WATER-RESOURCES APPRAISAL OF THE LAKE TRAVERSE INDIAN RESERVATION IN SOUTH DAKOTA

By Stephen J. Lawrence

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CONVERSION FACTORS

For readers who may prefer to use metric (International System) units rather than inch-pound units, the conversion factors for the inch-pound units used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
acre	0.4047	hectare
acre-foot (acre-ft)	1,234	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
inch	25.4	millimeter
mile (mi)	1.609	kilometer
mile per hour (mi/h)	1.609	kilometer per hour
square mile (mi^2)	2.590	square kilometer

To convert degrees Celsius (°C) to degrees Fahrenheit (°F) use the following formula:

$$°F = 1.8 \times °C + 32.$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

WATER-RESOURCES APPRAISAL OF THE LAKE TRAVERSE

INDIAN RESERVATION IN SOUTH DAKOTA

By Stephen J. Lawrence

ABSTRACT

The water resources within the Lake Traverse Indian Reservation consist of streams, lakes, wetlands, and ground water stored in alluvium and glacial outwash deposits. Streamflow may cease during dry periods and during the winter. Lakes and ponds within the reservation are located predominantly within internally drained basins. Evaporation and ground-water recharge affect the fluctuations in lake levels and the water quality of the lakes. Dissolved-solids concentrations in lakes generally range from 500 to 10,000 milligrams per liter. Dissolved-solids concentrations in streams generally range from 500 to 1,000 milligrams per liter; the water generally is suitable for domestic, agricultural, and some industrial use. However, nutrient concentrations tend to be greater than natural background concentrations in both lakes and streams, and indicate unidentified sources of nutrients that affect the water quality. The development of surface-water resources is hindered by a lack of storage capacity within the numerous lakes, a lack of sustained streamflow, and a lack of suitable sites for construction of reservoirs. Therefore, the ground-water resource remains the only source with a potential for development into dependable water supplies within the reservation.

Ground-water resources within the Coteau des Prairies, a glacial upland, occur within glacial-outwash and alluvial deposits. Recharge and discharge points may be present in the Coteau where gravel deposits are within 5 feet of land surface. Locally, the sand and gravel deposits in the Coteau may be as thick as 70 feet. The water within these sand and gravel deposits generally is suitable for most uses; calcium, magnesium, and bicarbonate are the dominant ions. Ground water also occurs in sand and gravel deposits within the Minnesota River-Red River lowlands. Water in these deposits tends to be more mineralized than water in the sand and gravel deposits in the Coteau des Prairies. The regional ground-water flow generally is to the east in the Minnesota River-Red River lowlands, and to the west in the Coteau des Prairies. Additional data are needed to define the ground-water resource with sufficient detail to allow knowledgeable development of ground-water supplies.

INTRODUCTION

A knowledge of the quantity and quality of both surface- and ground-water resources is an important component of any plan designed to direct the economic development of semiarid areas such as South Dakota. Both the Indian tribal councils and the U.S. Bureau of Indian Affairs have become keenly aware of the importance of water to the Indian tribes of South Dakota. Such awareness has been increased by debate about Indian water rights, particularly with respect to the "first in time, first in right" and "use it or lose it" concepts in the "appropriation" and "riparian" doctrines of water law, and by the need for additional water supplies to support the expanding agricultural base and expanding domestic needs on the Indian reservations. In meeting this need for water-resources knowledge, most of the tribal councils have completed at least limited studies of the water resources within their reservations. Prior to this study, the Lake Traverse Indian Reservation was the only reservation in South Dakota without such a study.

This study of the Lake Traverse Indian Reservation in South Dakota (fig. 1) brings into a single document both published and unpublished data and information regarding the surface- and ground-water resources in the reservation. The 105 mi^2 of the reservation within North Dakota was not considered in this study. This report focuses on the quantity and quality of water, and on distribution of streams, lakes, and water-yielding geologic materials to provide knowledge of the water resources and to identify areas where data are lacking.

Physiography

Within South Dakota, the reservation occupies a triangular area of 1,490 mi^2 in the Central Lowlands physiographic province. The reservation is located in parts of five counties in South Dakota: Codington, Day, Grant, Marshall, and Roberts (fig. 1), and two physiographic divisions: the Minnesota River-Red River lowlands and the Coteau des Prairies (Flint, 1955) (fig. 2). Each physiographic division occupies about 50 percent of the reservation.

The two physiographic divisions have different topographic characteristics. The Minnesota River-Red River lowlands is a nearly flat ground moraine that consists of isolated areas of debris left by retreating glaciers (recessional moraine) and glacial meltwaters (outwash) (Koch, 1975). The Coteau des Prairies is a plateau of rolling, sometimes rugged, morainal topography. This topography was formed by the deposition of rock debris (lateral moraines) when Wisconsin ice sheets moved down the James River and Des Moines River valleys during the Pleistocene Epoch (Koch, 1975; Lindroth, 1976). The result is a hilly topography of moderate to high relief with numerous lakes and wetlands. The western face of the Coteau rises 600 ft from the James River lowland at a rate of 200 ft/mi, whereas the eastern face rises 800 ft from the Minnesota River-Red River lowlands at a rate of 300 ft/mi.

Climate

The climate in the study area is typically continental. Maximum daily temperatures average 25 to 31 °C and tend to occur from June through August (Hodge, 1960). Minimum daily temperatures occur from December through February and commonly are less than zero during January. The mean maximum daily temperature is 12.8 °C; the mean minimum is -0.6 °C for the 30-year (1951-80) period of record at Sisseton.

Although the Coteau des Prairies is a prominent upland, there doesn't appear to be any orographic effect caused by the Coteau. A majority of the precipitation in the area of the reservation occurs during March through September. Much of the precipitation is produced by low-pressure areas with associated cold fronts (frontal cyclones) moving across the reservation and frontal-induced thunderstorms (Hodge, 1960). The average annual precipitation ranges from 20 inches in the eastern part of the reservation to 22 inches in the southern part (National Oceanic and Atmospheric Administration, 1985). Precipitation tends to be greatest in May, June, and July, and least in December, January, and February. Total monthly precipitation equal to or greater than 8 inches could occur 5 percent of the time during May or June at either Sisseton or Watertown (fig. 3; National Oceanic and Atmospheric Administration, 1985). The average annual snowfall ranges from 32 inches in the northern part of the reservation to 36 inches in the central part of the reservation (National Oceanic and Atmospheric Administration, 1985). Snowfall is greatest in February and March.

