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

Bear Den Creek near Mandaree, North Dakota (06332515)

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 Bear Den Creek HBN Basin is in the Missouri Plateau Section of the Great Plains physiographic province (Fenneman, 1946) in western North Dakota (Figure 17. *Map showing study area in the Bear Den Creek Basin and photograph of the streamflow gaging station*). The HBN station is about 8.8 km northwest of Mandaree, N. Dak., at a latitude of 47×47'14" and a longitude of 102×46'05". Bear Den Creek drains 192 km^2 of grass-covered hills and badlands that are gently rolling in the upper basin to steep land

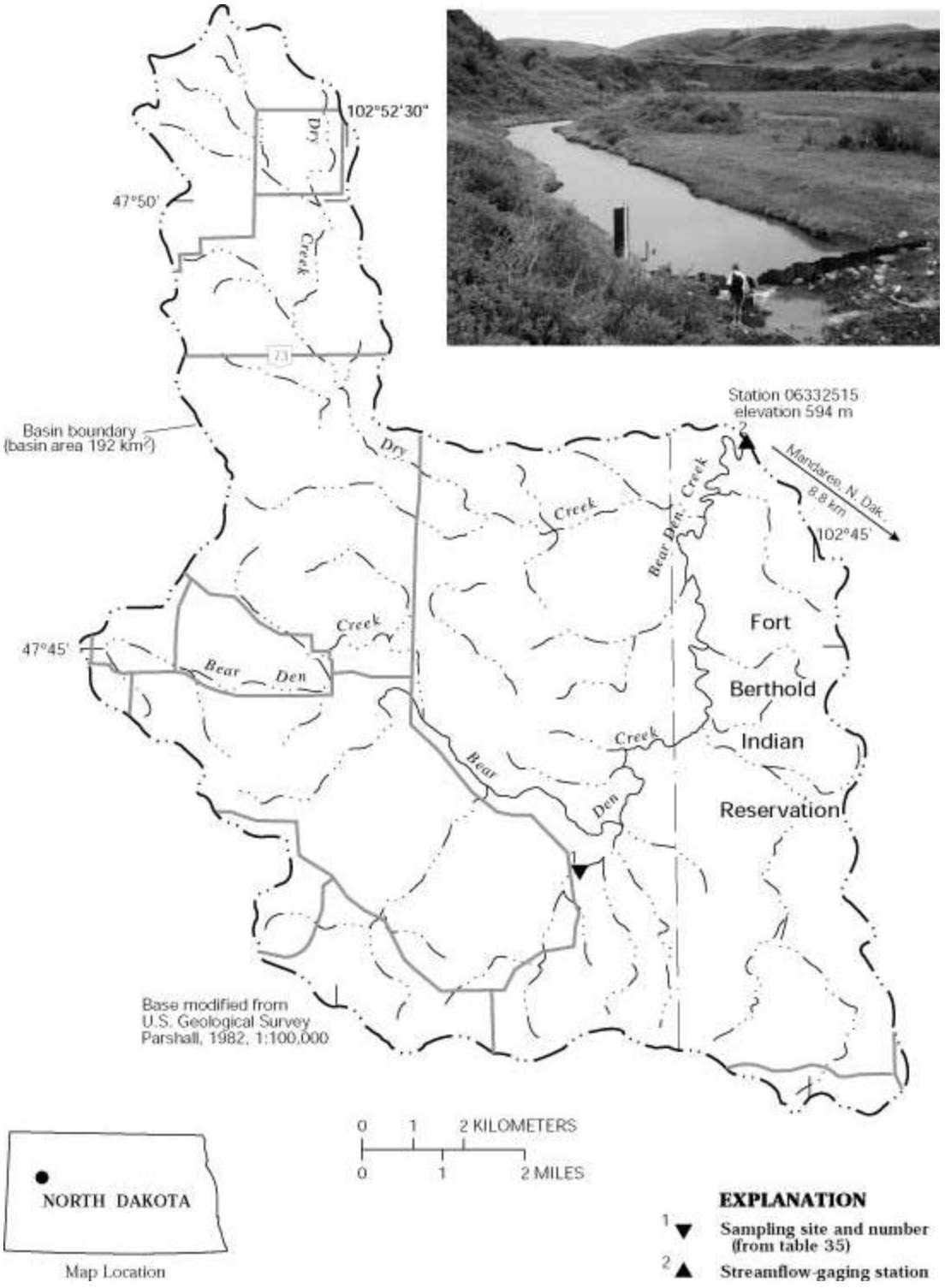

Figure 17. *Map showing study area in the Bear Den Creek Basin and photograph of the streamflow gaging station*

