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

Encampment River above Hog Park Creek near Encampment, Wyoming (06623800)

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.

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Site Characteristics and Land Use

The Encampment River HBN Basin is in the Southern Rocky Mountains physiographic province (Fenneman, 1946) in northern Colorado and southern Wyoming (Figure 26. *Map showing study area in Encampment River Basin and photograph of the*

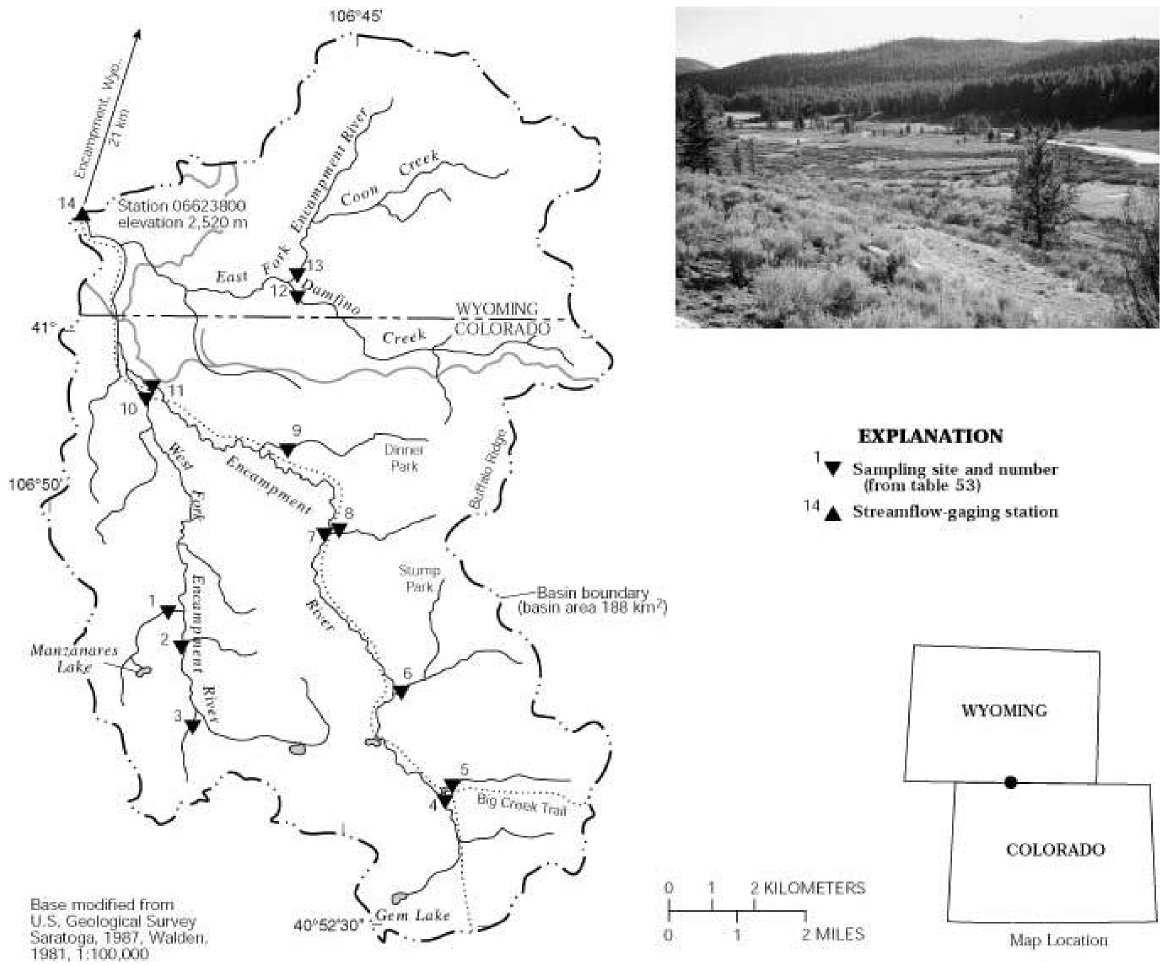

Figure 26. *Map showing study area in Encampment River Basin and photograph of the East Fork Encampment River*