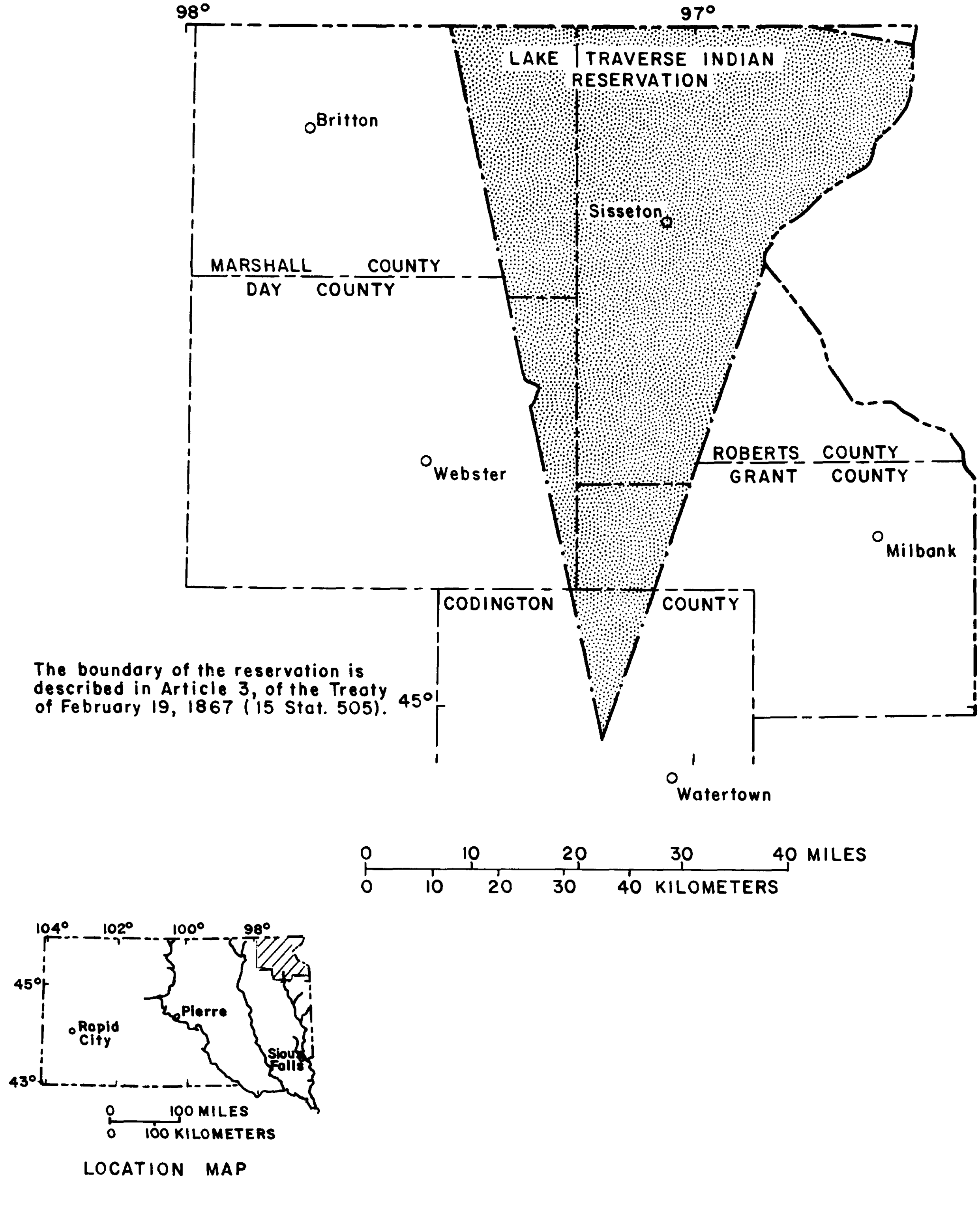


Figure 1.--Location of the Lake Traverse Indian Reservation in South Dakota.

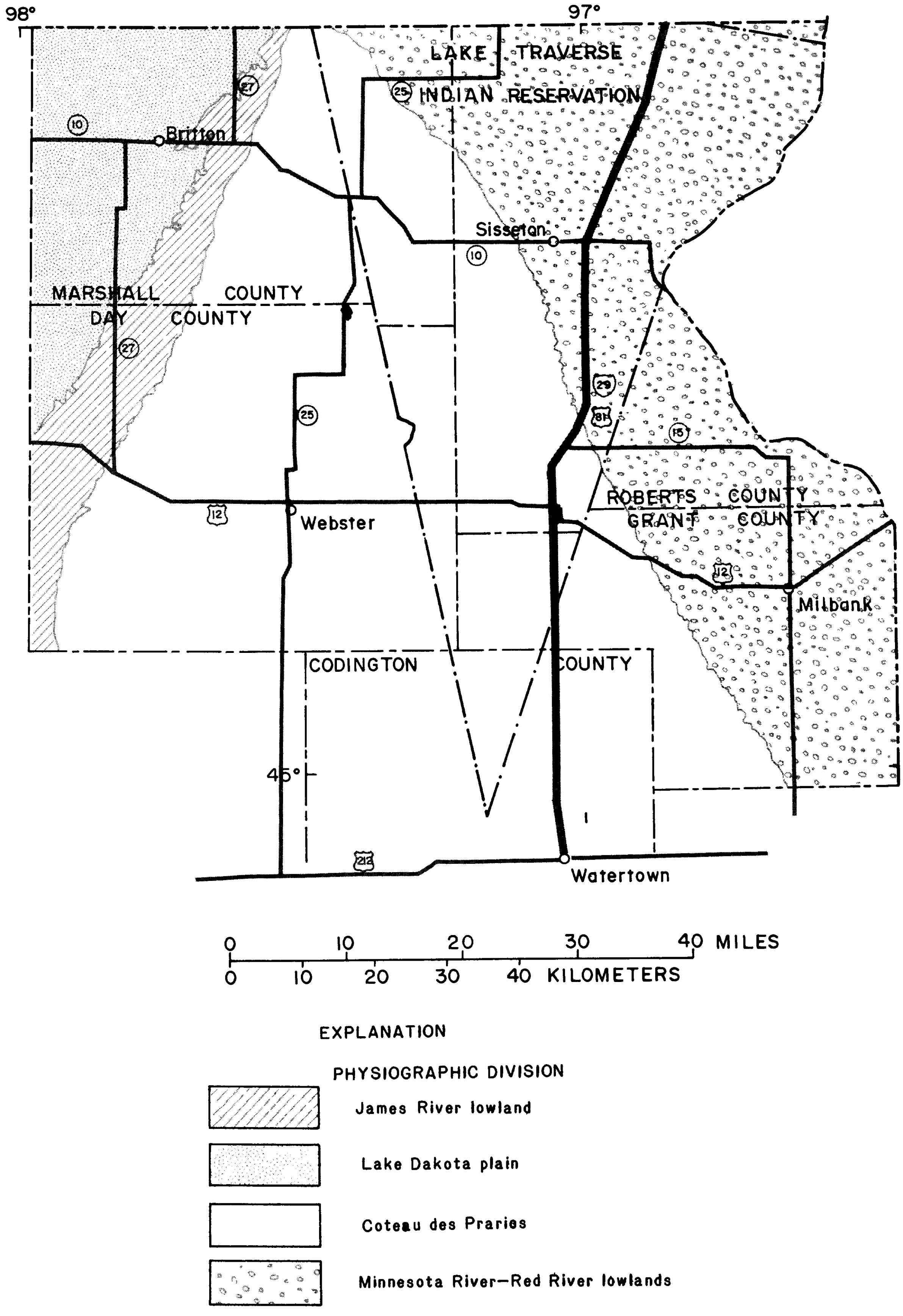


Figure 2.--Physiographic divisions in and near the Lake Traverse Indian Reservation.