slopes in the lower basin. Basin elevations range from about 594 to 869 m. The ecoregion of the basin is classified as the Great Plains-Palouse Dry Steppe Province (Bailey, 1995). The Bear Den Creek Basin predominantly is covered with a fairly dense sod of native grass with small trees growing in some of the drainages. Part of the western basin is cultivated with grain crops. Bear Den Creek drains into Lake Sakakawea on the Missouri River.

Bear Den Creek is an intermittent stream. At times during the late summer and winter months, little or no flow occurs in the channel. Spring rains produce the highest flows in March and April. Mean monthly discharges range from 0.004 m^3/s in December to 1.0 m^3/s in March (Harkness and others, 1996). Average annual precipitation at the Keene weather station (17 km northwest of the HBN station) is 39 cm. Most of the precipitation falls as rain in the spring and early summer. Average annual runoff is about 3 cm (Harkness and others, 1996). The climate is characterized by cold winters and mild summers; mean monthly temperatures ranged from -12.3×C in January to 20.5×C in July during the period of record, 1959–95 (National Climatic Data Center, 1996).

The Bear Den Creek Basin is underlain by the Sentinel Butte Formation of Paleocene age. The formation contains interbedded brownish-gray and gray silt, clay, sand, and lignite (Carlson, 1985). The formation is characterized by bentonitic clay, petrified wood, and scoria. Lignite, a low-grade coal consisting of plant fragments and petrified wood, are from ancient swamps that formed along ancient streams flowing eastward from the Rocky Mountain uplift. The reddish layers of scoria-like material are composed of sediment that was baked by burning lignite (Bluemle, 1975). Flood-plain deposits are composed of brownish-gray silt and clay with minor amounts of sand and gravel.

The Bear Den Creek HBN station is in McKenzie County. The Bear Den Creek Basin is 75 percent privately owned, 20 percent is owned by the Fort Berthold Indian Reservation, 2 percent is State land, 2 percent is Federal land, and 1 percent other (Paul Deutsch, Natural Resources Conservation Service, written commun., 1996). Access to the HBN station is by a primitive road off a secondary highway on the Fort Berthold Indian Reservation. The basin is accessible year round, as weather permits. Primitive roads, improved roads, and primary access routes (typically suited for automobile travel) traverse parts of the upper basin. No roads exist in parts of the lower and eastern basin. Land use in the basin is predominantly agriculture, including pastures with cattle and horse grazing in the central and eastern parts and a small amount of cultivation in the western part. Rural residences and stock ponds are present in the basin. An oil and gas field and pipeline associated with oil production is located in the northwest part of the basin (Lawrence, 1987). Oil drilling was active during the 1970's and 1980's (L.L. Rutschke, U.S. Geological Survey, oral commun., 1997). Scoria gravel pits also are present in the basin.

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Bear Den Creek HBN station includes 236 water-quality samples that were collected from August 1966 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 during the period of record. The most complete data set exists for the period between 1968 and 1981 when 10–14 samples were collected annually. After 1981, sampling frequency decreased; five or six samples were collected in most water years. 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 1966 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 18a and 18b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Bear Den Creek, North Dakota.* More than 95 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. 18). The decrease in scatter of cations may be related to more variation in discharge, which reflects greater sampling frequency in the early part of record. The method changes in 1982 and 1990 for sulfate are less apparent in the data scatter at this site probably owing to the large range of concentrations observed at this site. The positive bias introduced by the sulfate turbidimetric titration method between 1982 and 1989 probably is not substantial because the method bias occurred at low concentrations (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 Bear Den Creek HBN station and VWM concentrations in wet precipitation measured at the Theodore Roosevelt National Park NADP station are presented in table 32. The NADP station is about 59 km southwest of the HBN station. Precipitation chemistry at the NADP station is dilute and slightly acidic with VWM pH of 5.3 during the period of record, 1981–95. Ammonium, the dominant cation in precipitation, contributed 37 percent of the total cation concentration, followed by calcium, which contributed 30 percent of the total cation concentration. The dominant anion in precipitation was sulfate,