East Fork Encampment River). The HBN station is 21 km south of Encampment, Wyo., at a latitude of 41×01'25" and a longitude of 106×49'27". The Encampment River drains 188 km^2 of mountainous terrain in the Park Range of northern Colorado and the Sierra Madres of southern Wyoming. Elevations in the basin range from 2, 520 to more than 3,470 m. The stream gradient of the main stream is about 19 m/km. The ecoregion of the basin is classified as the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest- Alpine Meadow Province (Bailey, 1995). Over 90 percent of the area is covered by montane and subalpine forest types, including spruce and subalpine fir, lodgepole pine, and minor amounts of aspen (Jerry Schmidt, U.S. Forest Service, written commun., 1997). Vegetation of the alpine meadows and valleys includes grasses, wildflowers, and small shrubs. A small part of the basin is bare ground or rock, lying above timberline. The Encampment River is tributary to the North Platte River.

The Encampment River is a perennial stream with a snowmelt-dominated hydrograph. Mean monthly discharge ranges from 0.52 m^3/s during base flow in February to 17 m^3/s during snowmelt runoff in June (Smalley and others, 1996). Average annual precipitation at the Encampment weather station is about 37 cm. Precipitation increases in the basin with increasing elevation. At the higher elevations, precipitation is about 76 cm, which mostly falls as snow during the period October through May (Cobb and Biesecker, 1971). Average annual runoff is about 50 cm. The climate of the basin is characterized by cold winters and mild summers. Mean monthly temperatures ranged from -5.8×C in January to about 17.2×C in July at the Encampment weather station during the period 1948–95 (National Climatic Data Center, 1996). Basin temperatures decrease with increasing elevation.

The geology of the basin is dominated by crystalline rocks. The rocks generally are resistant to erosion and form ledges and cliffs. Most of the area is underlain by intrusive and metamorphic rock types (Snyder, 1980; Houston and Graff, 1995). The Precambrian intrusive rocks are red to gray, massive, and range in composition from biotite granite to quartz monzonite to granodiorite. The metamorphic rocks include felsic gneiss and amphibolite metavolcanics that predominantly are faintly layered pink, gray, or green gneisses and are about 50 percent felsic and 50 percent mafic. Minerals in the metamorphic unit include quartz, feldspars, biotite, muscovite, magnetite, hornblende, garnet, sillimanite, and epidote. A small part of the southwestern part of the basin contains Permian or Triassic calcareous siltstone, shale, mudstone, and conglomerate. Precambrian metavolcanics and metasedimentary rocks are complexly folded and faulted (Snyder and others, 1987). Mineralization also occurred locally. Quaternary glacial till and remnant moraines lie within canyons and at the mouths of canyons.

The Encampment River HBN station is in the Medicine Bow-Routt National Forest. The headwaters lie within the Mount Zirkel Wilderness Area. The area near the HBN station also is designated as wilderness. About 99 percent of the land is federally owned. A small part of the East Fork Encampment Basin in Wyoming is State-owned and private land. Land cover is about 90 percent coniferous forest, 9 percent brush and grasses, and 1 percent roads and parking areas. Access to the HBN station is by light-duty road to within about 2 km of the site, then by hiking trail. Access has been improved by upgrading local gravel roads due to increased recreational use during the 1970’s and 1980’s. Four-wheel-drive roads and pack trails provide access to the tributary drainages during the summer. Access to the basin in winter is limited to snowmobiles, skis, and snowshoes. Mechanized vehicles are not allowed within the wilderness area.

