Hydrologic Benchmark Network Stations in the West-Central U.S. 1963-95 (USGS Circular 1173-C)

Abstract and Map Index	List of all HBN Stations	Introduction to Circular	Analytical Methods

Rio Mora near Tererro, New Mexico (08377900)

This report details one of the approximately 50 stations in the Hydrologic Benchmark Network (HBN) described in the four-volume U.S. Geological Survey Circular 1173. The suggested citation for the information on this page is:

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All of the tables and figures are numbered as they appear in each circular. Use the navigation bar above to view the abstract, introduction and methods for the entire circular, as well as a map and list of all of the HBN sites. Use the table of contents below to view the information on this particular station.

Table of Contents

Site Characteristics and Land Use

The Rio Mora HBN Basin is in the Southern Rocky Mountains physiographic province (Fenneman, 1946) in northern New Mexico (Figure 15. *Map showing study area in the Rio Mora Basin and photograph of the landscape in the upper part of the basin*). The HBN station is 4.2 km north of Tererro, N. Mex., at a latitude of 35×46'38" and longitude of 105×39'27". Rio Mora drains about 138 km^2 of rugged, mountainous terrain

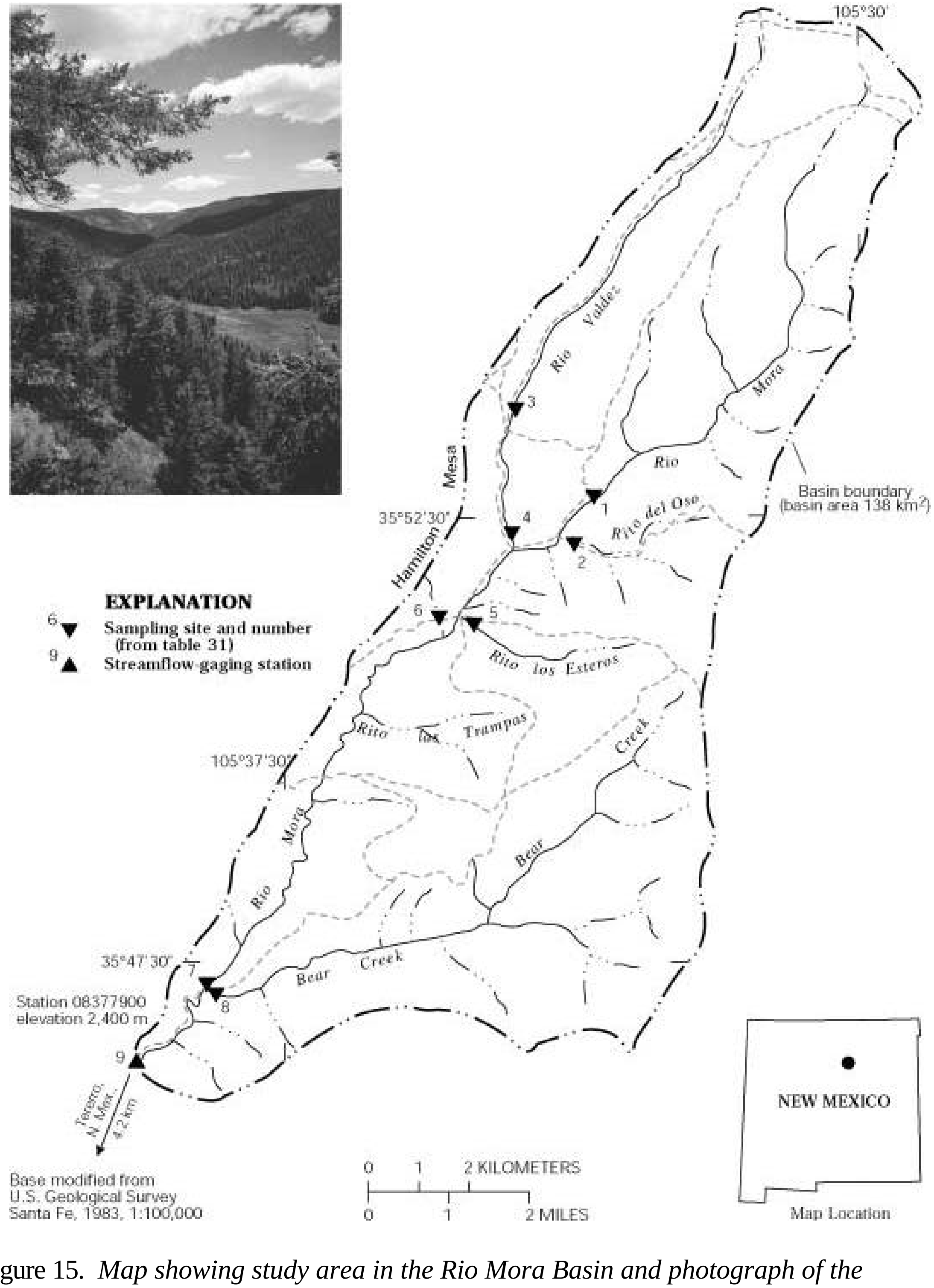


Figure 15. *Map showing study area in the Rio Mora Basin and photograph of the landscape in the upper part of the basin*

in the Sangre De Cristo Range. Basin elevations range from about 2,400 to 3,900 m. Stream slope varies from about 19 m/km in open reaches to 57 m/km in canyon reaches. The ecoregion of the basin is classified as the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province (Bailey, 1995). Trees are the predominant vegetative cover; about 80 percent of the basin is covered by pine, spruce, and fir. Large aspen groves grow in some parts of the basin. The south slopes of the lower part of the basin are covered with scrub oak. High mountain meadows are common in the upper basin. The Rio Mora is tributary to the Pecos River.

