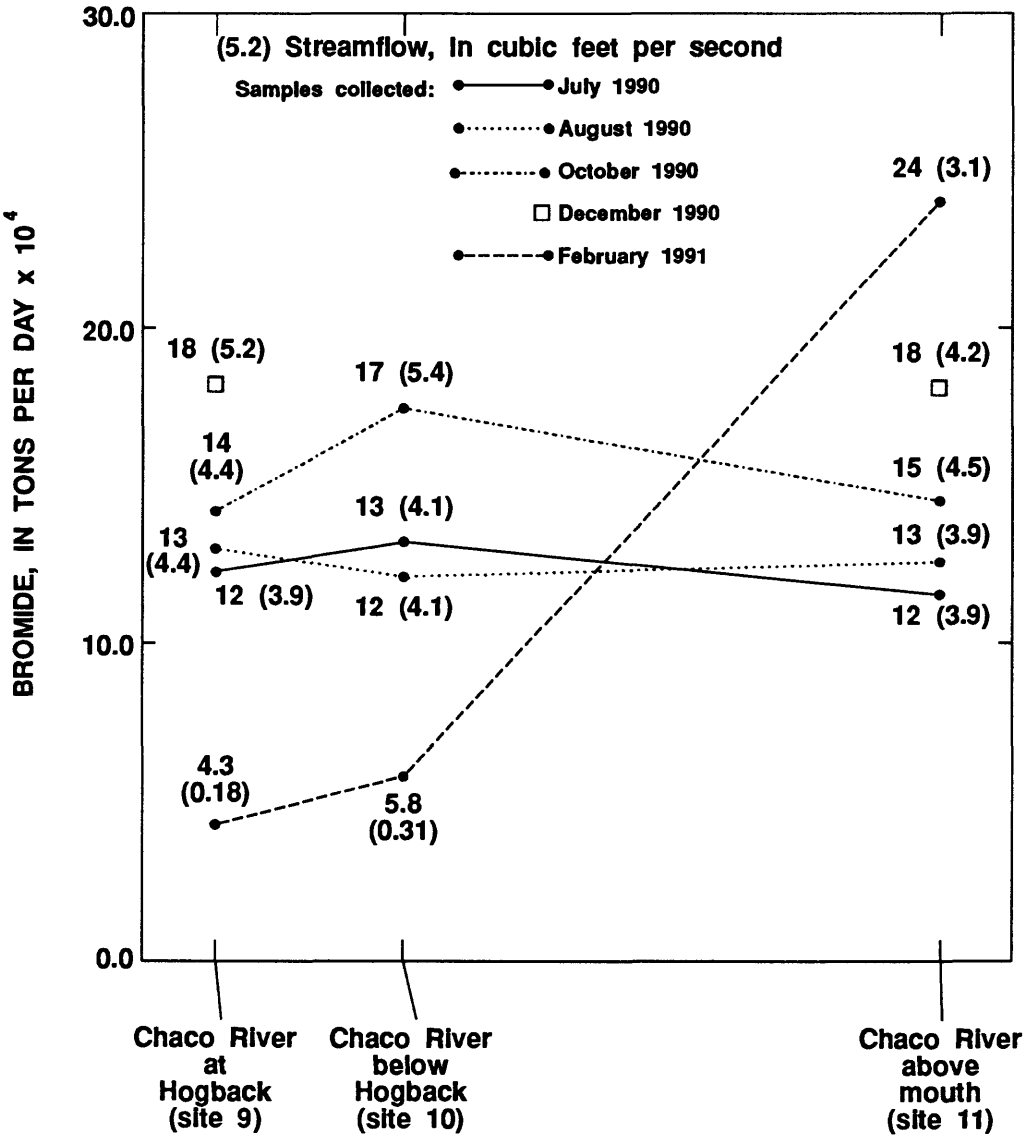

Figure 8.--Daily loads of bromide in the Chaco River, San Juan County, New Mexico.

Statistical summaries of concentrations of selected water-quality constituents are shown in table 4. The number of samples and minimum, maximum, and median concentrations are shown for samples collected from June 1990 to February 1991. The differences between the minimum and maximum concentrations in surface-water samples collected from the San Juan River are smaller than in those collected from the Chaco River.

The relation between the ratio of bromide to chloride concentrations and chloride concentrations for samples collected from June 1990 to February 1991 is shown in figure 9. The relation between the ratio of bromide to chloride concentrations and chloride concentrations for samples collected in 1987 is shown in figure 10. Both surface- and ground-water samples plot in the same general area, indicating no substantial difference in the bromide to chloride ratios in surface-water and ground-water samples collected from June 1990 to February 1991. However, the data in figure 10, compared with those in figure 9, indicate a similar range of the ratio of bromide to chloride concentrations but a larger range in chloride concentration.

Chemical-constituent diagrams for water samples collected in August 1990 and January and February 1991 are shown in figures 11 and 12. For each site the chemical-constituent diagrams shown in figures 11 and 12 are similar in shape; this indicates that water types at a given site were similar in August 1990 and in January or February 1991. Additional chemical analyses of surface- and ground-water samples collected in December 1987 are presented in figure 13.

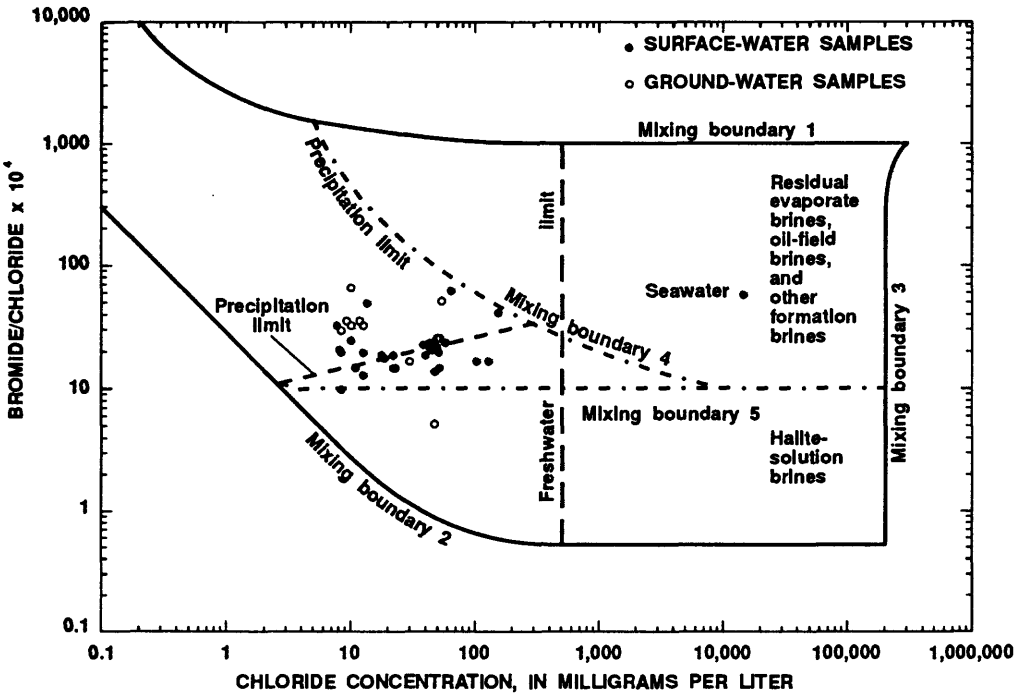

Figure 9.--Relation between the ratio of bromide to chloride concentrations and chloride concentrations for surface-water and ground-water samples collected from June 1990 to February 1991, San Juan County, New Mexico (modified from Whittemore, 1988).