Activities in the Encampment River HBN Basin that may affect water quality include logging operations, primarily at lower elevations, cattle grazing, and recreational use (Jerry Schmidt, U.S. Forest Service, written commun., 1997). Grazing was intense around the turn of the century and continued until the mid-1900’s when animal numbers were reduced. Grazing by sheep continued until 1968, when the allotment was temporarily rested. In 1978, the allotment was reopened to cattle grazing. Timber harvest has occurred in many of the drainages outside the wilderness area from the early 1900’s to present (2000). Timber harvest was minimal in the West Fork and East Fork Encampment River tributaries during the period 1960 to 1990. Timber harvest was allowed in these basins during 1990–96; a total of about 620 km^2 was harvested during this period. Best-management practices, including limiting clearcut size and tractor-logging harvesting, presently are used to minimize impact to forest resources. In the early 1900’s, railroad ties were floated or “driven” down tributary creeks of the Encampment River (Young and others, 1994). The tie drives and stream clearing associated with the driving reduced channel complexity and decreased the amount of large woody debris in streams. Recreational use is mainly fishing, hiking, horseback riding, backpacking, and hunting. Some primitive camping takes place in the basin. One closed mine is in the upper East Fork drainage, but the site is dry with no visible drainage. Several mines that are in the immediate vicinity, but outside the drainage area, have produced minor amounts of ore (Snyder and others, 1987).

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Encampment River HBN station includes 204 water-quality samples that were collected from October 1964 to September 1995. Sampling frequency is described on the basis of water year, which begins on October 1 and ends on September 30. Generally, about 8–10 samples were collected each year from 1968 through 1982. Sampling frequency was quarterly for most of the remaining sampling period. Samples were analyzed at USGS district water-quality laboratories until the early 1970’s. 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 1965 to current water 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 27a and 27b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Encampment River, Wyoming*. More than 90 percent of the samples had ion balances within the ±10 percent range, indicating that the major-ion analytical results generally were of good quality and that unmeasured constituents, such as organic anions,