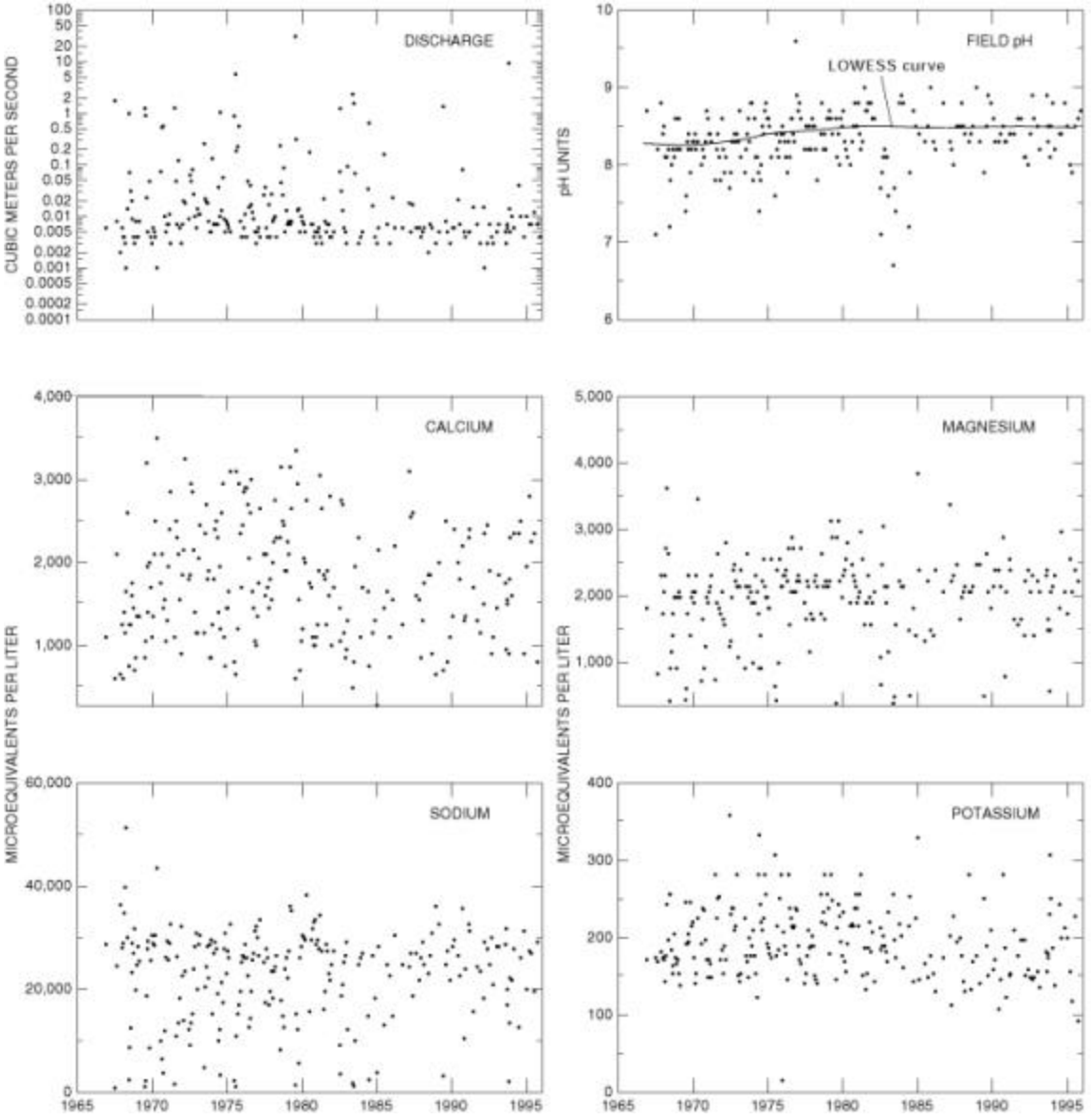

Figure 18a. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Bear Den Creek, North Dakota*