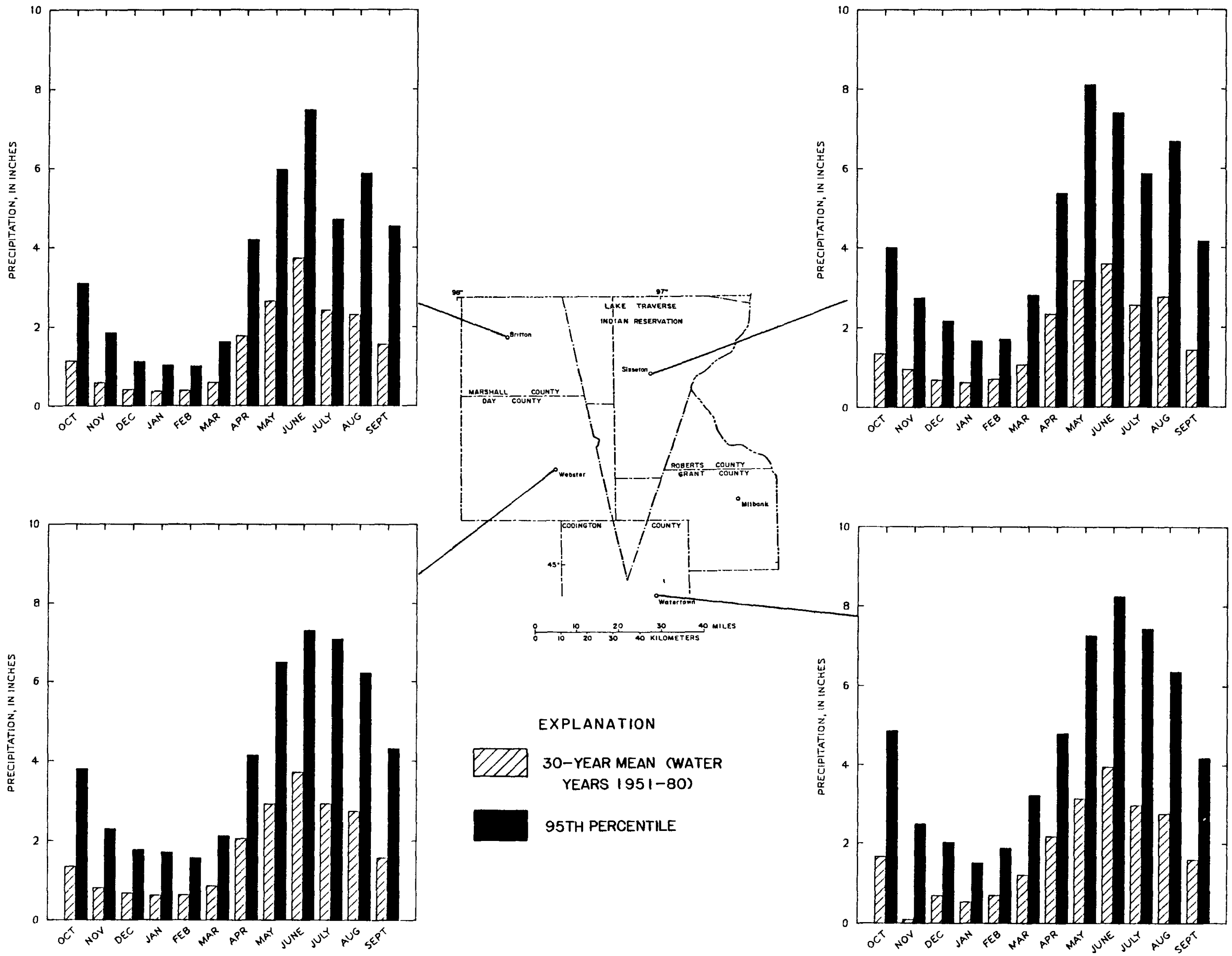


Figure 3.--The 30-year (water years 1951-80) mean monthly precipitation and the 95th-percentile value for selected sites in and near the Lake Traverse Indian Reservation.

The predominant wind direction is from the south and southeast during the summer, and from the north and northwest during the winter. The average annual wind speed is 11 mi/h (Hodge, 1960). The average annual evaporation from class A evaporation pans in eastern South Dakota is 46 inches with 83 percent of that occurring from May to October (Hodge, 1960).

Geology

On the basis of their depositional history, the geologic units within the Lake Traverse Indian Reservation are divided into three groups: (1) Precambrian crystalline rocks, (2) Cretaceous sedimentary rocks, and (3) Alluvium and glacial-outwash deposits and glacial lake sediments (figs. 4 and 5). Within Marshall County, the Precambrian crystalline rocks (granite) are 906 to 1,113 ft below land surface at an elevation of 242 to 407 ft above sea level (Koch, 1975). The depth to the Precambrian crystalline rocks is not known for much of the Lake Traverse Indian Reservation.

The Cretaceous sedimentary rocks include shale (Pierre, Carlile, and Graneros Shales), interlayered beds of limestone (Niobrara Formation and Greenhorn Limestone), and sandstone with interbedded layers of shale and siltstone (Dakota Sandstone). The Dakota Sandstone directly overlies the crystalline rocks. Undifferentiated rock occurs in the northeastern corner of the reservation (fig. 4). The individual layers of sedimentary rock generally become progressively thinner in an easterly direction (fig. 6).

During the Quaternary period, glacial and post-glacial unconsolidated sediments were deposited in the area of the reservation. The following description and generalization of the glacial geology of the Lake Traverse Indian Reservation is derived from the studies by Flint (1955), Koch (1975), and Lindroth (1976).

Glacial deposits or drift within the reservation consist of till, glaciofluvial (stream) sediments, and glaciolacustrine (lake) sediments (fig. 5). Glacial till is a heterogeneous mixture of clay, silt, sand, gravel, and boulders. Landforms such as ground, end, and stagnation moraines are commonly associated with glacial till within the reservation. Glaciofluvial sediments include glacial-outwash deposits of sand and gravel deposited by flowing glacial meltwaters. Glacial-outwash deposits are stratified to semistratified deposits of poorly sorted fine sand and coarse gravel. Some glacial-outwash deposits may have till inclusions and may overlie alluvium. Glaciolacustrine sediments consist of layered deposits of clay, silt, and sand transported into ancient lakes by glacial meltwaters. Alluvium along old and recent flood plains and lake beds generally consists of semistratified deposits of silt, sand, and gravel, commonly in association with humic material.

SURFACE WATER

Important components of a surface-water investigation include a description of the surface-water resources, an analysis of the flow regime including peak and low-flow periods, an analysis of storage capacity, and an analysis of water-quality data. The goal is to determine if the quantity, timing, and location of surface water can meet the demand for beneficial uses of that water.

Surface water within the Lake Traverse Indian Reservation includes intermittent streams and numerous lakes and wetlands. The reservation is located in parts of three major river basins--the Missouri, the Souris-Red-Rainy, and the Upper Mississippi River basins (Seaber and others, 1984). The

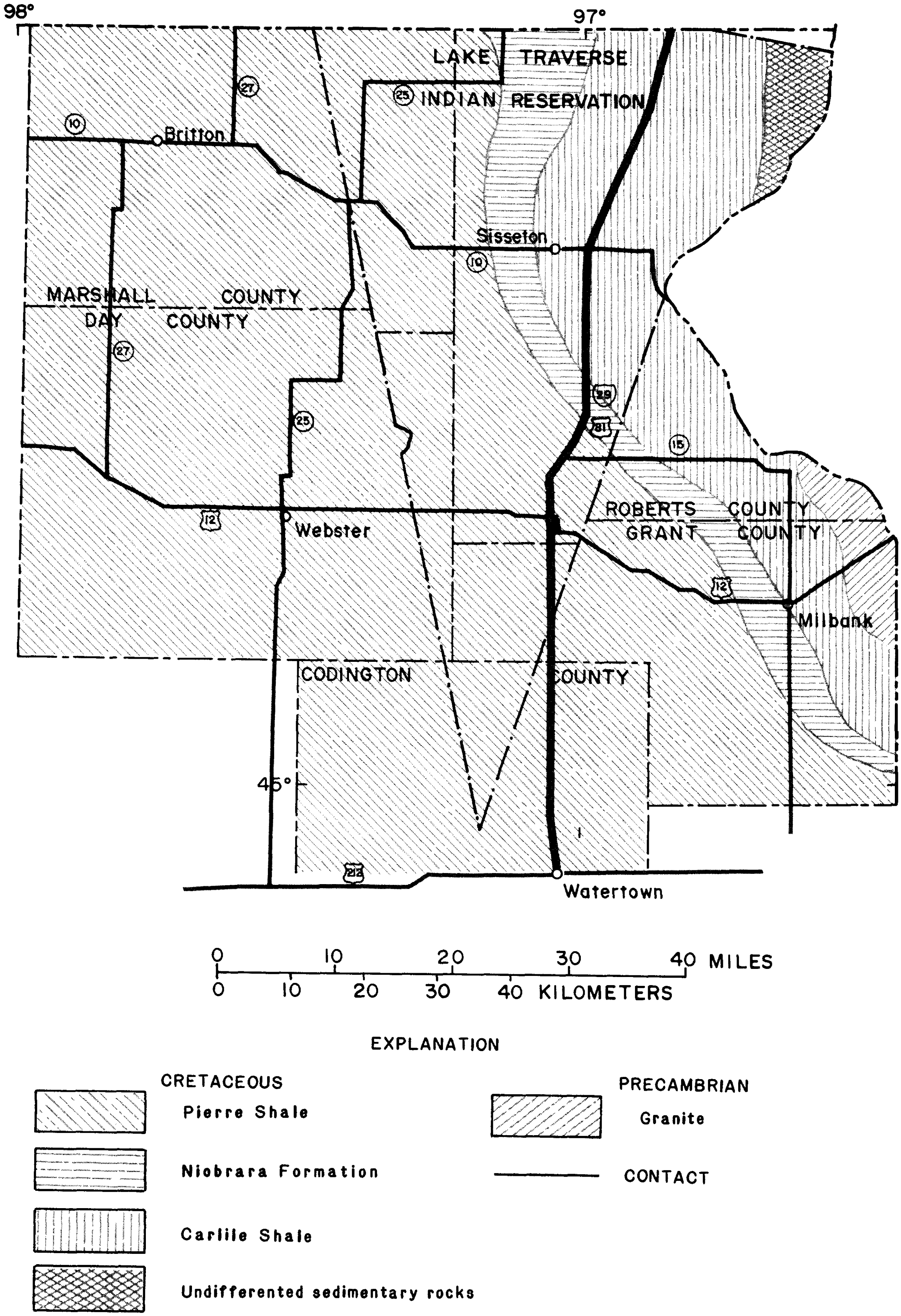


Figure 4.--Bedrock geology in and near the Lake Traverse Indian Reservation.