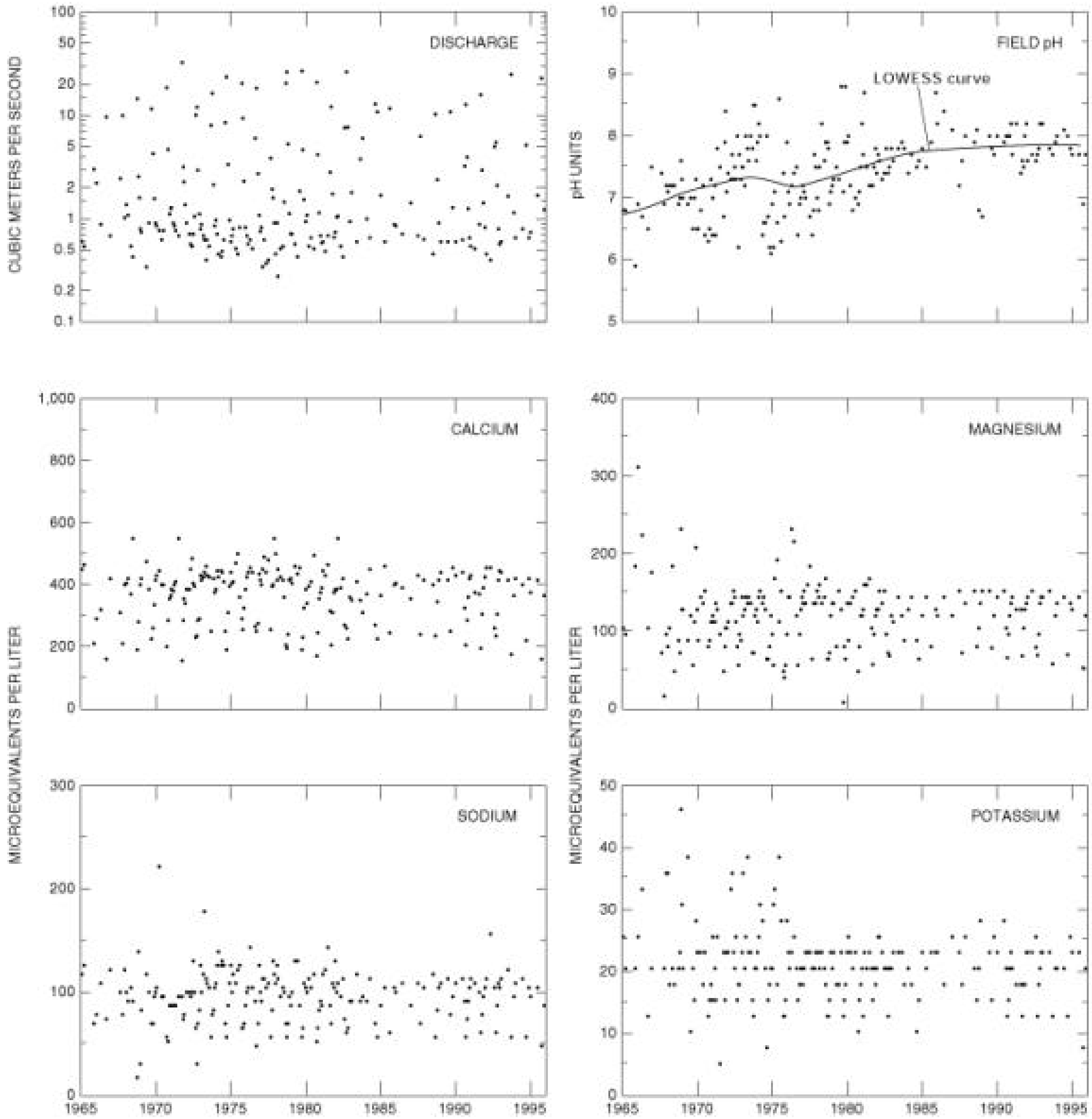

Figure 27a. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Encampment River, Wyoming*