The Rio Mora is a perennial stream with mean monthly discharges that range from 0.17 m^3/s in January to 3.6 m^3/s in May (Ortiz and Lange, 1996). Average annual precipitation at the Tererro weather station, which is at an elevation about 120 m lower than the HBN station, is 45 cm. Precipitation in the basin increases with increasing elevation. The snowpack usually accumulates from December to late February. Average annual runoff is about 20 cm (Ortiz and Lange, 1996). Mean monthly temperatures ranged from -2.2×C in January to 15.8×C in July during the period of record, 1948–61 (National Climatic Data Center, 1996).

The Sangre De Cristo Range is an uplifted block of Precambrian plutonic and stratified metamorphic rocks partially overlain by sedimentary rocks of Paleozoic age (Moench and others, 1988; U.S. Geological Survey and others, 1980). Igneous and metamorphic rocks are exposed along the drainages. Intrusive igneous rocks of Precambrian age are predominantly biotite granite. The granites are pink or red, medium to coarse grained, with variable foliation. Mineral composition is 30–40 percent quartz, 60 percent microcline and oligoclase, and 5–10 percent biotite. Other plutonic rocks include dark, fine-grained, massive intrusive amphibolites, medium-gray, medium-grained tonalite, quartz diorite, and diabase. The metamorphic rocks of Precambrian age are dominated by white, pink, tan, or black quartzites with minor amounts of trace minerals, including magnetite, muscovite, tourmaline, chloritoid, and graphite. These quartzites are interbedded with two-mica, pelitic schist. Lower units contain white, gray, or tan quartzites composed of nearly 100 percent quartz. The geology of the Rio Mora Basin is dominated by rocks of Paleozoic age at higher elevations. Mississippian-age rocks are sandy, clastic, crossbedded limestone, massive crystalline limestone, limestone breccia, and quartz-rich sandstone. Overlying these rocks are the Madera and Sandia Formations of Pennsylvanian age. The lower part of the Madera Formation contains fossiliferous marine limestone, dark-gray shale, and thin to thick sandstones. The Sandia Formation contains sandstone, conglomeratic sandstone, interbedded gray shale, sandy shale, and shaly limestone. Coarse alluvium has accumulated near the mouth of the basin.