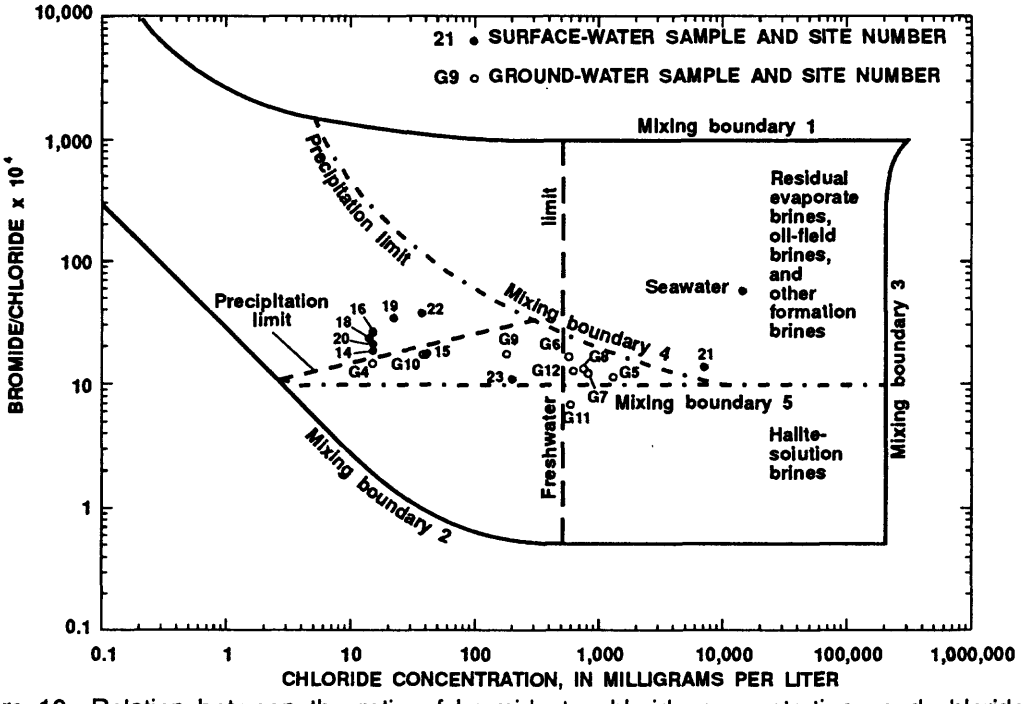

Figure 10.--Relation between the ratio of bromide to chloride concentrations and chloride concentrations for surface-water and ground-water samples collected in December 1987, San Juan County, New Mexico (from C.L. Thomas, U.S. Geological Survey, written commun., 1987). Location of sites is shown in figure 2.

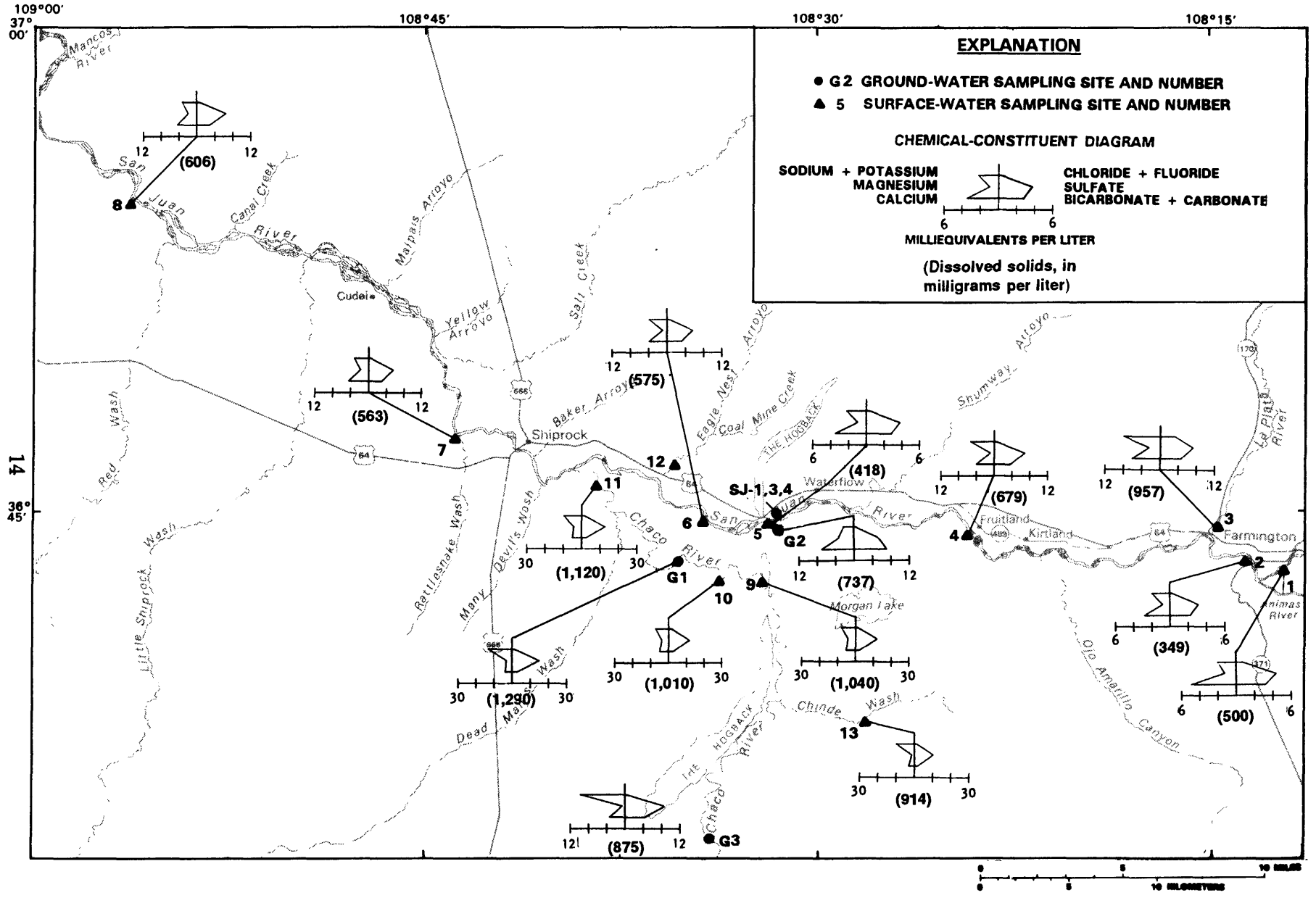

Figure 11.--Chemical constituent diagrams of surface-water and ground-water samples collected in August 1990 from the San Juan River basin.