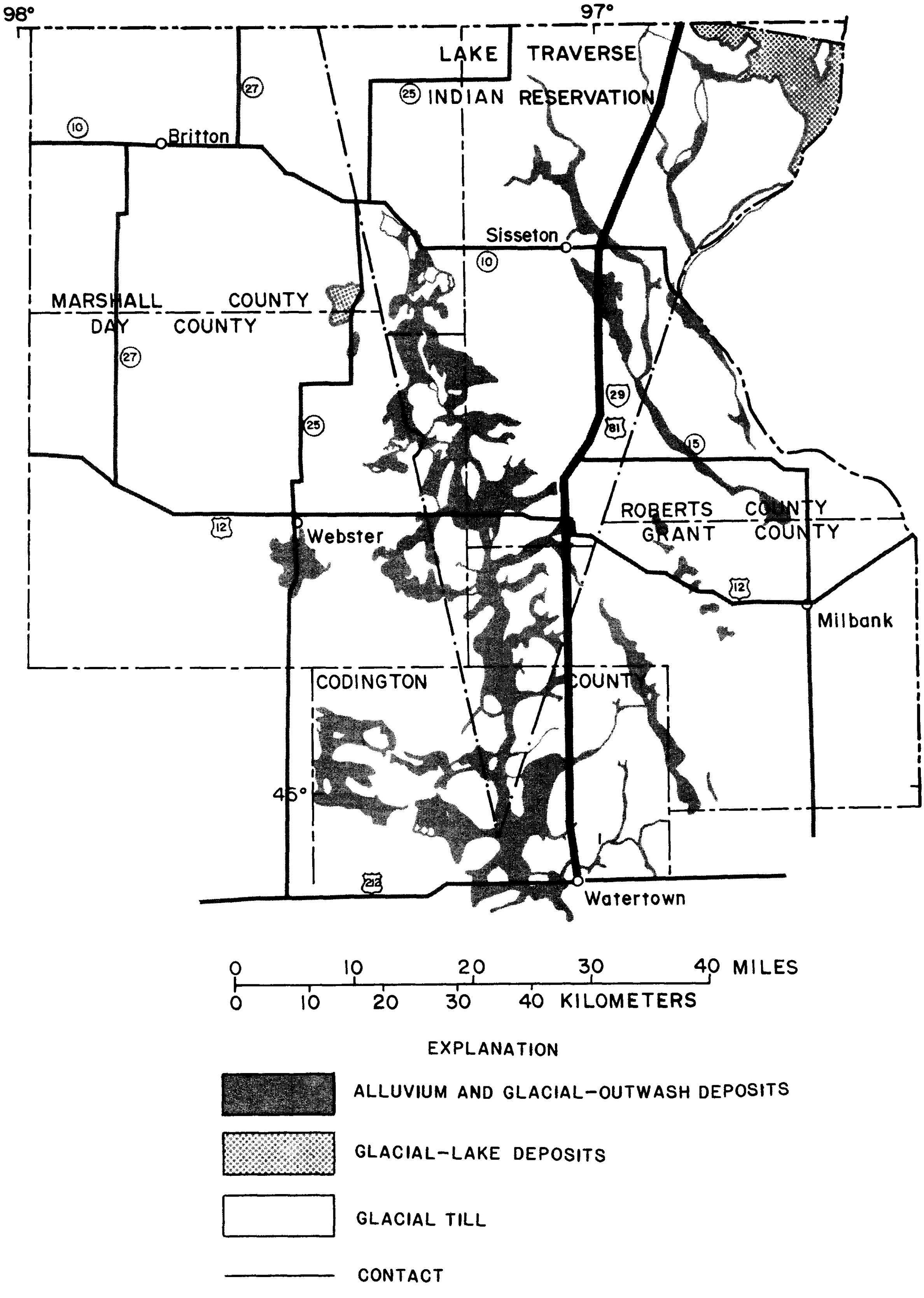


Figure 5.--Glacial deposits of Pleistocene and Holocene age in and near the Lake Traverse Indian Reservation.

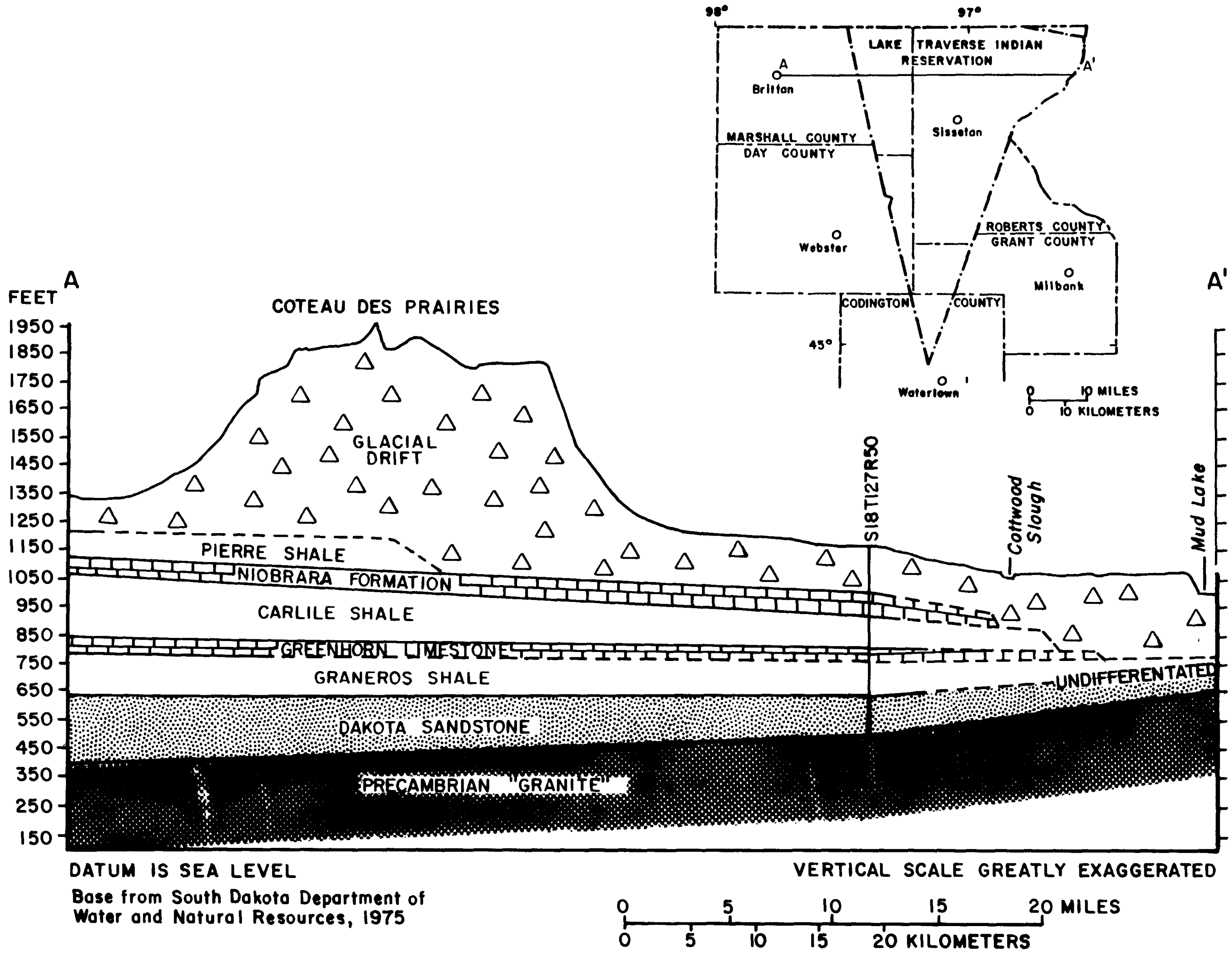


Figure 6.--Geologic section across the northern part of the Lake Traverse Indian Reservation.

Big Sioux and James Rivers are tributaries of the Missouri River and drain 578 mi^2 of the Lake Traverse Indian Reservation. In most years, about 324 mi^2 of the basins of the Big Sioux and James Rivers are noncontributing, draining internally. However, this area may contribute runoff to the Big Sioux and James Rivers during extremely wet periods. The headwaters of the Big Sioux originate within the reservation with most of the headwater streams flowing intermittently from the east side of the basin (fig. 7). The Big Sioux River is hydraulically connected to surficial glacial outwash and alluvial deposits throughout its length. Although primarily a gaining stream, the river also is a losing stream in some reaches. The Big Sioux River discharges into the Missouri River at Sioux City, Iowa.