The Rio Mora HBN station is in San Miguel County. The Rio Mora HBN Basin lies almost entirely within the Santa Fe National Forest except for a small, privately owned area near the HBN station. About 90 percent of the basin lies within the Pecos Wilderness Area. Access to the HBN station, during both summer and winter, is by an improved dirt road. An unimproved road continues upstream, past the HBN station. The rest of the basin is accessed primarily by a series of pack trails. Because most of the basin is within a designated wilderness area, access is restricted to foot trails and horseback. Recreation and grazing are the predominant land uses. Recreational activities in the basin include backcountry hiking, camping, hunting, and cross-country skiing.

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Rio Mora HBN station includes 201 water-quality samples that were collected from November 1962 to August 1995. Sampling frequency is described on the basis of water year, which begins on October 1 and ends on September 30. Sampling frequency was variable; 1 sample was collected in water year 1963 and between 5 to 14 samples were collected between water years 1964 to 1975. From 1976 to 1982, sampling frequency was bimonthly and was reduced to quarterly from 1983 to 1995. Samples were analyzed at the USGS New Mexico District water-quality laboratory until early 1970. From early 1970 through 1973, samples were analyzed at the USGS water-quality laboratory in Salt Lake City, Utah. After 1973, with the creation of the USGS Central Laboratory System, all samples were analyzed at the water- quality laboratory (now called NWQL) in Arvada, Colo. The period of record for discharge is from water year 1964 to current year (2000).

Data quality was checked using ion balances and time-series plots. Calculated ion balances for samples with complete major-ion analyses are shown in Figures 16a and 16b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rio Mora, New Mexico.* More than 90 percent of the samples had ion balances within the ±5 percent range, indicating that the major-ion analytical results generally were of good quality and that unmeasured constituents, such as organic anions, nutrients, and trace metals, do not contribute substantially to the ion composition of the stream water. Time-series plots of ion concentrations were inspected for evidence of influences that are related to analytical method changes (fig. 16). A small decrease in scatter of sulfate concentrations after 1982 corresponds with the change from a methylthymol blue procedure to a turbidimetric titration method (U.S. Geological Survey Office of Water Quality Technical Memorandum No. 83.07, 1983). Temporal patterns also were evident in the field pH measurements, particularly in the early part of the record. Changes were made in meters and electrodes used for field pH determinations during the study period. When changes in methods or instrumentation result in improved precision or elimination of measurement bias, time-series data can exhibit less scatter or a directional shift, respectively. The time-series data, therefore, may reflect the method or instrument change rather than an environmental change.

The median and range of major-ion concentrations in the stream water collected at the Rio Mora HBN station and the VWM concentrations in wet precipitation measured at the Bandelier National Monument NADP station are presented in table 28. The NADP station is about 68 km west of the HBN station. Precipitation chemistry at the NADP station is dilute and slightly acidic with a VWM pH of 5.0 during the period of record, 1982–95. The dominant cation in precipitation was calcium, which contributed about 32 percent of the total cation concentration; hydrogen contributed about 29 percent and