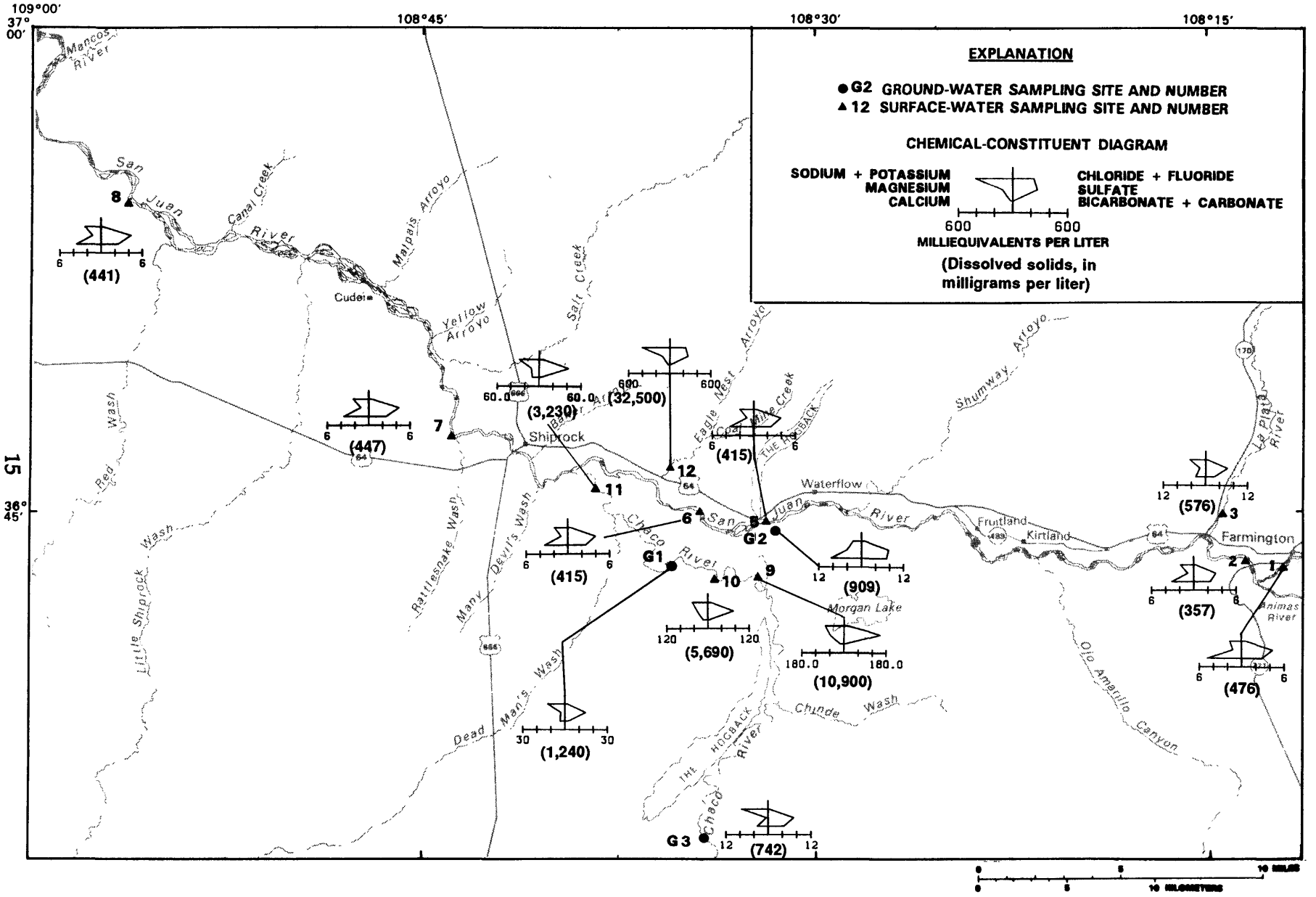

Figure 12.--Chemical constituent diagrams of surface-water and ground-water samples collected in January and February 1991 from the San Juan River basin.

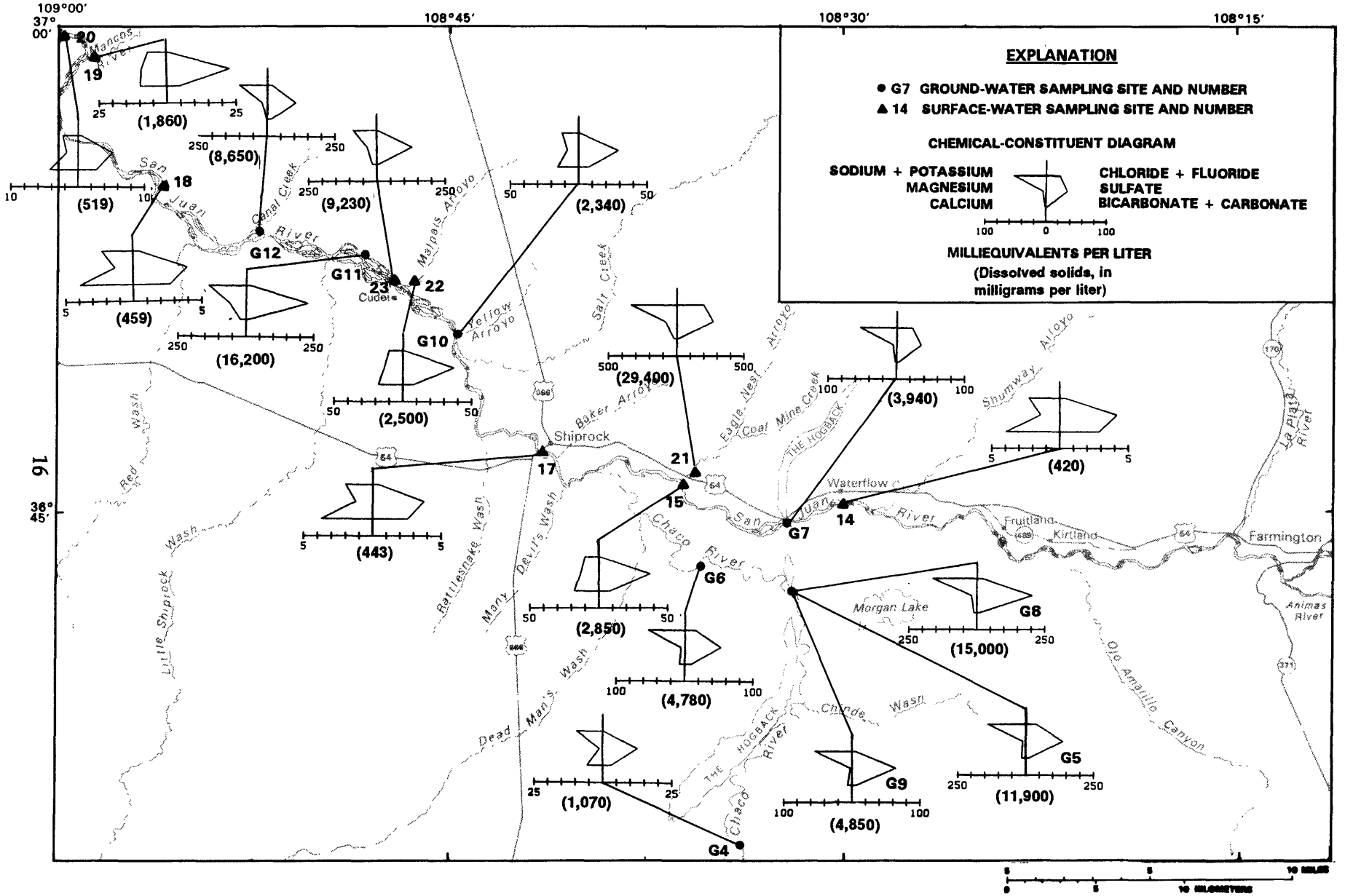

Figure 13.--Chemical-constituent diagrams of surface-water and ground-water samples collected in December 1987 from the San Juan River basin (C.L. Thomas, written commun., 1987).

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Whittemore, D.O., 1988, Bromide as a tracer in ground-water studies--Geochemistry and analytical determination: Proceedings of Ground Water Geochemistry Conference, Denver, Colo., National Water Well Association, Dublin, Ohio, p. 339-360.

Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: Techniques of Water-Resources Investigations of the U.S. Geological Survey, book 1, chap. D2, 24 p.