Most lakes and ponds in the reservation are located in the noncontributing parts of the Big Sioux River and James River basins (fig. 8). Many lakes lie within closed basins and vary in size and depth with time because of vagaries of weather; however, a significant number of lakes are hydraulically connected to and sustained by glacial-outwash aquifers. Long-term records of lake levels are available for only three lakes in the noncontributing area; however, since 1982 the South Dakota Department of Water and Natural Resources, Division of Water Rights, has collected lake-level data for numerous lakes in the noncontributing area. No substantial streams are located in this area.

Because the Big Sioux River is important from an irrigation and water rights standpoint in eastern South Dakota, six of the eleven streamflow-gaging stations located within the reservation are in the Big Sioux River basin. As of 1986, two of the gages (sites 8 and 13) provide a continuous record of streamflow; the other four have been discontinued (table 1).

About 414 mi^2 of the reservation (fig. 9) is drained by headwater streams of the Red River of the North, which is located north of the study area in the Souris-Red-Rainy River basin. The eastern part of this area of the reservation typically is almost flat; surface runoff flows to and is stored in numerous sloughs before flowing into Lake Traverse. Lake Traverse is a natural lake, 1 mi wide by 17 mi long, situated in a trough along the Minnesota-South Dakota border. Although the lake is natural, a dam and control structure has increased the storage capacity to 137,000 acre-ft with a surface area of 11,500 acres at maximum pool (South Dakota Department of Water and Natural Resources, 1975). Mud Lake, downstream from Lake Traverse, is an additional flood-control reservoir in the basin. The channelized Bois de Sioux River flows north from the Mud Lake dam at White Rock and into the Red River of the North at Wahpeton, N. Dak., about 36 river miles north of White Rock. The streamflow-gaging station at White Rock (fig. 9) is the only station in the Red River of the North basin within the reservation that has a continuous streamflow record, albeit regulated flow. Small headwater streams of the Wild Rice River originate in and flow northwestward from the north end of the Coteau des Prairies. The Wild Rice River subsequently discharges into the Red River of the North.

The Little Minnesota River drains 498 mi^2 of the Upper Mississippi River basin (fig. 10). The headwaters of both the Little Minnesota River and its major tributary, the Jorgenson River, are located within the reservation. The headwaters of both rivers are sustained by springs originating in glacial-outwash deposits in the Coteau des Prairies. These streams flow down the steep eastern escarpment of the Coteau and across the reservation within the Minnesota River-Red River lowlands to Big Stone Lake, which is south of Lake Traverse and outside of the reservation. The streamflow-gaging station near Peever (fig. 10 and table 1) provides continuous discharge records for the Little Minnesota River.

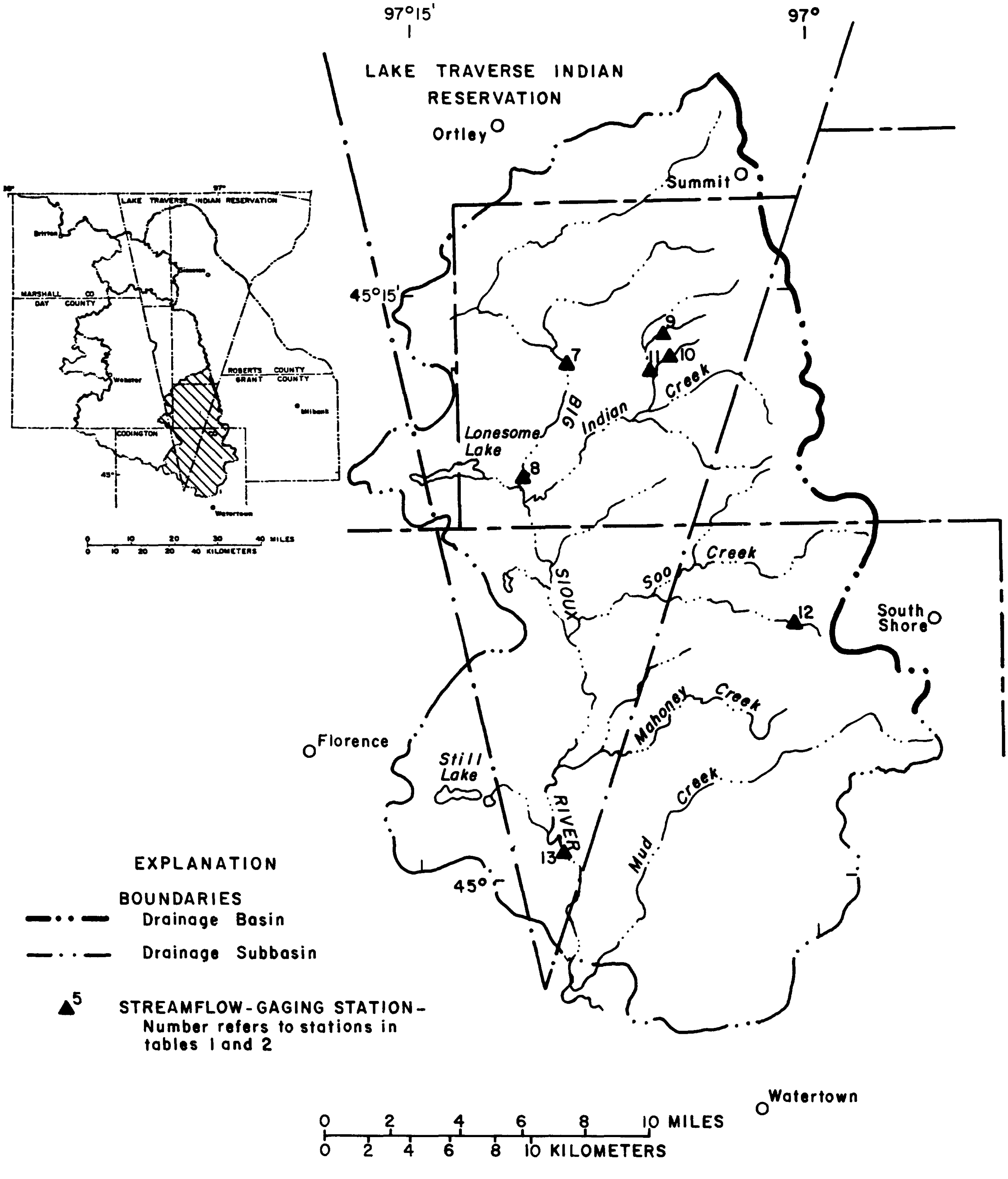


Figure 7.--Contributing drainage area of the Big Sioux River basin upstream from confluence with Mud Creek and location of streamflow-gaging stations in the contributing part of the basin in and near the Lake Traverse Indian Reservation.