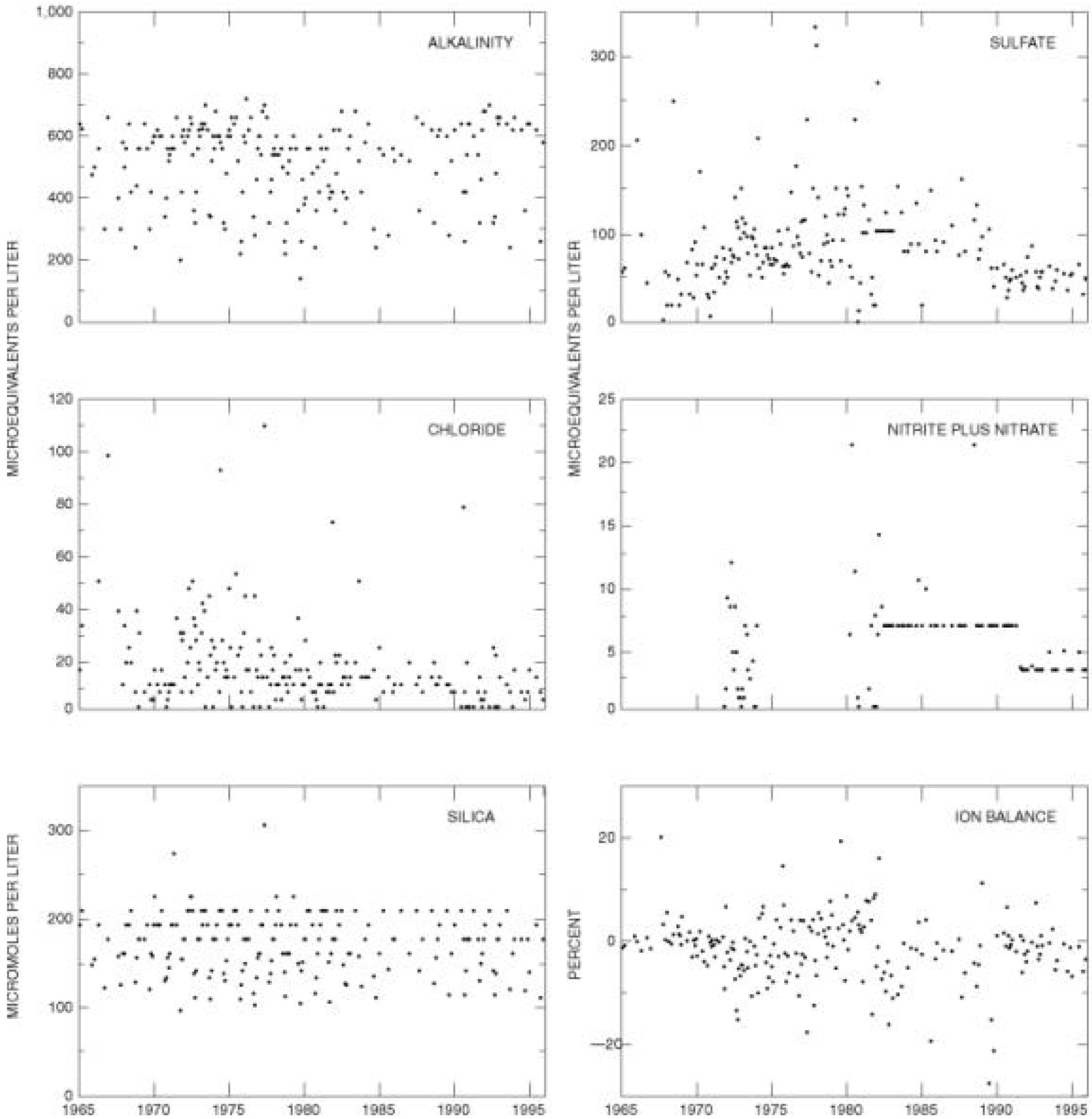

Figure 27b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Encampment River, Wyoming - Continued*

nutrients, and trace metals, generally do not contribute substantially to the ion composition of the stream water. Time-series plots of ion concentrations were inspected for data quality (fig. 27). Magnesium and sodium have slightly more scatter in the early part of the record and a decrease in scatter after 1983. This decrease coincides with a change in the analytical method for these analytes from AA spectroscopy to ICP spectroscopy (U.S. Geological Survey Office of Water Quality Technical Memorandum No. 82.18, 1982). The 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). The further decrease in the scatter of sulfate concentrations after 1990 corresponds with the change from turbidimetric titration to an ion-exchange chromatography analytical method (U.S. Geological Survey Office of Water Quality Technical Memorandum No. 90.04, 1989; U.S. Geological Survey Office of Water Quality Technical Memorandum No. 90.13, 1990). Changes also 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 Encampment River HBN station and VWM concentrations in wet precipitation measured at the Nash Fork NADP station are presented in table 50. The NADP station is about 80 km northeast of the HBN station. Precipitation chemistry at the NADP station was dilute and slightly acidic with a VWM pH of 5.2 during the period of record, 1987–92. The dominant cation in precipitation was calcium, which contributed 33 percent of the total cation concentration; ammonium contributed 25 percent and hydrogen contributed 22 percent. The dominant anions in precipitation were sulfate, which contributed 47 percent, and nitrate, which contributed 44 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 50. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major-ions measured in water-quality samples from the Encampment River, 1965—95, and volume-weighted mean concentrations in wet precipitation collected at the Nash Fork Station, Wyoming, 1987—92

[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]

Parameter	Stream Water						Precipitation VWM
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge	0.27	0.62	0.91	2.9	33	204	--
Spec. cond., field	17	50	62	69	140	203	--
pH, field	5.9	7.0	7.5	7.8	8.8	201	5.2[a]
Calcium	160	300	390	420	550	203	9.7
Magnesium	8.2	88	120	140	310	204	2.0
Sodium	17	83	100	110	220	203	3.5
Potassium	5.1	18	20	23	46	201	.48
Ammonium	<.7	<1.1	1.4	3.6	13	75	7.2
Alkalinity, laboratory	140	420	560	620	720	204	--
Sulfate	2.1	54	75	100	330	203	14
Chloride	<2.8	8.5	14	21	110	204	2.7
Nitrite plus nitrate	<.7	<3.6	6.4	7.1	21	107	13[b]
Silica	97	150	180	190	310	204	--

[a] Laboratory pH.