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991

[Site numbers are plotted in figures 2, 4, and 11-13; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; *, analysis from filtered (dissolved) samples; µg/L, micrograms per liter; 0/00, per mil; --, no data; <, less than]

Site number	Site name and identification number	Date sampled	Time	Discharge (ft^3/s)	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Calcium (mg/L)*	Magnesium (mg/L)*	Sodium (mg/L)*	Potassium (mg/L)*
1	Animas River at Farmington	07-05-90	1200	673	400	8.3	22.0	58	7.9	19	2.2
	09364500	08-06-90	1500	147	720	8.5	26.0	98	15	43	3.2
		10-15-90	1530	557	460	8.6	13.5	66	9.6	22	2.1
		12-18-90	1315	358	600	9.5	0.0	92	14	34	3.0
		02-04-91	1400	242	650	8.8	3.5	97	15	36	3.3
2	San Juan River at Farmington	07-05-90	1500	852	480	8.3	23.0	58	8.4	28	2.2
	09365000	08-06-90	1730	369	500	8.0	24.0	56	9.0	43	2.4
		10-15-90	1700	1,120	450	8.5	12.5	55	8.5	29	2.2
		12-18-90	1630	747	450	9.0	1.0	59	9.7	35	2.3
		02-04-91	1600	826	500	8.6	5.0	62	10.0	37	8.6
3	La Plata River near Farmington	07-05-90	1700	0.28	1,050	8.5	24.5	100	21	99	2.9
	09367500	08-10-90	0830	0.16	1,500	8.1	16.0	120	29	180	2.6
		10-18-90	0900	2.2	3,710	8.4	4.0	320	120	430	4.5
		12-20-90	1230	17	2,130	8.3	0.0	240	100	200	2.9
		02-07-91	1600	74	780	8.3	2.0	55	19	100	2.1
4	San Juan River near Fruitland	08-08-90	1700	376	950	8.2	25.0	80	11	120	3.7
	09367540										
5	San Juan River above Hogback	08-08-90	1430	298	620	8.6	27.5	70	12	49	2.7
	364447108320710	02-05-91	1000	827	550	8.4	3.0	68	12	44	2.5
6	San Juan River below Hogback	08-09-90	0930	140	810	8.3	25.0	77	11	87	3.3
	363502108342110	02-05-91	1400	815	560	8.3	5.0	68	12	43	2.4
7	San Juan River at Shiprock	08-07-90	1400	131	790	8.9	26.0	86	20	67	3.3
	09368000	02-06-91	0930	892	590	8.4	3.5	72	14	49	2.5

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991--Continued

Site number	Site name and identification number	Date sampled	Time	Discharge (ft^3/s)	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Calcium (mg/L)*	Magnesium (mg/L)*	Sodium (mg/L)*	Potassium (mg/L)*
8	San Juan River below Shiprock 365543108573710	07-06-90	1000	757	600	8.1	23.0	72	13	41	2.8
		08-07-90	1000	149	890	8.3	22.0	87	23	71	3.5
		02-06-91	1300	909	600	8.4	6.5	70	14	50	2.4
9	Chaco River at Hogback 364234108315110	07-06-90	1730	3.9	1,410	8.5	31.0	89	48	160	6.5
		08-08-90	1200	4.4	1,500	8.6	29.5	98	49	170	6.8
		10-16-90	1000	4.4	1,800	8.5	18.0	110	60	200	7.4
		12-19-90	1230	5.2	1,850	8.5	11.0	110	59	190	6.9
		02-07-91	1400	0.18	11,200	8.3	11.0	300	720	1,800	24.0
10	Chaco River below Hogback 364254108334510	07-06-90	1600	4.1	1,560	8.5	31.5	97	50	170	7.3
		08-08-90	0900	4.1	1,430	8.6	19.5	96	46	160	6.4
		10-16-90	1230	5.4	1,700	8.5	19.5	110	56	190	7.3
		12-19-90	1430	--	1,650	8.4	0.5	100	55	180	6.6
		02-07-91	1200	0.31	7,170	8.2	3.0	260	370	1,000	14.0
11	Chaco River above mouth 364601108382910	07-06-90	1400	3.9	1,500	8.6	29.5	90	52	180	6.9
		08-07-90	1700	3.9	1,700	8.8	29.5	96	49	210	7.6
		10-16-90	1730	4.5	1,700	8.6	15.5	110	55	200	7.3
		12-20-90	0930	4.2	1,710	8.4	0.0	120	66	220	6.9
		02-07-91	0930	3.1	4,200	8.5	2.0	190	130	640	8.3
12	Eagle Nest Arroyo 364628108353210	02-05-91	1730	0.05	36,500	8.3	6.0	390	1,300	9,200	29.0
13	Chinde Wash near Fruitland 363829108285210	07-07-90	1130	0.13	1,410	8.6	27.5	67	14	230	4.1
		08-09-90	1530	0.12	1,380	8.6	31.0	59	15	220	3.4
		10-17-90	1230	0.14	2,650	8.8	14.5	120	30	410	4.1

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991--Continued

Site number	Site name and identification number	Date sampled	Time	Alkalinity (mg/L)*	Sulfate (mg/L)*	Chloride (mg/L)*	Fluoride (mg/L)*	Bromide (mg/L)*	Iodide (mg/L)*	Dissolved solids, sum of constituents (mg/L)*	Nitrogen (mg/L)*
1	Animas River at Farmington	07-05-90	1200	105	97	13	0.40	0.020	0.001	267	<0.10
	09364500	08-06-90	1500	159	210	26	0.40	0.040	0.003	500	0.20
		10-15-90	1530	117	110	15	0.50	0.030	0.002	303	0.20
		12-18-90	1315	143	170	26	0.40	0.050	0.001	434	0.30
		02-04-91	1400	141	210	23	0.40	0.050	0.002	476	0.20
2	San Juan River at Farmington	07-05-90	1500	109	110	10	0.40	0.010	0.003	290	0.20
	09365000	08-06-90	1730	113	150	9.2	0.50	0.030	0.003	349	0.50
		10-15-90	1700	108	130	9.7	0.30	0.020	0.003	309	0.20
		12-18-90	1630	115	140	10	0.30	0.020	0.004	336	0.50
		02-04-91	1600	117	150	10	0.30	0.030	0.003	357	0.60
3	La Plata River near Farmington	07-05-90	1700	219	230	61	0.70	0.090	0.004	659	<0.10
	09367500	08-10-90	0830	236	350	120	0.40	0.200	0.006	957	<0.10
		10-18-90	0900	250	1,700	180	1.50	0.760	0.010	2,920	0.30
		12-20-90	1230	268	990	75	0.30	0.470	0.007	1,780	0.60
		02-07-91	1600	124	300	18	0.30	0.080	0.002	576	1.00
4	San Juan River near Fruitland	08-08-90	1700	180	330	12	0.20	0.030	0.005	679	0.70
	09367540										
5	San Juan River above Hogback	08-08-90	1430	140	180	12	0.30	0.030	0.004	418	<0.10
	364447108320710	02-05-91	1000	127	190	13	0.30	0.040	0.003	415	0.90
6	San Juan River below Hogback	08-09-90	0930	161	270	16	0.20	0.080	0.005	575	0.80
	363502108342110	02-05-91	1400	128	190	13	0.20	0.040	0.003	415	0.50
7	San Juan River at Shiprock	08-07-90	1400	150	270	21	0.40	0.040	0.004	563	0.40
	09368000	02-06-91	0930	127	210	14	0.30	0.040	0.003	447	0.60