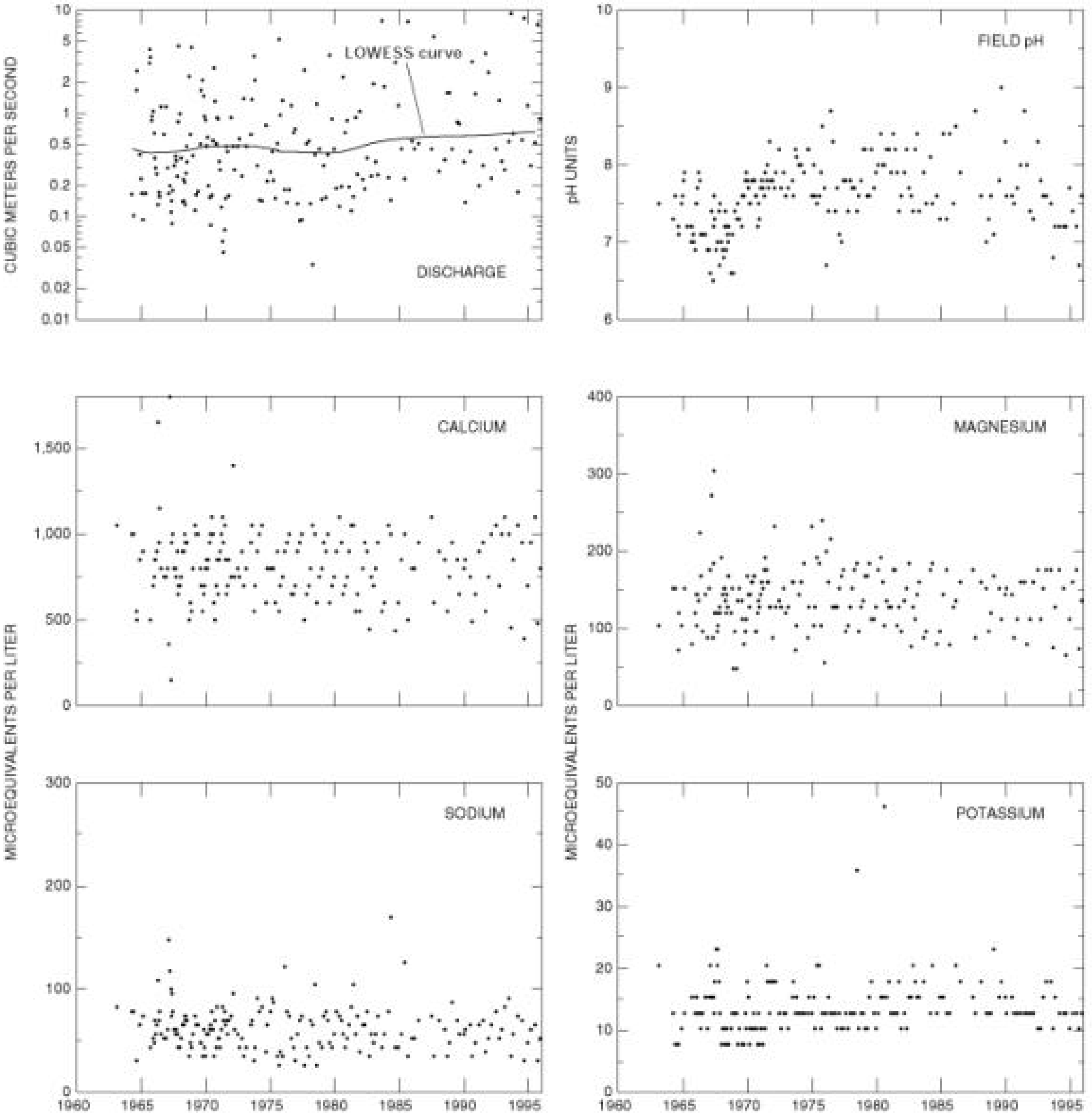