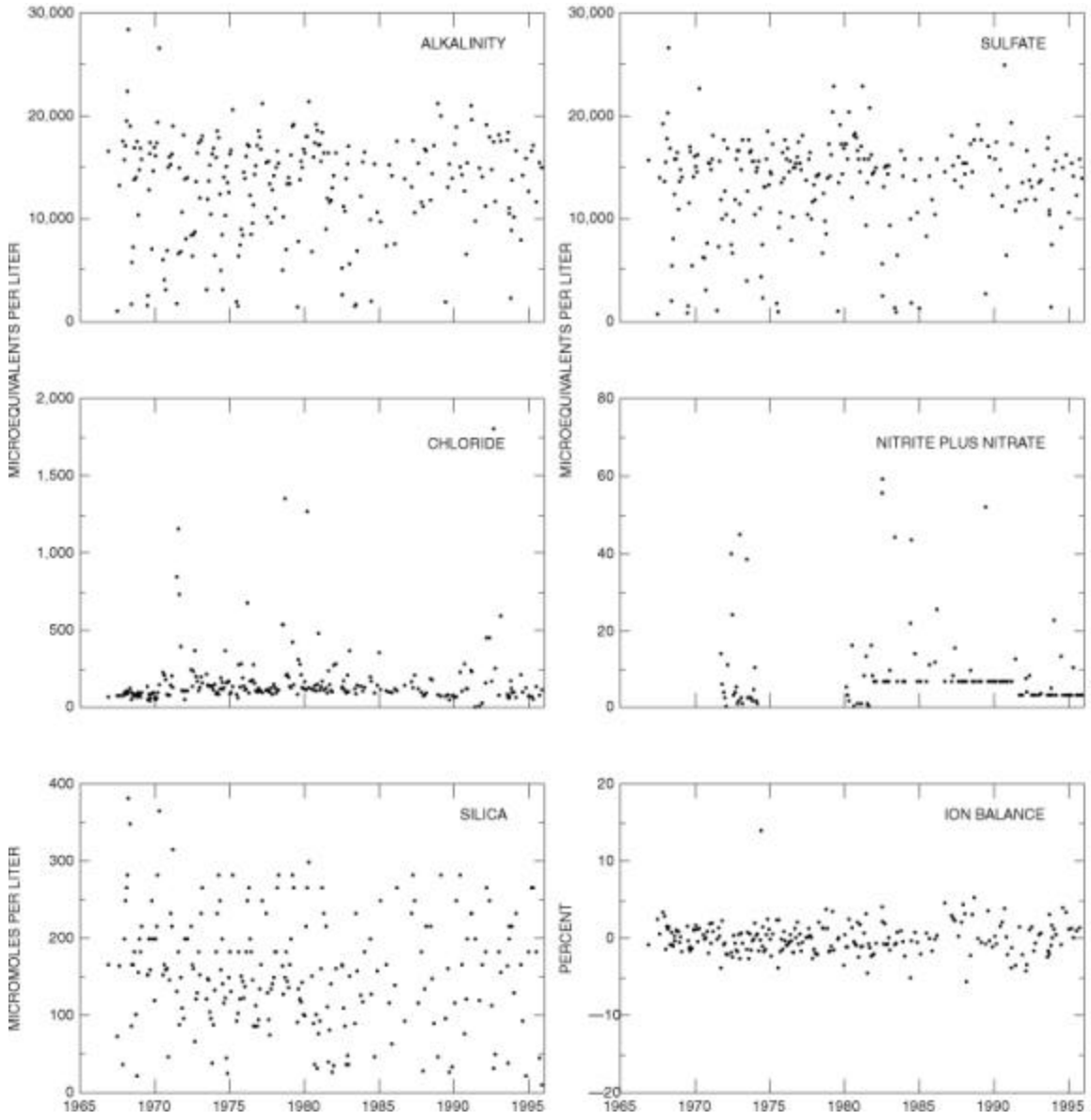

Figure 18b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Bear Den Creek, North Dakota - Continued*

which contributed 57 percent of the total anion concentration, followed by nitrate, which contributed 38 percent of the concentration. Contributions from nitrogen species were less at this site than in precipitation from eastern North Dakota, possibly because the area is farther from the intensive crop activities in the Midwest.