[b] Nitrate only.

Stream water in the Encampment River is a mildly alkaline, calcium bicarbonate type. The sum of ion concentrations ranged from about 510 to about 1,900 meq/L. Alkalinity ranged from 140 to 720 meq/L, and bicarbonate was the primary contributor to alkalinity at this station. The major cations in the stream water were calcium (62 percent), magnesium (19 percent), and sodium (16 percent). Bicarbonate, the major anion, contributed 86 percent of the median anion concentration. Dissolved solids generally are low at this site because granitic and gneissic bedrock is resistant to weathering. Annual precipitation and runoff data indicate that evapotranspiration can account for less than a twofold increase in stream-water concentrations compared to precipitation. About 38 percent of the median sulfate concentration can be attributed to precipitation after accounting for evapotranspiration. Similar to sulfate, only 39 percent of the median chloride concentration is attributable to precipitation. Igneous minerals, including hornblende, can contribute small amounts of chloride to stream water (Hem, 1992). Silica is a substantial component of the dissolved solids and is contributed by the feldspar- and quartz-rich rocks. Median concentrations of ammonium and nitrate were lower in the stream water than in the precipitation, indicating that nitrogen generally is retained by the biomass in the basin.

Table 51. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Encampment River, 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	-0.132	--	--	--	--	--	--	--	--
Ca	-.849	0.137	--	--	--	--	--	--	--
Mg	-.869	.110	0.935	--	--	--	--	--	--
Na	-.830	.125	.855	0.894	--	--	--	--	--
K	-.483	.209	.633	.571	0.576	--	--	--	--
Alk	-.777	.215	.782	.796	.738	0.512	--	--	--
SO_4	-.264	.044	.270	.328	.290	.359	0.099	--	--
Cl	.137	-.059	-.163	-.117	-.088	.168	-.177	0.353	--
SiO_2	-.864	.103	.850	.920	.862	.534	.699	.348	0.001

Correlations among dissolved constituents and discharge were determined for the Encampment River (table 51). The base cations and anions, except dissolved chloride, showed inverse relations with discharge. These results are consistent with a hydrologic system where base flow is diluted during periods of increased discharge, particularly annual 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. The consistency and strength of the relations of calcium (rho value = -0.849), sodium (-0.830), magnesium (-0.869), and silica (-0.864) with discharge indicate that the high concentrations of these constituents, which occur at low flow, reflect the ground-water chemistry. Strong correlations existed among the base cations calcium, magnesium, and sodium (rho value = 0.855 or greater). The strongest correlation was between calcium and magnesium (rho value = 0.935). Strong correlations also existed between the base cations and dissolved silica: calcium (rho value = 0.850); magnesium (rho value = 0.920); and sodium (rho value = 0.862). These relations reflect the weathering of felsic and mafic silicate minerals in the Precambrian rocks.

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for the Encampment River from 1965 through 1995 are presented in table 52. A statistically significant upward trend (a = 0.01) for unadjusted pH was determined. The flow-adjusted test, however, did not confirm this trend. The large number of censored nitrate values resulted in insufficient data to calculate a trend for nitrate concentrations. The pattern in the scatter of nitrate concentrations in the time- series plot is a function of a change in the minimum reporting level for the laboratory method about 1991, rather than an environmental change. An upward trend in sulfate and a downward trend in alkalinity determined by Smith and Alexander (1983) at this station were no longer detected in the data. Precipitation-chemistry data have shown a decrease in sulfate concentrations in many regional NADP stations for the period 1980–92 (Lynch and others, 1995). No trend in stream-water sulfate was detected at this station, but concentrations were consistently low after about 1990.