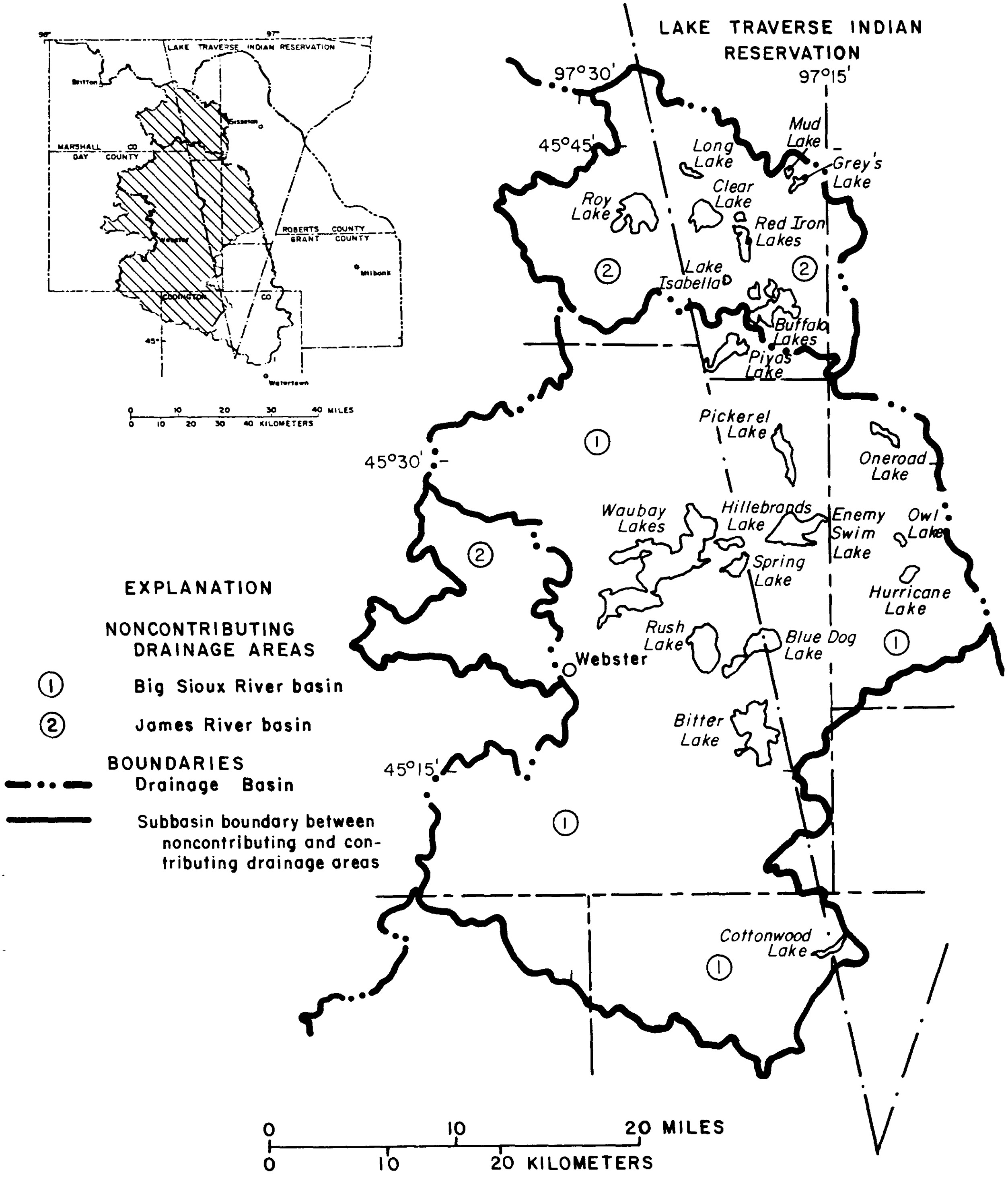


Figure 8.--Noncontributing drainage areas of the Big Sioux and James River basins, and location of selected lakes in and near the Lake Traverse Indian Reservation.

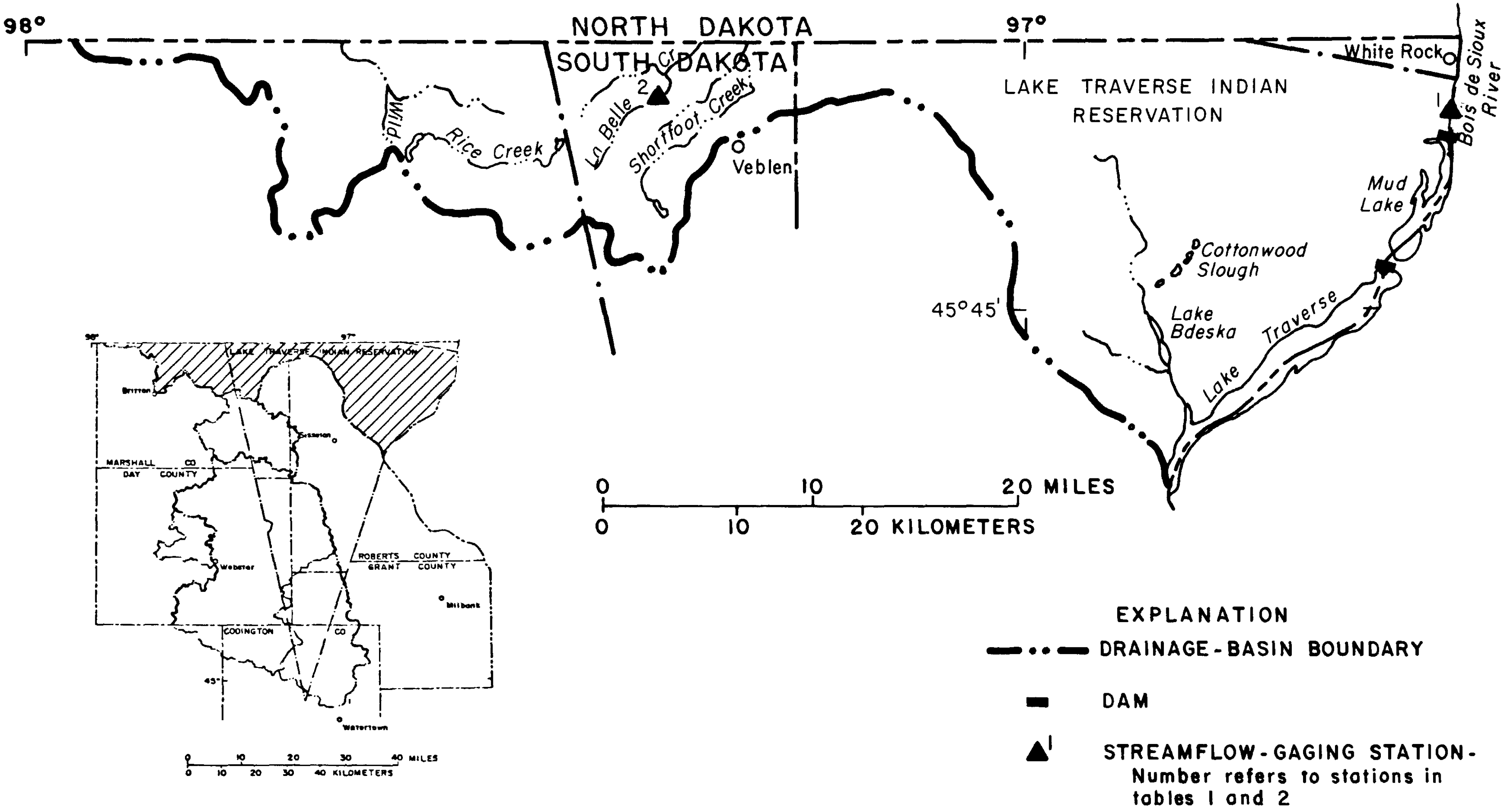


Figure 9.--Drainage area of the Souris-Red-Rainy River basin and location of streamflow-gaging stations in and near the Lake Traverse Indian Reservation.