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991--Continued

Site number	Site name and identification number	Date sampled	Time	Alkalinity (mg/L)*	Sulfate (mg/L)*	Chloride (mg/L)*	Fluoride (mg/L)*	Bromide (mg/L)*	Iodide (mg/L)*	Dissolved solids, sum of constituents (mg/L)*	Nitrogen (mg/L)*
8	San Juan River below Shiprock 365543108573710	07-06-90	1000	130	170	15	0.40	0.020	0.003	400	<0.10
		08-07-90	1000	142	310	22	0.40	0.040	0.004	606	0.20
		02-06-91	1300	126	210	10	0.30	0.041	0.003	441	0.60
9	Chaco River at Hogback 364234108315110	07-06-90	1730	96	610	48	0.80	0.110	0.009	1,030	1.10
		08-08-90	1200	124	580	51	0.70	0.110	0.009	1,040	1.40
		10-16-90	1000	140	680	57	1.00	0.120	0.010	1,210	1.90
		12-19-90	1230	146	700	58	0.70	0.130	0.009	1,220	2.40
		02-07-91	1400	270	7,400	500	0.30	0.890	0.034	10,900	<0.10
10	Chaco River below Hogback 364254108334510	07-06-90	1600	113	640	51	0.80	0.120	0.009	1,100	1.40
		08-08-90	0900	129	560	48	0.70	0.110	0.009	1,010	1.30
		10-16-90	1230	139	660	60	0.70	0.120	0.010	1,180	1.70
		12-19-90	1430	140	650	55	0.70	0.130	0.008	1,140	2.20
		02-07-91	1200	204	3,600	310	0.80	0.690	0.024	5,690	<0.10
11	Chaco River above mouth 364601108382910	07-06-90	1400	102	640	53	0.9	0.11	0.007	1,090	0.80
		08-07-90	1700	119	620	57	0.9	0.12	0.008	1,120	1.00
		10-16-90	1730	139	660	58	1.1	0.12	0.010	1,180	1.60
		12-20-90	0930	146	780	68	0.7	0.16	0.008	1,360	3.00
		02-07-91	0930	125	2,000	180	0.7	0.29	0.013	3,230	7.20
12	Eagle Nest Arroyo 364628108353210	02-05-91	1730	458	13,000	8,300	5.2	9.50	0.016	32,500	<0.10
13	Chinde Wash near Fruitland 363829108285210	07-07-90	1130	121	480	56	0.9	0.08	0.005	934	0.10
		08-09-90	1530	103	500	47	0.3	0.09	0.005	914	0.10
		10-17-90	1230	124	900	150	<0.1	0.25	0.008	1,700	3.20

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991--Continued

Site number	Site name and identification number	Date sampled	Time	Barium (µg/L)*	Boron (µg/L)*	Iron (µg/L)*	Manganese (µg/L)*	Selenium (µg/L)*	Strontium (µg/L)*	Zinc (µg/L)*	S-34/S-32 stable isotope ratio (0/00)*
1	Animas River at Farmington	07-05-90	1200	59	50	4	--	<1	680	4	4.70
	09364500	08-06-90	1500	87	80	8	10	<1	1,500	6	5.30
		10-15-90	1530	66	50	4	16	<1	790	6	5.40
		12-18-90	1315	76	80	190	130	<1	1,100	19	5.00
		02-04-91	1400	75	80	<3	79	<1	1,200	7	5.50
2	San Juan River at Farmington	07-05-90	1500	61	40	5	--	<1	720	4	4.00
	09365000	08-06-90	1730	69	40	7	5	<1	780	<3	2.30
		10-15-90	1700	64	40	6	6	<1	680	7	3.40
		12-18-90	1630	63	360	5	21	<1	710	<3	3.90
		02-04-91	1600	66	50	6	21	<1	780	4	3.50
3	La Plata River near Farmington	07-05-90	1700	71	100	9	--	<1	1,500	4	2.40
	09367500	08-10-90	0830	58	120	8	390	<1	1,800	4	0.60
		10-18-90	0900	<100	160	<10	680	<1	5,100	<10	-7.30
		12-20-90	1230	<100	110	<10	160	2	2,900	<10	-9.10
		02-07-91	1600	26	50	42	33	<1	770	<3	-7.00
4	San Juan River near Fruitland	08-08-90	1700	110	70	190	9	1	1,000	4	3.20
	09367540										
5	San Juan River above Hogback	08-08-90	1430	68	50	3	16	<1	940	<3	1.16
	364447108320710	02-05-91	1000	63	50	5	7	<1	840	4	2.20
6	San Juan River below Hogback	08-09-90	0930	95	80	4	2	1	970	4	1.10
	363502108342110	02-05-91	1400	61	50	4	6	<1	830	4	2.10
7	San Juan River at Shiprock	08-07-90	1400	76	80	3	17	1	1,200	8	-2.10
	09368000	02-06-91	0930	62	60	5	4	1	900	6	0.90

Table 1.--Chemical analyses of water samples collected from surface-water sites, San Juan County, New Mexico, July 1990-February 1991--Concluded

Site number	Site name and identification number	Date sampled	Time	Barium (µg/L)*	Boron (µg/L)*	Iron (µg/L)*	Manganese (µg/L)*	Selenium (µg/L)*	Strontium (µg/L)*	Zinc (µg/L)*	S-34/S-32 stable isotope ratio (0/00)*
8	San Juan River below Shiprock	07-06-90	1000	110	60	130	--	1	940	6	0.40
	365543108573710	08-07-90	1000	120	100	<3	6	2	1,300	3	-3.60
		02-06-91	1300	100	50	10	10	1	940	10	0.30
9	Chaco River at Hogback	07-06-90	1730	110	440	<3	--	3	1,700	<3	-3.10
	364234108315110	08-08-90	1200	130	440	<3	1	2	1,800	6	-2.80
		10-16-90	1000	130	500	<3	1	3	2,000	<3	-4.40
		12-19-90	1230	120	480	<3	4	3	1,900	<3	-4.00
		02-07-91	1400	100	2,400	10	70	4	5,900	10	-12.00
10	Chaco River below Hogback	07-06-90	1600	110	470	15	--	3	1,800	<3	-3.60
	364254108334510	08-08-90	0900	120	390	3	<1	2	1,800	4	-2.40
		10-16-90	1230	140	480	<3	2	2	2,000	<3	-3.50
		12-19-90	1430	94	430	5	1	2	1,700	<3	-3.90
		02-07-91	1200	100	1,500	20	30	15	4,500	10	-12.00
11	Chaco River above mouth	07-06-90	1400	89	450	<3	--	2	1,700	<3	-2.60
	364601108382910	08-07-90	1700	130	450	<3	2	2	1,800	<3	-4.50
		10-16-90	1730	170	480	6	3	2	2,000	<3	-3.10
		12-20-90	0930	79	490	8	3	3	1,900	<3	-5.10
		02-07-91	0930	79	590	3	24	9	3,700	3	-6.00
12	Eagle Nest Arroyo	02-05-91	1730	100	1,100	10	<10	150	11,000	<10	-16.00
	364628108353210										
13	Chinde Wash near Fruitland	07-07-90	1130	34	100	10	--	3	1,400	8	0.50
	363829108285210	08-09-90	1530	36	90	3	2	4	1,300	<3	-0.10
		10-17-90	1230	<100	140	<10	<10	10	2,700	<10	0.50

Table 2.--Chemical analyses of water samples collected from ground-water sites, San Juan County, New Mexico, October 1969 and June 1990-January 1991

[Site numbers are plotted in figures 2 and 11-13; uS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; *, analysis from filtered (dissolved) samples; ug/L, micrograms per liter; 0/00, per mil; --, no data; <, less than]