Table 52. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Encampment River, 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	-0.12	0.411	--	--
pH	.03	<.001	([a])	--
Calcium	.6	.199	0.4	0.200
Magnesium	<.01	.651	-.02	.872
Sodium	<.01	.723	.06	.622
Potassium	<.01	.299	-.03	.255
Alkalinity	.9	.194	.7	.201
Sulfate	.09	.761	-.01	.970
Chloride	-.2	.040	([a])	--
Nitrite plus nitrate	([b])	--	--	--
Silica	<.01	.749	-.2	.221

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

[b] Insufficient data to calculate trend.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling conducted September 10–12, 1990, in the Encampment River Basin are presented in table 53, and locations of the sampling sites are shown in figure 26. Discharge at the HBN station (site 14) was 0.54 m^3/s compared to the mean monthly discharge of 0.90 m^3/s for the month of September (Smalley and others, 1996). The water type of all tributary and main-stem sites sampled in the basin was calcium bicarbonate. The sum of ion concentrations in tributaries ranged from about 620 (site 4) to about 5,000 meq/L (site 3). The sum of ions concentration at the HBN station (site 14) was about 1,300 meq/L; concentrations of major cations and anions were near the median concentrations for the period 1965–95 (table 50). Concentrations of ions in tributary water samples were within the range of ion concentrations for the HBN station (table 49), except for concentrations of certain constituents at sites 2 and 3. Concentrations of calcium, magnesium, bicarbonate, and sulfate in the sample collected at the unnamed south tributary to the West Fork Encampment River (site 3) were much higher (3 to 10 times) than the median concentrations of ions in samples from the HBN station. The geology in the upper basin upstream from site 3 includes an area draining sedimentary rocks containing siltstone, shales, mudstone, and conglomerate. Water in contact with fine-grained sedimentary deposits such as these tends to have higher dissolved solids than water in contact with the more resistant Precambrian igneous and metamorphic rocks that are predominant in the rest of the basin. Contributions from this unnamed south tributary (site 3) contribute to the elevated concentrations of constituents in the upper West Fork Encampment River (site 2), particularly calcium, which exceeds the maximum concentration at the HBN station. Low dissolved solids were reported for sites 4 and 5. Pleistocene till deposits dominate the surficial geology around those sites. Rocks in the basin upstream from sites 4 and 5 are Precambrian quartz monzonite. The percent difference of cations and anions in all synoptic samples ranged from 0.2 to 3.8 percent, indicating that unmeasured ions did not substantially contribute to the ionic content of the water. Nitrate concentrations were low in all basins and are characteristic of undeveloped areas (Mueller and others, 1995).

Table 53. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Encampment River Basin, September 10—12, 1990

[Site locations shown in fig. 26; 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; SO_4, sulfate; Cl, chloride; NO_3, nitrate; SiO_2, 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, LU = land use]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO_4	Cl	NO_3	SiO_2	Criteria
1	405627106475100	--	51	7.8	280	140	100	19	500	27	4.8	<0.7	200	BG
2	405603106474200	--	90	8.0	650	190	83	24	780	170	5.1	2.1	120	TRIB
3	405508106472800	--	198	8.3	1,800	510	140	22	1,800	770	5.6	<.7	120	BG
4	405409106431600	--	32	7.5	180	55	61	18	280	25	4.8	<.7	110	BG
5	405414106432000	--	31	7.6	170	55	74	18	280	31	4.2	<.7	150	BG
6	405528106440900	--	39	7.8	240	72	83	12	390	35	5.6	<.7	160	BG
7	405731106452000	--	63	7.9	440	110	78	28	660	44	6.5	1.4	140	TRIB
8	405731106451400	--	51	7.9	360	79	83	16	500	35	5.1	<.7	180	BG
9	405831106460100	--	50	7.9	300	130	110	16	490	35	5.9	<.7	220	BG
10	405916106482800	--	71	8.0	450	180	100	25	650	81	8.7	<.7	170	TRIB
11	405919106481500	--	67	8.0	450	140	87	26	640	48	7.3	<.7	160	LU
12	410039106460101	--	55	8.0	350	130	120	17	540	38	9.6	<.7	200	TRIB
13	410041106460101	--	38	7.8	220	88	96	14	360	38	7.0	<.7	180	TRIB
14	06623800	0.54	60	7.9	400	140	100	23	600	58	9.0	<.7	180	--