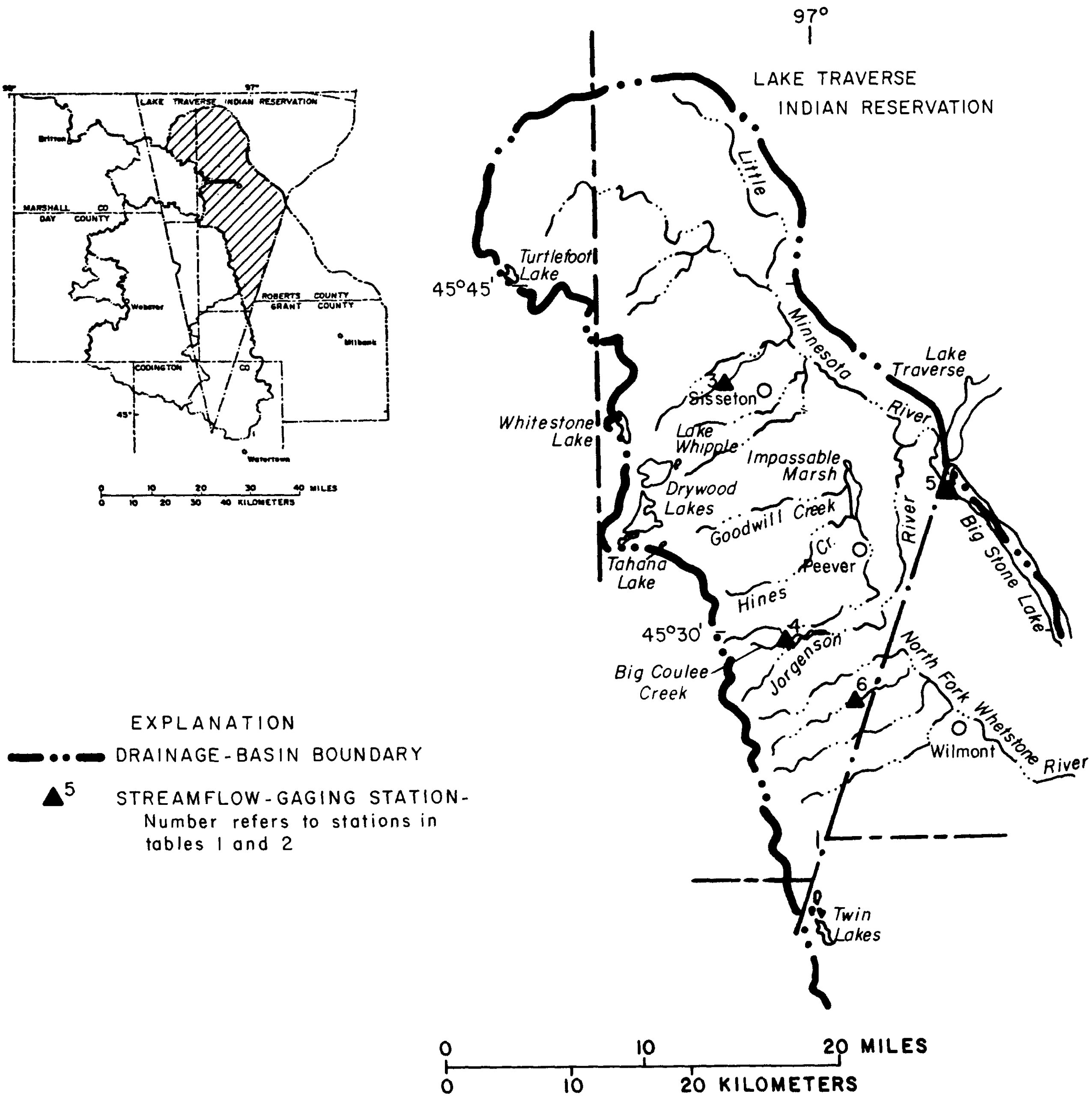


Figure 10.--Drainage area of the Upper Mississippi River basin and location of streamflow-gaging stations in and near the Lake Traverse Indian Reservation.

Table 1.--Streamflow-gaging stations operated by the U.S. Geological Survey in and near the Lake Traverse Indian Reservation

Site number	Station number	Station name	Drainage area (square miles)	Period of record (water years)
1	05050000	Bois de Sioux River near White Rock	1,160	1942-86
2	05051650	La Belle Creek near Veblen[1]		
3	05289950	Little Minnesota River tributary at Sisseton[2]	236	1970-79
4	05289985	Big Coulee Creek near Peever[1]		
5	05290000	Little Minnesota River near Peever	447	1940-81
6	05290300	North Fork Whetstone River tributary near Wilmot	.96	1970-79
7	06479200	Big Sioux River near Ortley[2]	53.8	1956-68
8	06479215	Big Sioux River near Florence[3]	638	1984-86
9	06479230	Big Sioux River tributary near Summit	1.27	1956-67
10	06479240	Big Sioux River tributary No. 2 near Summit[2]	.26	1956-73
11	06479260	Big Sioux River tributary No. 3 near Summit[2]	6.61	1956-78
12	06479350	Soo Creek tributary near South Shore[2]	1.56	1970-79
13	06479438	Big Sioux River near Watertown[4]	1,007	1973-86

[1]Gaging station established at end of water year 1986.
[2]Crest-stage gage, only peak flows recorded.
[3]Contributing drainage area is 67.9 square miles.
[4]Contributing drainage area is 228 square miles.

Surface-Water Quantity

Streams

The purpose of this section is to provide a brief analysis of the quantity, timing, and dependability of streamflow within the Lake Traverse Indian Reservation. Logarithms of annual flood peaks and the minimum 7 and 15 consecutive days of flow in each month were fit to a Pearson Type III distribution to estimate the frequency of high and low flows. The percentage of time a daily flow was less than a certain value during a given month also was computed for several gaging-station records.

Streamflow for the Big Sioux, Little Minnesota, and Bois de Sioux Rivers has significant seasonal trends, with streamflow generally being greatest from March through June (fig. 11). Most of the annual runoff occurs during this period and is caused by melting of the winter snowpack and by spring rains. The smallest discharges occur from December through February not only because precipitation is less, but also because the streams are ice-covered and snow is the principal form of precipitation during this time.

The mean monthly discharge of the Little Minnesota River near Peever is less than 0.08 ft^3/s for 10 percent of the time from December through February, whereas the mean monthly discharge at the Bois de Sioux River near White Rock and the Big Sioux River near Watertown is less than 0.01 ft^3/s.

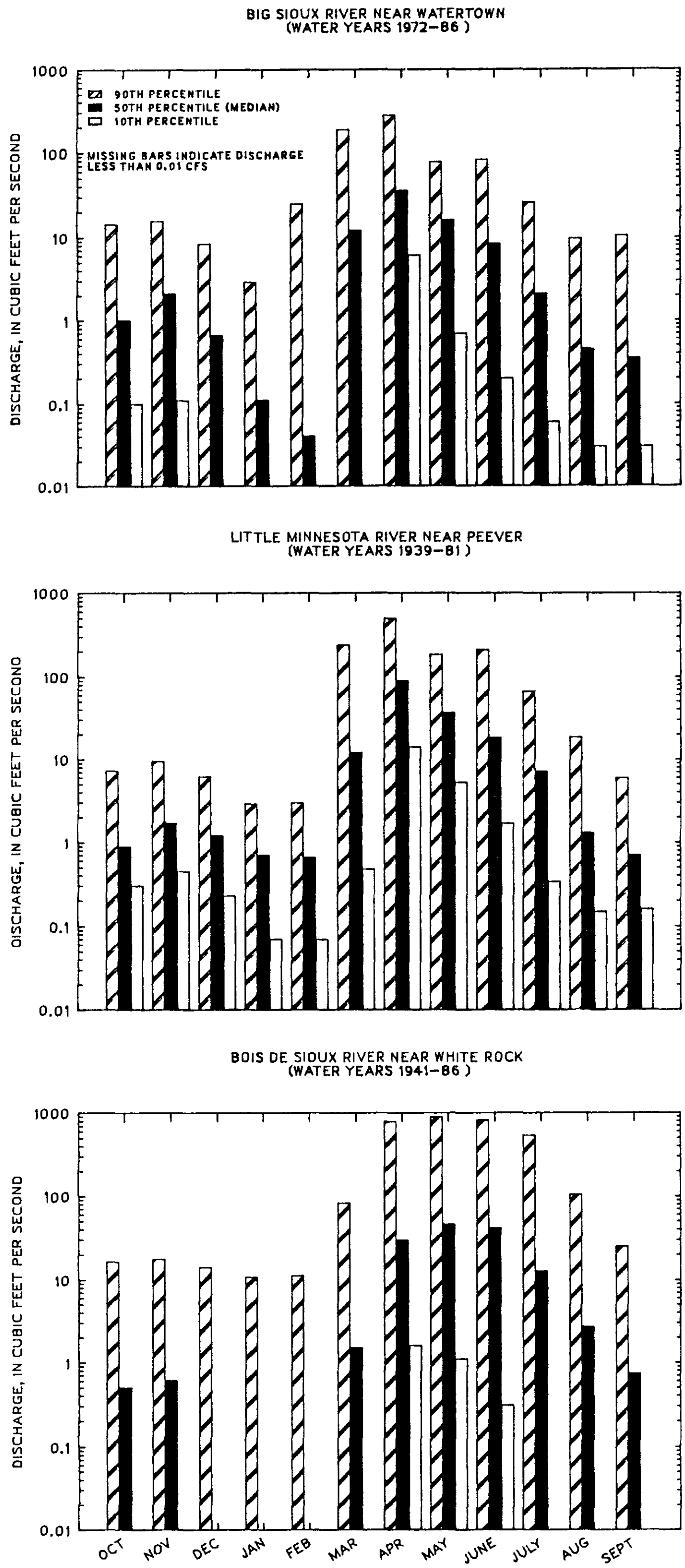


Figure 11.--Statistics of mean monthly discharge for the period of record at three streamflow-gaging stations in and near the Lake Traverse Indian Reservation.