Table 32. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major ions measured in water-quality samples from Bear Den Creek, North Dakota, 1966—95, and volume-weighted mean concentrations in wet precipitation collected at the Theodore Roosevelt National Park Station, North Dakota, 1981—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]

Parameter	Stream Water						Precipitation VWM
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge	<0.001	0.005	0.007	0.02	31	236	--
Spec. cond., field	192	1,950	2,650	2,900	4,600	236	--
pH, field	6.7	8.2	8.4	8.6	9.6	233	5.3[a]
Calcium	270	1,200	1,700	2,300	3,500	235	12
Magnesium	340	1,600	2,100	2,300	3,800	234	4.0
Sodium	830	17,000	25,000	29,000	51,000	235	3.3
Potassium	15	160	190	230	360	235	.80
Ammonium	<.7	1.4	3.6	7.9	27	88	15
Alkalinity, laboratory	1,000	10,000	14,000	17,000	28,000	234	--
Sulfate	730	11,000	15,000	16,000	27,000	236	21
Chloride	2.8	93	120	170	1,800	235	2.2
Nitrite plus nitrate	<.7	<3.6	7.1	8.3	59	124	14[b]
Silica	10	110	160	200	380	235	--

[a] Laboratory pH; [b] Nitrate only.

Stream water in Bear Den Creek is a sodium sulfate-bicarbonate type. The sum of ion concentrations ranged from about 3,800 to about 100,000 meq/L. Alkalinity ranged from 1,000 to 28,000 meq/L, and bicarbonate is the primary contributor to alkalinity at this station. The dominant cation in the stream water was sodium, which accounted for 86 percent of the median cation concentration. The sodium concentrations were over 10 times greater than the calcium or magnesium concentrations. Wide ranges of sodium can occur in natural waters because high concentrations of sodium can be reached before any precipitate is formed (Hem, 1992, p. 101). Potassium concentrations were high, which probably reflect the weathering of the clay materials in the basin (Deer and others, 1966). Dissolved solids at this HBN station were higher than any other station in the Hydrologic Benchmark Network. Streams in basins with low average annual runoff and geologic settings that contain fine-grained sediments generally are characterized by high dissolved-solids concentrations (Biesecker and Leifeste, 1975). Specific conductance (192 to 4,600 mS/cm) is an indicator of the high dissolved solids at this station. Annual precipitation and runoff data indicate that evapotranspiration can account for at least a tenfold increase in stream-water concentrations compared to precipitation. Sodium concentrations were about 7,600 times higher in the stream than in precipitation, indicating a large source for sodium in the materials in the basin. Chloride concentrations also were higher than can be accounted for by evaporation of precipitation alone. In arid regions, when precipitation and runoff are insufficient to redissolve salts, salt residues accumulate in the soil or on exposed streambeds. Median concentrations of bicarbonate and sulfate in stream water were 48 and 51 percent of the total anion concentration, respectively. The highest dissolved solids occurred during low- flow conditions; ground-water recharge from the fractured lignite beds generally is high in dissolved solids (Cobb and Biesecker, 1971). 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 Bear Den Creek (table 33). The base cations and anions showed weak and mixed, positive and inverse relations with discharge. The average annual runoff is very low, which indicates that dilution of stream waters from precipitation is not a substantial process in the basin on an annual basis. Dilution from precipitation may be important, however, on an event basis. Some increases in discharge may be associated with temporary increases in dissolved-solids concentrations because salts that have accumulated in the soil are flushed out during the initial phases of the melting of snow, thawing of frozen ground, or rainfall events. Strong correlations were between sodium and alkalinity (rho value = 0.903) and sodium and sulfate (rho value = 0.869). Magnesium also was correlated with sodium, alkalinity, and sulfate. These relations, as well as the high concentrations of these constituents, indicate that dissolution of sodium- and magnesium-rich carbonate and sulfate salts contributes to the ion composition of the stream water.

Table 33. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Bear Den Creek, North Dakota, 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	-0.410	--	--	--	--	--	--	--	--
Ca	.080	-0.301	--	--	--	--	--	--	--
Mg	-.295	.056	0.485	--	--	--	--	--	--
Na	-.538	.299	.107	0.667	--	--	--	--	--
K	.195	-.057	-.143	-.168	-0.291	--	--	--	--
Alk	-.637	.214	.135	.637	.903	-0.388	--	--	--
SO_4	-.431	.299	.250	.735	.869	-.121	0.717	--	--
Cl	.002	-.197	.111	.079	.027	.192	-.008	0.036	--
SiO_2	.124	-.508	.621	.181	-.076	-.167	.067	-.054	0.041

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for Bear Den Creek from 1967 through 1995 are presented in table 34. The only statistically significant trend (a = 0.01) was an increase in unadjusted pH values. The flow-adjusted model did not predict a significant trend in pH, indicating variations in discharge may be controlling the hydrogen concentrations. Other trends in regional precipitation chemistry may be difficult to detect at this HBN station because, even after accounting for evapotranspiration, precipitation concentrations of base cations and anions were very small compared to stream-water concentrations of these constituents.