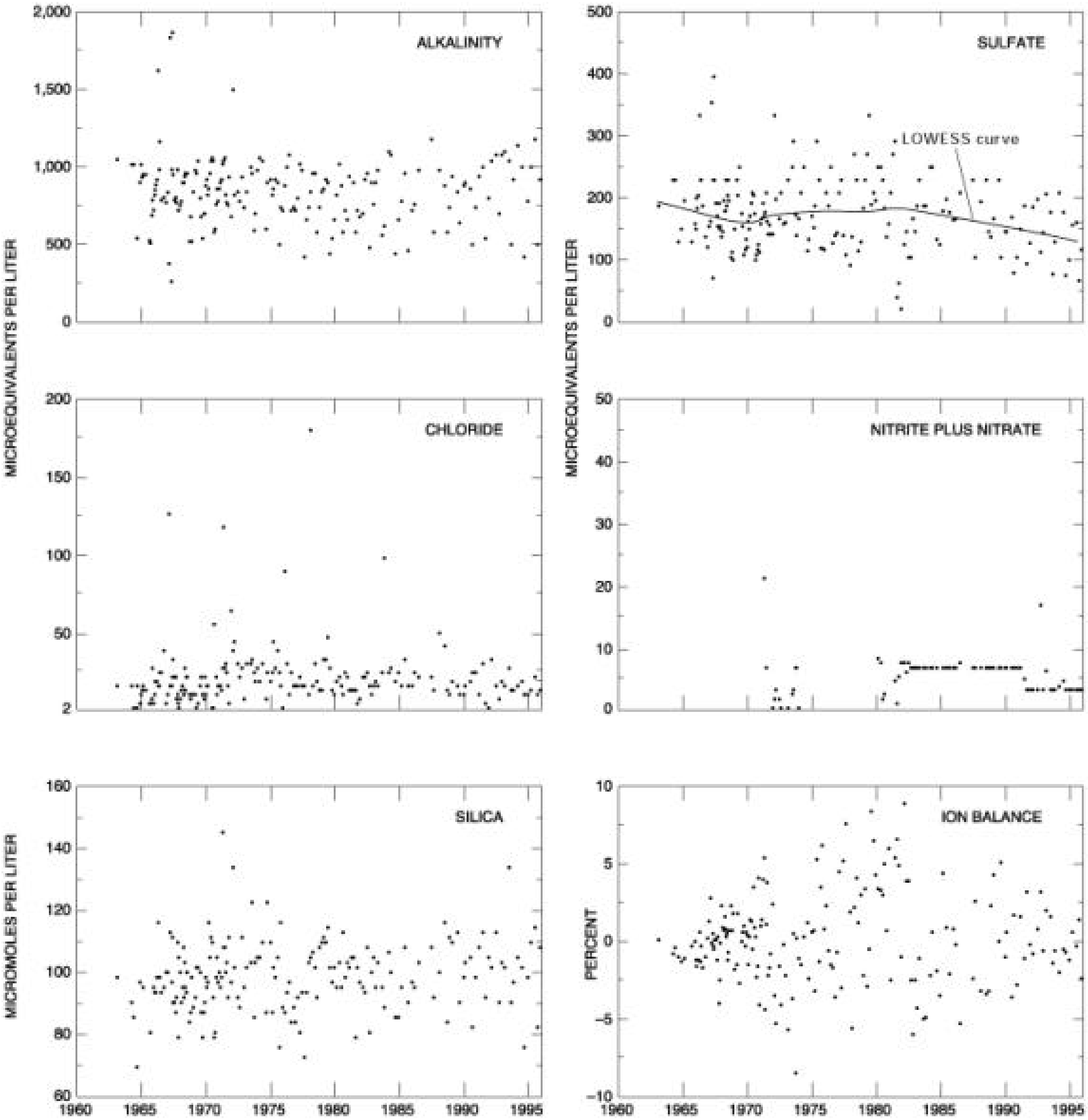