Site number	Site name and identification number	Date sampled	Time	Specific conductance (uS/cm)	pH (units)	Temperature (°C)	Calcium (mg/L)*	Magnesium (mg/L)*	Sodium (mg/L)*	Potassium (mg/L)*
G1	Chaco River recorder well 364325108353001	06-12-90	0930	2,000	7.4	15.5	86	44	330	6.0
		08-02-90	1000	1,890	7.4	18.0	69	35	290	6.2
		10-16-90	1500	1,880	7.6	18.5	66	33	280	6.3
		11-29-90	1230	1,820	7.9	13.5	67	34	300	6.2
		01-31-91	1230	1,950	7.9	9.5	64	33	270	5.3
G2	San Juan River flowing well 364430108312501	06-12-90	1530	1,100	7.3	16.0	160	44	53	1.9
		08-01-90	1530	990	7.1	18.5	140	40	48	1.9
		10-17-90	1530	1,100	7.1	16.0	150	40	50	2.0
		11-29-90	1500	990	7.4	12.0	150	40	50	1.8
		01-31-91	1430	1,270	7.3	5.5	170	47	51	1.6
G3	Alluvial well on Chaco River 363458108342401	08-03-90	1100	1,200	7.5	24.0	67	7.5	220	4.8
		10-17-90	0930	1,300	7.8	16.5	66	5.5	210	4.3
		11-30-90	1000	1,000	7.8	12.5	66	5.6	200	3.3
		01-31-91	0930	1,000	7.7	7.0	60	4.9	170	2.8
SJ-1	Augered well near Waterflow 364500108312901	10-06-69	--	2,160	7.9	16.0	325	85	115	4.1
SJ-3	Augered well near Waterflow 364445108312701	10-06-69	--	3,200	8.0	19.0	425	175	239	7.8
SJ-4	Augered well near Waterflow 364453108312801	10-06-69	--	2,960	8.0	16.0	515	116	150	5.4

Table 2.--Chemical analyses of water samples collected from ground-water sites, San Juan County, New Mexico, October 1969 and June 1990-January 1991--Continued

Site number	Site name and identification number	Date sampled	Time	Alkalinity (mg/L)*	Sulfate (mg/L)*	Chloride (mg/L)*	Fluoride (mg/L)*	Bromide (mg/L)*	Iodide (mg/L)*	Dissolved solids, sum of constituents (mg/L)*	Nitrogen (mg/L)*
G1	Chaco River recorder well 364325108353001	06-12-90	0930	137	770	58	1.2	0.13	0.014	1,400	1.50
		08-02-90	1000	156	720	56	1.0	0.03	0.011	1,290	1.30
		10-16-90	1500	147	700	63	1.3	0.33	0.010	1,260	1.30
		11-29-90	1230	137	750	58	0.8	0.15	0.011	1,330	1.30
		01-31-91	1230	133	710	61	1.2	0.16	0.011	1,240	1.20
G2	San Juan River flowing well 364430108312501	06-12-90	1530	311	330	15	0.5	0.05	0.007	818	1.10
		08-01-90	1530	352	260	12	0.3	0.04	0.009	737	0.30
		10-17-90	1530	385	260	14	<0.1	0.05	0.012	770	0.60
		11-29-90	1500	372	--	27	0.4	0.04	0.006	561	0.80
		01-31-91	1430	358	370	35	0.7	0.06	0.007	909	1.60
G3	Alluvial well on Chaco River 363458108342401	08-03-90	1100	214	420	10	1.0	0.03	0.003	875	0.30
		10-17-90	0930	262	410	12	0.7	0.08	0.003	881	0.40
		11-30-90	1000	230	390	11	0.4	0.04	0.001	813	0.40
		01-31-91	0930	222	350	9.6	0.9	0.04	0.002	742	0.20
SJ-1	Augered well near Waterflow 364500108312901	10-06-69	--	--	1,140	29	0.6	--	--	1,860	--
SJ-3	Augered well near Waterflow 364445108312701	10-06-69	--	--	1,860	50	0.6	--	--	2,910	--
SJ-4	Augered well near Waterflow 364453108312801	10-06-69	--	--	1,700	28	0.6	--	--	2,710	--

Table 2.--Chemical analyses of water samples collected from ground-water sites, San Juan County, New Mexico, October 1969 and June 1990-January 1991--Concluded

Site number	Site name and identification number	Date sampled	Time	Barium (ug/L)*	Boron (ug/L)*	Iron (ug/L)*	Manganese (ug/L)*	Selenium (ug/L)*	Strontium (ug/L)*	Zinc (ug/L)*	S-34/S-32 stable isotope ratio (0/00)*
G1	Chaco River recorder well 364325108353001	06-12-90	0930	32	1,000	5,100	550	<1	4,200	1,200	-6.80
		08-02-90	1000	23	1,100	4,100	420	<1	3,500	320	-6.00
		10-16-90	1500	24	1,100	8,100	440	<1	3,300	120	-4.70
		11-29-90	1230	24	1,100	9,000	490	<1	3,400	630	-4.70
		01-31-91	1230	20	850	7,400	420	<1	3,100	910	-3.90
G2	San Juan River flowing well 364430108312501	06-12-90	1530	33	100	13	1	3	1,600	9	--
		08-01-90	1530	32	110	23	8	2	1,400	4	-1.60
		10-17-90	1530	32	100	11	18	<1	1,500	4	-1.20
		11-29-90	1500	31	90	11	<1	2	1,500	9	-1.20
		01-31-91	1430	30	90	10	<1	2	1,600	10	-3.00
G3	Alluvial well on Chaco River 363458108342401	08-03-90	1100	45	90	110	900	<1	1,100	5	-6.50
		10-17-90	0930	28	80	63	100	<1	810	<3	-3.80
		11-30-90	1000	22	60	260	270	<1	790	3	-2.40
		01-31-91	0930	24	50	25	58	1	690	4	-1.20
SJ-1	Augered well near Waterflow 364500108312901	10-06-69	--	--	280	10	--	--	--	--	--
SJ-3	Augered well near Waterflow 364445108312701	10-06-69	--	--	370	0	--	--	--	--	--
SJ-4	Augered well near Waterflow 364453108312801	10-06-69	--	--	360	180	--	--	--	--	--

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987

[Data from C.L. Thomas, U.S. Geological Survey, written commun., 1987. Site numbers are plotted in figure 2; ft^3/s, cubic feet per second; uS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; *, analysis from filtered (dissolved) samples; ug/L, micrograms per liter; 0/00, per mil; E, estimate; <, less than; --, no data]

Site number	Site name and identification number	Date sampled	Time	Discharge (ft^3/s)	Specific conductance (uS/cm)	pH (units)	Temperature (°C)	Calcium (mg/L)*	Magnesium (mg/L)*	Sodium (mg/L)*	Potassium (mg/L)*
				Surface-water sites							
14	San Juan River near Waterflow 364510108295010	12-01-87	0941	E941	610	8.5	1.5	75	15	44	2.4
15	Irrigation drain 364550108360310	12-01-87	1230	<10	3,100	8.1	6.5	350	160	220	9.1
16	San Juan River above Chaco River 364629108385910	12-01-87	1430	--	620	8.6	5.0	78	16	49	2.6
17	San Juan River at Highway 666 364650108412110	12-01-87	1615	E1,000	630	8.8	4.0	78	16	50	2.5
18	San Juan River below Red Wash 365515108560410	12-03-87	1115	E955	660	9.0	3.5	79	17	50	2.4
19	Mancos River at mouth 365856108584510	12-03-87	1420	E34	2,200	8.4	1.5	190	110	150	3.4
20	San Juan River at Four Corners 370020109020010	12-03-87	1515	989	730	8.5	4.0	85	21	52	2.5
21	Eagle Nest Arroyo 364628108353210	12-03-87	1255	<1	38,000	8.1	7.0	390	1,000	7,600	29
22	Irrigation drain 365211108461010	12-03-87	1017	<1	2,700	7.9	3.5	350	140	170	4.7
23	Unnamed creek 365248108472410	12-02-87	1618	<1	8,500	8.3	4.5	300	410	1,900	11