Table 34. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Bear Den Creek, North Dakota, 1967 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	<0.01	0.064	--	--
pH	.01	.004	<0.01	0.091
Calcium	<.01	.767	-3	.704
Magnesium	9	.033	4	.263
Sodium	100	.145	-36	.454
Potassium	-1	.025	-.5	.277
Alkalinity	59	.072	-37	.075
Sulfate	11	.654	-32	.224
Chloride	-.9	.197	-.6	.441
Nitrite plus nitrate	.2[a]	.071	--	--
Silica	-1	.048	-1	.023

[a] Trend test for highly censored data was used.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling event conducted on June 6, 1993, in the Bear Den Creek Basin are presented in table 35, and locations of the sampling sites are shown in figure 17. Discharge at the HBN station (site 2) was 0.03 m^3/s, which is slightly less than the mean monthly discharge of 0.08 m^3/s for the month of June (Harkness and others, 1996). Bear Den Creek typically starts to go dry about this time of year. Although a rain event occurred 1 day prior to the synoptic sampling, most of the ephemeral tributaries were dry during the synoptic sampling. One unnamed tributary in the south part of the drainage was sampled, but it was not measurably flowing.

Table 35. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Bear Den Basin, June 6, 1993

[Site locations shown in fig. 17; 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; criteria used in selection of sampling sites: TRIB = major tributary]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO_4	Cl	NO_3	SiO_2	Criteria
1	474235102485100	--	3,650	8.3	2,200	2,800	33,000	250	16,000	23,000	480	0.4	140	TRIB
2	06332515	0.03	2,410	8.8	1,200	1,400	22,000	140	13,000	12,000	45	.4	100	--

The sums of ions were 78,000 meq/L at the unnamed tributary site (site 1) and 50,000 meq/L at the HBN station (site 2). All analyzed constituents from the samples that were collected during the synoptic study were within the range recorded at the HBN station for the period of record, 1966–95 (table 32). The water type at the unnamed tributary (site 1) was sodium sulfate. The water type at the HBN station (site 2) was a sodium bicarbonate, although sulfate was a substantial component, contributing 48 percent of the total anion concentration. The composition of the water at site 1 indicates that dissolution of several salts contribute to the ion composition, including sodium carbonate, sodium sulfate, and sodium chloride. The chloride concentration at site 1 was more than 10 times the concentration at the HBN station. After adjusting for the effects of evapotranspiration, precipitation is estimated to contribute only about 5 percent of the chloride at site 1 compared to about 50 percent of the chloride at site 2. Sulfate contributions from precipitation were about 1 percent at site 1 and about 2 percent at site 2. This is a much smaller percentage than is typical of stations in the HBN program; precipitation is estimated to contribute at least 90 percent of the mean stream sulfate concentration at about one-half of the HBN stations around the country (Smith and Alexander, 1983). Precipitation chemistry can account for the nitrate concentrations in samples that were collected during the synoptic study.

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Blue Buttes, North Dakota (1:24,000), 1965, streamflow-gaging station
- Croff, North Dakota (1:24,000), 1959
- Figure 4 Ranch, North Dakota (1:24,000), 1970
- Johnsons Corner, North Dakota (1:24,000), 1965
- Mandaree, North Dakota (1:24,000), 1970
- Sanish SW, North Dakota (1:24,000), 1967

b. Geologic maps:

- Bluemle, J.P., 1988, Guide to the geology of southeastern North Dakota, North Dakota Geological Survey Educational Series 18, 36 p.
- Carlson, C.G., 1985, Geology of McKenzie County, North Dakota, North Dakota Geological Survey, Bulletin 80, pt 1.

c. Soil surveys:

No soil survey available.

d. Other maps:

- Parshall, North Dakota, 30' x 60' quadrangle, Bureau of Land Management, 1982, scale 1:100,000
- U.S. Department of Agriculture, 1986, Little Missouri National Grassland, North Dakota: U.S. Department of Agriculture, Forest Service, scale 1:126,720.

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	474235102485100	UNNAMED TRIBUTARY SOUTH OF MIDDLE BEAR DEN CREEK
2	06332515	BEAR DEN CREEK NEAR MANDAREE, NORTH DAKOTA