Figure 16a. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rio Mora, New Mexico*



Figures 16b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rio Mora, New Mexico - Continued*

ammonium contributed about 23 percent. Sulfate, the dominant anion in precipitation, contributed about 54 percent of the total anion concentration; nitrate contributed about 39 percent of the total anion concentration. A high proportion of nitrate in precipitation in the Rocky Mountains has been attributed to exhaust from cars and other vehicles in urban areas and agricultural activity in the Great Plains States (National Atmospheric Deposition Program/National Trends Network, 1997).

Table 28. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major ions measured in water-quality samples from Rio Mora, New Mexico, 1963—95, and volume-weighted mean concentrations in wet precipitation collected at the Bandelier National Monument Station, New Mexico, 1982—95

[Parameters in units of microequivalents per liter, except for discharge in cubic meters per second, specific conductance in microsiemens per centimeter at 25 degrees Celsius, pH in standard units, and silica in micromoles per liter; n, number of stream samples; VWM, volume-weighted mean; spec. cond., specific conductance; --, not reported; <, less than; [a] Laboratory pH]

Parameter	Stream Water						Precipitation VWM
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge	0.03	0.19	0.42	0.91	9.3	200	--
Spec. cond., field	34	86	101	117	223	200	--
pH, field	6.5	7.3	7.6	7.9	9.0	201	5.0[a]
Calcium	150	700	800	950	1,800	195	11
Magnesium	48	110	140	160	300	195	1.8
Sodium	26	48	61	74	170	193	2.8
Potassium	7.7	10	13	15	46	191	.77
Ammonium	<.7	.7	2.1	4.3	18	66	8.0
Alkalinity, laboratory	260	720	860	960	1,900	201	--
Sulfate	21	140	170	210	400	193	18
Chloride	<2.8	11	17	25	180	199	2.6
Nitrite plus nitrate	<.7	<3.6	6.0	7.1	21	86	13[b]
Silica	69	92	98	100	150	192	--

Stream water in the Rio Mora is a slightly alkaline, calcium bicarbonate type. The sum of ion concentrations ranged from about 700 to about 4,500 meq/L. Alkalinity ranged from 260 to 1,900 meq/L, and bicarbonate was the primary contributor to alkalinity at this station. Calcium, the major cation, accounted for about 79 percent of the median cation concentration in stream water; bicarbonate, the major anion, accounted for about 82 percent of the median anion concentration. The predominance of these two ions indicates that the weathering of carbonate rocks, particularly limestone, is important to stream chemistry. Annual precipitation and runoff data indicate that evapotranspiration can account for almost a threefold increase in stream- water concentrations compared to precipitation. After adjusting for evapotranspiration, sulfate and chloride concentrations in precipitation at the NADP station accounted for about 32 to 46 percent of the median stream-water concentrations, respectively. This is a conservative estimate of sulfate precipitation contributions, however, because dry deposition is not included. Median concentrations of ammonium and nitrate were lower in the stream water than in precipitation, indicating that nitrogen generally is retained by the biomass in the basin.

Correlations among dissolved constituents and discharge were determined for the Rio Mora (table 29). The base cations and anions showed inverse relations with discharge. These results are consistent with a hydrologic system where base-flow chemistry that is dominated by ground water is diluted during periods of increased discharge, including snowmelt runoff. Ion concentrations in ground water tend to be greater than in surficial sources because the contact time with rocks and minerals is longer. Strong correlations existed among the major carbonate ions. Carbonate rocks, including limestone, are common in the basin and are important in controlling the ion composition of the ground- and stream-water chemistry. The calcium-magnesium (rho value = 0.950) calcium-alkalinity correlations (rho value = 0.951) were the highest. The correlation between magnesium and alkalinity was 0.906. A strong correlation (rho value = 0.918) also exists between magnesium and sodium.

Table 29. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Rio Mora, New Mexico, 1980 through 1995

[Q, discharge; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO_4, sulfate; Cl, chloride; SiO_2, silica; --, not applicable]

	Q	pH	Ca	Mg	Na	K	Alk	SO_4	Cl
pH	-0.135	--	--	--	--	--	--	--	--
Ca	-.771	0.070	--	--	--	--	--	--	--
Mg	-.805	.094	0.950	--	--	--	--	--	--
Na	-.792	.045	.872	0.918	--	--	--	--	--
K	-.121	.110	.101	.165	0.226	--	--	--	--
Alk	-.712	-.063	.951	.906	.814	0.118	--	--	--
SO_4	-.593	.188	.700	.681	.683	.269	0.590	--	--
Cl	-.230	-.020	.330	.387	.319	.247	.324	0.424	--
SiO_2	-.388	-.023	.683	.685	.631	.136	.708	.460	0.150

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for the Rio Mora from 1965 through 1995 are presented in table 30. Statistically significant upward trends (a = 0.01) occurred in discharge. The trend in discharge is only representative of instantaneous measurements made during water-quality sampling and may not correspond with a trend in the continuous discharge record. Insufficient data existed for nitrate to calculate a trend. The scatter in the time-series plot for nitrate concentrations is a function of a change in the minimum reporting level for the laboratory method about 1991, rather than an environmental change.