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987--Continued

Site number	Site name and identification number	Date sampled	Time	Discharge (ft^3/s)	Specific conductance (uS/cm)	pH (units)	Temperature (^oC)	Calcium (mg/L)*	Magnesium (mg/L)*	Sodium (mg/L)*	Potassium (mg/L)*
				Ground-water sites							
G4	Alluvial well on Chaco River 363458108342401	12-02-87	1038	--	1,400	7.6	9.0	110	11	210	4.7
G5	Chaco River alluvial water on Hogback axis 364238108315201	12-01-87	1209	--	13,900	8.0	10.0	270	120	3,200	15
G6	Chaco River recorder well 364325108353001	12-01-87	1430	--	6,100	7.7	13.0	140	69	1,200	9.2
G7	San Juan River alluvial water at Hogback 364440108321201	12-03-87	1412	--	5,500	6.9	11.0	25	60	1,200	10
G8	Seep 364250108315201	12-04-87	1013	--	16,000	8.2	3.0	200	230	3,700	17
G9	Little Geyser Spring 364220108315201	12-04-87	1040	--	5,000	7.2	6.0	110	25	1,200	21
G10	Seep below Cudei diversion ditch 365048108444301	12-02-87	1120	--	2,740	7.3	9.0	300	96	270	3.9
G11	Alluvial well near Cudei 365301108481401	12-02-87	1319	--	15,000	7.8	10.0	390	740	3,100	18
G12	Canal Creek well near Cudei 365347108522601	12-02-87	1630	--	12,000	9.1	13.0	11.0	250	2,300	16

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987--Continued

Site number	Site name and identification number	Date sampled	Time	Alkalinity (mg/L)*	Sulfate (mg/L)*	Chloride (mg/L)*	Fluoride (mg/L)*	Bromide (mg/L)*	Dissolved solids, sum of constituents (mg/L)*
			Surface-water sites						
14	San Juan River near Waterflow 364510108295010	12-01-87	0941	130	180	15	0.30	0.028	420
15	Irrigation drain 364550108360310	12-01-87	1230	415	1,800	41	0.40	0.073	2,850
16	San Juan River above Chaco River 364629108385910	12-01-87	1430	--	190	15	0.30	0.040	361
17	San Juan River at Highway 666 364650108412110	12-01-87	1615	135	190	15	0.30	0.039	443
18	San Juan River below Red Wash 365515108560410	12-03-87	1115	144	200	14	0.30	0.033	459
19	Mancos River at mouth 365856108584510	12-03-87	1420	240	1,100	22	0.30	0.076	1,860
20	San Juan River at Four Corners 370020109020010	12-03-87	1515	140	250	15	0.40	0.032	519
21	Eagle Nest Arroyo 364628108353210	12-03-87	1255	420	13,000	7,100	0.30	9.8	29,400
22	Irrigation drain 365211108461010	12-03-87	1017	286	1,600	37	0.60	0.14	2,500
23	Unnamed creek 365248108472410	12-02-87	1618	313	6,200	200	0.30	0.22	9,230

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987--Continued

Site number	Site name and identification number	Date sampled	Time	Alkalinity (mg/L)*	Sulfate (mg/L)*	Chloride (mg/L)*	Fluoride (mg/L)*	Bromide (mg/L)*	Dissolved solids, sum of constituents (mg/L)*
			Ground-water sites						
G4	Alluvial well on Chaco River 363458108342401	12-02-87	1038	164	610	15	0.80	0.022	1,070
G5	Chaco River alluvial water on Hogback axis 364238108315201	12-01-87	1209	540	6,600	1,300	0.70	1.5	11,900
G6	Chaco River recorder well 364325108353001	12-01-87	1430	490	2,500	540	1.70	0.94	4,780
G7	San Juan River alluvial water at Hogback 364440108321201	12-03-87	1412	170	1,700	820	0.30	1.0	3,940
G8	Seep 364250108315201	12-04-87	1013	432	9,800	750	2.70	1.0	15,000
G9	Little Geyser Spring 364220108315201	12-04-87	1040	326	3,100	180	2.90	0.32	4,850
G10	Seep below Cudei diversion ditch 365048108444301	12-02-87	1120	365	1,400	38	0.20	0.066	2,340
G11	Alluvial well near Cudei 365301108481401	12-02-87	1319	472	11,000	590	0.30	0.41	16,200
G12	Canal Creek well near Cudei 365347108522601	12-02-87	1630	740	5,000	620	0.50	0.80	8,650

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987--Continued

Site number	Site name and identification number	Date sampled	Time	Barium (ug/L)*	Boron (ug/L)*	Iron (ug/L)*	Manganese (ug/L)*	Selenium (ug/L)*	Strontium (ug/L)*	S-34/S-32 stable isotope ratio (0/00)*
				Surface-water sites						
14	San Juan River near Waterflow 364510108295010	12-01-87	0941	66	50	10	40	<1	870	0.40
15	Irrigation drain 364550108360310	12-01-87	1230	<100	480	20	620	22	5,000	-16.70
16	San Juan River above Chaco River 364629108385910	12-01-87	1430	7	50	13	41	1	910	-0.7
17	San Juan River at Highway 666 364650108412110	12-01-87	1615	66	40	8	40	1	910	-0.90
18	San Juan River below Red Wash 365515108560410	12-03-87	1115	69	50	4	19	1	930	-1.90
19	Mancos River at mouth 365856108584510	12-03-87	1420	100	110	20	80	14	2,200	-17.60
20	San Juan River at Four Corners 370020109020010	12-03-87	1515	70	70	7	8	1	980	-4.20
21	Eagle Nest Arroyo 364628108353210	12-03-87	1255	<100	900	120	50	160	12,000	-18.00
22	Irrigation drain 365211108461010	12-03-87	1017	<100	380	20	100	20	4,900	-18.50
23	Unnamed creek 365248108472410	12-02-87	1618	<100	580	40	10	340	4,600	-21.20

Table 3.--Chemical analyses of water samples collected from surface-water and ground-water sites, San Juan County, New Mexico, December 1987--Concluded

Site number	Site name and identification number	Date sampled	Time	Barium (ug/L)*	Boron (ug/L)*	Iron (ug/L)*	Manganese (ug/L)*	Selenium (ug/L)*	Strontium (ug/L)*	S-34/S-32 stable isotope ratio (0/00)*
				Ground-water sites						
G4	Alluvial well on Chaco River 363458108342401	12-02-87	1038	64	60	610	2	<1	2	-12.80
G5	Chaco River alluvial water on Hogback axis 364238108315201	12-01-87	1209	100	650	40	10	<1	7,300	9.40
G6	Chaco River recorder well 364325108353001	12-01-87	1430	100	1,500	360	1,800	<1	4,000	-6.60
G7	San Juan River alluvial water at Hogback 364440108321201	12-03-87	1412	<100	320	14,000	1,200	<1	530	19.60
G8	Seep 364250108315201	12-04-87	1013	<100	1,300	60	30	<1	8,200	10.50
G9	Little Geyser Spring 364220108315201	12-04-87	1040	<100	460	520	70	<1	5,000	12.50
G10	Seep below Cudei diversion ditch 365048108444301	12-02-87	1120	<100	380	20	1,200	17	3,600	-14.50
G11	Alluvial well near Cudei 365301108481401	12-02-87	1319	<100	480	70	30	1,300	9,300	-21.70
G12	Canal Creek well near Cudei 365347108522601	12-02-87	1630	<100	570	70	50	<1	320	-19.40