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Blackhall Mountain, Wyoming-Colorado (1:24,000), 1983
- Davis Peak, Colorado (1:24,000), 1955
- Dudley Creek, Wyoming-Colorado (1:24,000), 1983, streamflow-gaging station
- Mount Zirkel, Colorado (1:24,000), 1955
- Saratoga, Wyoming-Colorado (1:100,000), 1982
- Walden, Wyoming-Colorado (1:100,000), 1981
- West Fork Lake, Colorado (1:24,000), 1962

b. Geologic maps:

- Houston, R.S., and Ebbett, B.E., 1977, Geologic map of the Sierra Madre and western Medicine Bow Mountains, southeastern Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–827, 1 sheet.
- Houston, R.S., and Graff, P.J., 1995, Geologic map of Precambrian rocks of the Sierra Madre, Carbon County, Wyoming, and Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I–2452, 2 sheets.

- Snyder, G.L., 1980, Geologic map of the northernmost Park Range and southernmost Sierra Madre, Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I–1113, scale 1:48,000.
- Snyder, G.L., Patten, L.L., and Daniels, J.J., 1987, Mount Zirkel Wilderness and northern Park Range vicinity, Colorado: U.S. Geological Survey Bulletin 1554.

c. Soil surveys: No soil survey available.

d. Other maps:

- U.S. Geological Survey orthophotoquad, 7.5-minute series: Blackhall Mountain, Wyoming-Colorado, 1980, Davis Peak, Colorado, 1983, Dudley Creek, Wyoming-Colorado, 1980, Mount Zirkel, Colorado, 1983, West Fork Lake, Colorado, 1983
- Routt National Forest map, Ranger Districts, 1996,U.S. Department of Agriculture.

Appendix B. NWIS Site-Identification Numbers

Site	Identification Number	Site Name
1	405627106475100	UNNAMED TRIBUTARY BELOW MANZANARES LAKE
2	405603106474200	WEST FORK ENCAMPMENT RIVER FOUR MILES UPSTREAM FROM GAGE
3	405508106472800	UNNAMED SOUTH TRIBUTARY TO WEST FORK ENCAMPMENT RIVER
4	405409106431600	ENCAMPMENT RIVER BELOW GEM LAKE
5	405414106432000	UNNAMED TRIBUTARY CROSSING BIG CREEK TRAIL
6	405528106440900	UNNAMED TRIBUTARY BELOW STUMP PARK
7	405731106452000	ENCAMPMENT RIVER ABOVE UNNAMED TRIBUTARY BELOW BUFFALO RIDGE
8	405731106451400	UNNAMED TRIBUTARY BELOW BUFFALO RIDGE
9	405831106460100	UNNAMED TRIBUTARY BELOW DINNER PARK
10	405916106482800	WEST FORK ENCAMPMENT RIVER
11	405919106481500	ENCAMPMENT RIVER ABOVE WEST FORK ENCAMPMENT RIVER
12	410039106460101	DAMFINO CREEK
13	410041106460101	EAST FORK ENCAMPMENT RIVER ABOVE DAMFINO CREEK
14	06623800	ENCAMPMENT RIVER ABOVE HOG PARK CREEK NEAR ENCAMPMENT, WYOMING