Table 30. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Rio Mora, New Mexico, 1965 through 1995

[Trends in units of microequivalents per liter per year, except for discharge in cubic meters per second per year, pH in standard units per year, and silica in micromoles per liter per year; p-value, attained significance level; --, not calculated; <, less than]

Parameter	Unadjusted		Flow adjusted	
	Trend	p-value	Trend	p-value
Discharge	0.3	0.004	--	--
pH	<.01	.749	([a])	--
Calcium	<.01	.503	1	0.317
Magnesium	<.01	.313	0.2	.436
Sodium	<.01	.661	.2	.224
Potassium	<.01	.094	([a])	--
Alkalinity	<.01	.525	3	.013
Sulfate	-1	.006	-.7	.039
Chloride	<.01	.227	([a])	--
Nitrite plus nitrate	([b])	--	--	--
Silica	.1	.080	.2	.012

[a] Concentration-flow model not significant at a = 0.10.

[b] Insufficient data to calculate trend.

A statistically significant downward trend (a = 0.01) occurred in unadjusted concentrations of sulfate. The sulfate trend was no longer detected after the concentrations were flow adjusted for variations in discharge. Trends in sulfate concentrations in New Mexico’s surface waters have varied over the study period in other studies. Smith and Alexander (1983) observed an upward trend in flow-adjusted sulfate concentrations and a corresponding down- ward trend in alkalinity (a = 0.01 to 0.10) for the period late 1960’s to 1981 at this station. For the study period 1975–89, downward trends in sulfate were reported at several surface-water stations in New Mexico (U.S. Geological Survey, 1993). The decrease was attributed to reductions in emissions from copper smelters. Lins (1987) reported that sulfur-dioxide emissions in New Mexico decreased by 33 percent for the period 1975–84. Lynch and others (1995) have reported corresponding decreases in precipitation sulfate concentrations for the period 1980–92.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling conducted June 18–20, 1991, in the Rio Mora Basin are presented in table 31, and locations of the sampling sites are shown in figure 15. Discharge at the HBN station (site 9) was 1.3 m^3/s compared to the mean monthly discharge of 2.5 m^3/s for the month of June (Ortiz and Lange, 1996). The sum of ions ranged from 700 (site1) to 2,700 meq/L (site 6); the concentration at the HBN station (site 9) was 1,500 meq/L. Concentrations of dissolved constituents were within the range of concentrations observed at the Rio Mora HBN station for the period of record, 1963–95 (table 28), except for sodium at the Rio Mora site upstream from the pack trail (site 1), which was less than any samples at the HBN station. The concentrations of constituents collected at the HBN station (site 9) during the synoptic sampling generally were less than the first-quartile values reported for the station (table 28). Concentrations of dissolved constituents, except sulfate and nitrate, increased in the downstream direction at sites on the Rio Mora (sites 1, 7, and 9). The water type of samples that were collected throughout the Rio Mora Basin was calcium bicarbonate. Sulfate concentrations were variable in the drainages and ranged from 46 (site 5) to 250 (site 3) meq/L. The percent difference of cations and anions ranged from 2.4 to 7.4 percent, indicating that unmeasured ions do not substantially contribute to the ionic content of the water.