Table 4.--Statistical summary of selected water-quality constituents in surface-water and ground-water samples, San Juan County, New Mexico, June 1990-February 1991

[Site numbers are plotted in figure 2. Selenium, micrograms per liter; all other constituents are in milligrams per liter; <, less than]

Site number	Site name and water-quality constituent	Number of samples	Minimum	Maximum	Median
1	Animas River at Farmington				
	Calcium	5	58	98	92
	Magnesium	5	7.9	15	14
	Sodium	5	19	43	34
	Sulfate	5	97	210	170
	Chloride	5	13	26	23
	Bromide	5	0.02	0.05	0.04
	Iodide	5	0.001	0.003	0.002
	Dissolved solids	5	267	500	434
	Selenium	5	<1	<1	<1
2	San Juan River at Farmington				
	Calcium	5	55	62	58
	Magnesium	5	8.4	10	9
	Sodium	5	28	43	35
	Sulfate	5	110	150	140
	Chloride	5	9.2	10	10
	Bromide	5	0.01	0.03	0.02
	Iodide	5	0.003	0.004	0.003
	Dissolved solids	5	290	357	336
	Selenium	5	<1	<1	<1
3	La Plata River near Farmington				
	Calcium	5	55	320	120
	Magnesium	5	19	120	29
	Sodium	5	99	430	180
	Sulfate	5	230	1,700	350
	Chloride	5	18	180	75
	Bromide	5	0.08	0.76	0.20
	Iodide	5	0.002	0.01	0.006
	Dissolved solids	5	576	2,920	957
	Selenium	5	<1	2	<1

Table 4.--Statistical summary of selected water-quality constituents in surface-water and ground-water samples, San Juan County, New Mexico, June 1990-February 1991--Continued

Site number	Site name and water-quality constituent	Number of samples	Minimum	Maximum	Median
5	San Juan River above Hogback				
	Calcium	2	68	70	69
	Magnesium	2	12	12	12
	Sodium	2	44	49	46.5
	Sulfate	2	180	190	185
	Chloride	2	12	13	12.5
	Bromide	2	0.030	0.040	0.035
	Iodide	2	0.003	0.004	0.0035
	Dissolved solids	2	415	418	416.5
	Selenium	2	<1	<1	<1
6	San Juan River below Hogback				
	Calcium	2	68	77	72.5
	Magnesium	2	11	12	11.5
	Sodium	2	43	87	65
	Sulfate	2	190	270	230
	Chloride	2	13	16	14.5
	Bromide	2	0.040	0.080	0.060
	Iodide	2	0.003	0.005	0.004
	Dissolved solids	2	415	575	495
	Selenium	2	<1	<1	<1
7	San Juan River at Shiprock				
	Calcium	2	72	86	79
	Magnesium	2	14	20	17
	Sodium	2	49	67	58
	Sulfate	2	210	270	240
	Chloride	2	14	21	17.5
	Bromide	2	0.040	0.040	0.040
	Iodide	2	0.003	0.004	0.0035
	Dissolved solids	2	447	563	505
	Selenium	2	1	1	1

Table 4.--Statistical summary of selected water-quality constituents in surface-water and ground-water samples, San Juan County, New Mexico, June 1990-February 1991--Continued

Site number	Site name and water-quality constituent	Number of samples	Minimum	Maximum	Median
8	San Juan River below Shiprock				
	Calcium	3	70	87	72
	Magnesium	3	13	23	14
	Sodium	3	41	71	50
	Sulfate	3	170	310	210
	Chloride	3	10	22	15
	Bromide	3	0.020	0.041	0.040
	Iodide	3	0.003	0.004	0.003
	Dissolved solids	3	400	606	441
	Selenium	3	1	2	1
9	Chaco River at Hogback				
	Calcium	5	89	300	110
	Magnesium	5	48	720	59
	Sodium	5	160	1,800	190
	Sulfate	5	580	7,400	680
	Chloride	5	48	500	57
	Bromide	5	0.11	0.89	0.12
	Iodide	5	0.009	0.034	0.009
	Dissolved solids	5	1,030	10,900	1,210
	Selenium	5	2	4	3
10	Chaco River below Hogback				
	Calcium	5	96	260	100
	Magnesium	5	46	370	55
	Sodium	5	160	1,000	180
	Sulfate	5	560	3,600	650
	Chloride	5	48	310	55
	Bromide	5	0.11	0.69	0.12
	Iodide	5	0.008	0.024	0.009
	Dissolved solids	5	1,010	5,690	1,140
	Selenium	5	2	15	2

Table 4.--Statistical summary of selected water-quality constituents in surface-water and ground-water samples, San Juan County, New Mexico, June 1990-February 1991--Continued

Site number	Site name and water-quality constituent	Number of samples	Minimum	Maximum	Median
11	Chaco River above mouth				
	Calcium	5	90	190	110
	Magnesium	5	49	130	55
	Sodium	5	180	640	210
	Sulfate	5	620	2,000	660
	Chloride	5	53	180	58
	Bromide	5	0.11	0.29	0.12
	Iodide	5	0.007	0.13	0.008
	Dissolved solids	5	1,090	3,230	1,180
	Selenium	5	2	9	2
13	Chinde Wash near Fruitland				
	Calcium	3	59	120	67
	Magnesium	3	14	30	15
	Sodium	3	220	410	230
	Sulfate	3	480	900	500
	Chloride	3	47	150	56
	Bromide	3	0.08	0.25	0.09
	Iodide	3	0.005	0.008	0.005
	Dissolved solids	3	914	1,700	934
	Selenium	3	3	10	4
G1	Chaco River recorder well				
	Calcium	5	64	86	67
	Magnesium	5	33	44	34
	Sodium	5	270	330	290
	Sulfate	5	700	770	720
	Chloride	5	56	63	58
	Bromide	5	0.03	0.33	0.15
	Iodide	5	0.010	0.014	0.011
	Dissolved solids	5	1,240	1,400	1,290
	Selenium	5	<1	<1	<1

Table 4.--Statistical summary of selected water-quality constituents in surface-water and ground-water samples, San Juan County, New Mexico, June 1990-February 1991--Concluded

Site number	Site name and water-quality constituent	Number of samples	Minimum	Maximum	Median
G2	San Juan River flowing well				
	Calcium	5	140	170	150
	Magnesium	5	40	47	40
	Sodium	5	48	53	50
	Sulfate	4	260	370	295
	Chloride	5	12	35	15
	Bromide	5	0.04	0.06	0.05
	Iodide	5	0.006	0.012	0.007
	Dissolved solids	5	561	909	770
	Selenium	5	<1	3	2
G3	Alluvial well on Chaco River				
	Calcium	4	60	67	66
	Magnesium	4	4.9	7.5	5.55
	Sodium	4	170	220	205
	Sulfate	4	350	420	400
	Chloride	4	9.6	12	10.5
	Bromide	4	0.030	0.080	0.040
	Iodide	4	0.001	0.003	0.002
	Dissolved solids	4	742	881	844
	Selenium	4	<1	1	<1