Table 31. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Rio Mora Basin, June 18—20, 1991

[Site locations shown in fig. 15; Q, discharge in cubic meters per second; SC, specific conductance in microsiemens per centimeter at 25 degrees Celsius; pH in standard units; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO4, sulfate; Cl, chloride; NO3, nitrate; SiO2, silica; concentrations in microequivalents per liter, except silica is in micromoles per liter; --, not measured; <, less than; criteria used in selection of sampling sites: BG = bedrock geology, TRIB = major tributary]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO_4	Cl	NO_3	SiO_2	Criteria
1	355241105333100	0.45	39	7.5	270	55	22	9.0	270	67	6.5	<0.7	75	BG
2	355216105335100	.05	92	7.8	700	160	74	13	790	200	8.7	<.7	140	BG
3	355329105343700	.18	71	7.8	600	88	26	9.7	530	250	6.2	<.7	73	BG
4	355215105323700	.26	73	7.8	600	100	26	10	560	130	6.5	1.4	77	TRIB
5	355120105350900	.09	92	7.9	750	120	44	11	770	46	8.7	<.7	93	BG
6	355127105352700	--	138	8.1	1,200	180	52	10	1,100	160	5.6	<3.6	110	BG
7	354725105383200	.91	65	7.8	500	88	35	10	490	230	7.3	<.7	85	TRIB
8	354724105383200	.19	133	8.1	1,100	150	52	12	1,100	75	8.5	<3.6	110	TRIB
9	08377900	1.3	81	7.9	650	110	39	11	620	100	8.5	<.7	92	--

Tributaries contributing high concentrations of calcium and bicarbonate were Bear Creek (site 8) and the unnamed tributary below Hamilton Mesa (site 6). The tributary below Hamilton Mesa may contain higher concentrations of calcium (1,200 meq/L) and bicarbonate (1,100 meq/L) because it is the only subbasin draining almost entirely sedimentary rocks. The concentrations of calcium (1,100 meq/L) and bicarbonate (1,100 meq/L) at Bear Creek (site 8), which drains sedimentary, igneous, and metamorphic rocks, are more than double the concentrations at the nearby Rio Mora site (site 7) upstream from the mouth of Bear Creek. The influence of Bear Creek on water quality at the Rio Mora HBN station (site 9) is reflected in higher concentrations of calcium, magnesium, and alkalinity, and a lower sulfate concentration compared to the upstream site (site 7). Nitrate concentrations are low in all basins and are characteristic of undeveloped areas (Mueller and others, 1995).

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Cowles, New Mexico (1:24,000), 1961, streamflow-gaging station
- Elk Mountain, New Mexico (1:24,000), 1963
- Gascon, New Mexico (1:24,000), 1965
- Pecos Falls, New Mexico (1:24,000), 1963

b. Geologic maps:

- Moench, R.H., Grambling, J.A., and Robertson, J.M., 1988, Geologic map of the Pecos Wilderness, Santa Fe, San Miguel, Mora, Rio Arriba, and Taos Counties, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1921–B, 2 pl., scale 1:48,000.
- U.S. Geological Survey, U.S. Bureau of Mines, New Mexico Bureau of Mines and Mineral Resources, 1980, Mineral resources of the Pecos Wilderness and adjacent areas, Santa Fe, San Miguel, Mora, Rio Arriba, and Taos Counties, New Mexico: U.S. Geological Survey Open-File Report 80–382, 103 p.

c. Soil surveys: No soil survey available.

d. Other maps:

- Santa Fe National Forest map, 1975, U.S. Department of Agriculture, scale 1 inch = 2 miles.
- Santa Fe, New Mexico, 30' x 60' quadrangle, Bureau of Land Management, 1983, scale 1:100,000.

Appendix B. NWIS Site-Identification Numbers

Table B–1. NWIS site-identification numbers and site names for water-quality sampling sites.

Site	Identification Number	Site Name
1	355241105333100	RIO MORA ABOVE PACK TRAIL
2	355216105335100	RITO DEL OSO
3	355329105343700	UPPER RIO VALDEZ
4	355215105323700	RIO VALDEZ
5	355120105350900	RITO LOS ESTEROS
6	355127105352700	TRIBUTARY BELOW HAMILTON MESA
7	354725105383200	RIO MORA ABOVE BEAR CREEK
8	354724105383200	BEAR CREEK
9	08377900	RIO MORA NEAR TERERRO, NEW MEXICO