The median of the mean monthly discharge for the Little Minnesota River near Peever ranges from 0.91 ft^3/s in January to 100 ft^3/s in April. The median for the Bois de Sioux River near White Rock ranges from less than 0.01 ft^3/s in December through February to 50 ft^3/s in May; the median for the Big Sioux River near Watertown ranges from 0.04 ft^3/s in February to 40 ft^3/s in April (fig. 11). The relatively small runoff amount from the Big Sioux River basin is due to the smaller contributing drainage area. Streamflow at the gaging station on the Bois de Sioux River near White Rock is regulated by releases from Mud Lake.

Peak-flow data are available for several gaging stations located within the Big Sioux River basin and one station located within the Little Minnesota River basin. Peak-flow data are used to estimate the probability of occurrence of peak flows of a given magnitude. Peak flows expected to occur at stations within the Lake Traverse Indian Reservation and their recurrence intervals are given in table 2. Because peak-flow data are based on short periods of record (10 to 23 years), the estimates of flood frequency have large uncertainties, particularly at the longer recurrence intervals.

Cumulative runoff statistics are given in figure 12. These graphs represent the cumulative monthly runoff that is not exceeded, on the average, 25, 50, and 75 percent of the time. This is a hypothetical flow condition that is unlikely to occur in any given year.

The cumulative runoff at the end of a water year in which the median flow occurred each month is 0.91 inch for the Little Minnesota River near Peever, 0.62 inch for the Bois de Sioux River near White Rock, and 0.16 inch for the Big Sioux River near Watertown. The Little Minnesota River has the greatest cumulative runoff of all three continuous-record gaging stations because of the larger drainage area and greater ground-water flows from the Coteau des Prairies to the headwaters of the Little Minnesota and Jorgenson Rivers. Except for the 25th-percentile flows, the cumulative runoff for the Bois de Sioux River near White Rock is about the same as for the Little Minnesota River near Peever. The 25th-percentile flows represent runoff during dry periods when releases from Mud Lake are minimal. The Big Sioux River near Watertown has cumulative runoff values that are smaller than those for the Little Minnesota or the Bois de Sioux Rivers. These smaller values result from a smaller quantity of runoff caused by a smaller contributing drainage basin and smaller ground-water flows.

A knowledge about periods of sustained flow, particularly low flows, is important to water-pollution-control efforts, water-supply forecasting, and reservoir operations. Therefore, an analysis was conducted to determine the minimum discharge expected for 7 and 15 consecutive days in a given month once every 10 years. These discharge values are known as the 7Q10 and 15Q10 flows, respectively, and are often used on an annual or seasonal basis by the State and the U.S. Environmental Protection Agency to establish minimum instream water-quality standards for streams receiving treated wastewater. A 7Q10 of 0.1 ft^3/s or less can be expected for the Big Sioux River near Watertown during June, October, and November; and a 7Q10 of zero can be expected from July through September and from December through March (fig. 13). The Little Minnesota River, with its larger contributing drainage area, has a slightly greater sustained flow than the Big Sioux River near Watertown, but a similar flow regime. Records for the Little Minnesota River near Peever and the Big Sioux River near Watertown indicate ground-water inflow during the fall due in part to recharge by irrigation water. In contrast, the Bois de Sioux River near White Rock has 7Q10 and 15Q10 flows nearly an order of magnitude smaller than either the Little Minnesota or the Big Sioux Rivers. This is probably due to the effect of the controlled flow out of Mud Lake.

Table 2.--Magnitude and recurrence interval of instantaneous peak flow at gaging stations in and near the Lake Traverse Indian Reservation

[Source: Hoffman and others, 1986]

Site number	Station number	Station name	Period of analysis (water years)	Discharge, in cubic feet per second, for recurrence interval, in years, and annual exceedance probability, in percent — Years: 2 / Percent: 50	Years: 5 / Percent: 20	Years: 10 / Percent: 10	Years: 25 / Percent: 4	Years: 50 / Percent: 2	Years: 100 / Percent: 1
3	05289950	Little Minnesota River tributary at Sisseton	1970-79	80	208	336	552	755	994
7	06479200	Big Sioux River near Ortley	1956-68	141	394	655	1,100	1,530	2,030
10	06479240	Big Sioux River tributary No. 2 near Summit	1956-73	8.9	25	41	68	94	125
11	06479260	Big Sioux River tributary No. 3 near Summit	1956-78	94	331	591	1,040	1,440	1,910
12	06479350	Soo Creek tributary near South Shore	1970-79	44	129	222	388	552	754
13	06479438	Big Sioux River near Watertown	1973-85	569	1,350	2,100	3,340	4,470	5,790

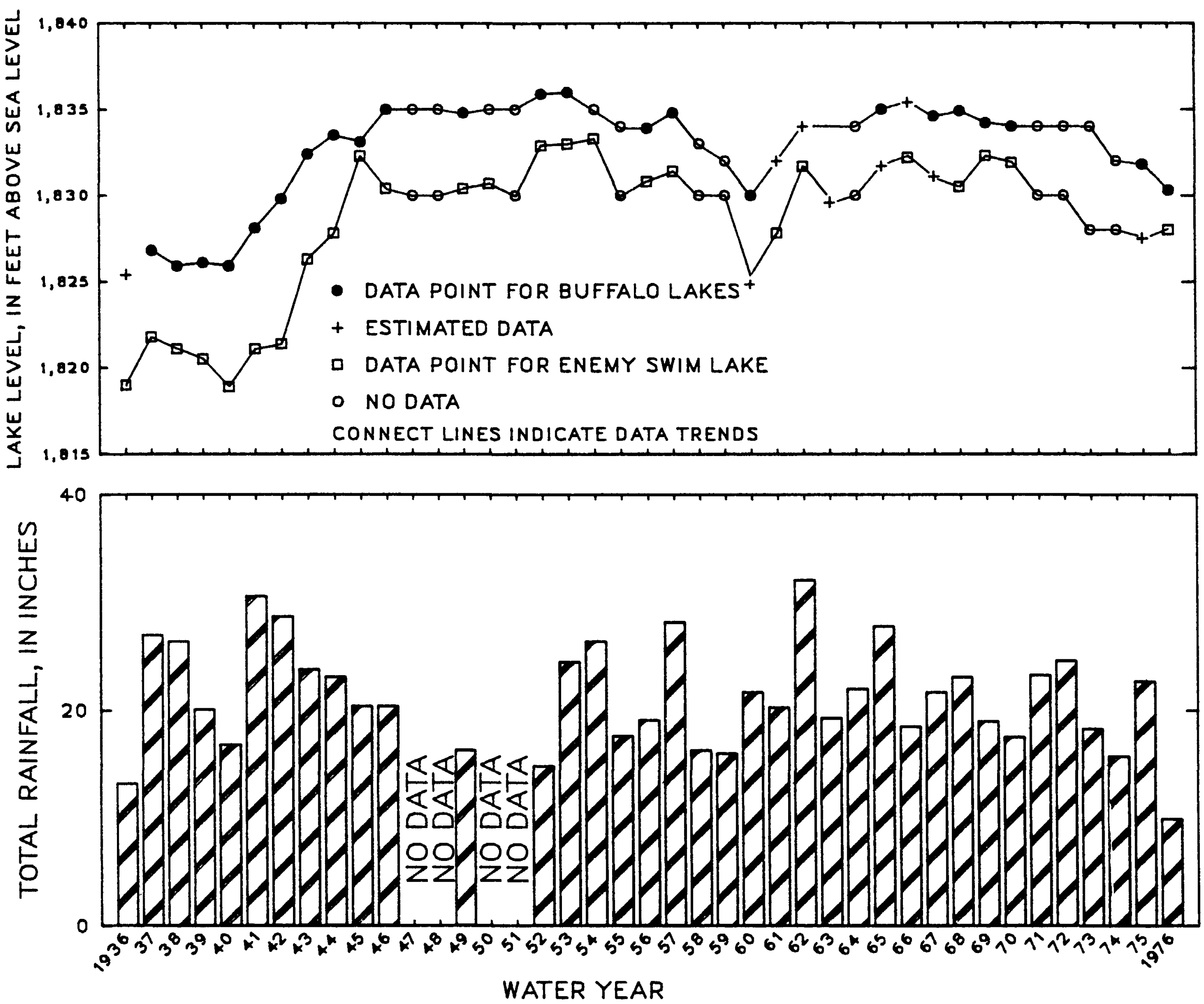


Figure 14.--Lake levels and corresponding total rainfall at Sisseton for water years 1936-76. Estimated data produced by regressing data for Buffalo Lakes against Enemy Swim Lake. (Source: State Lakes Preservation Committee, 1977.)

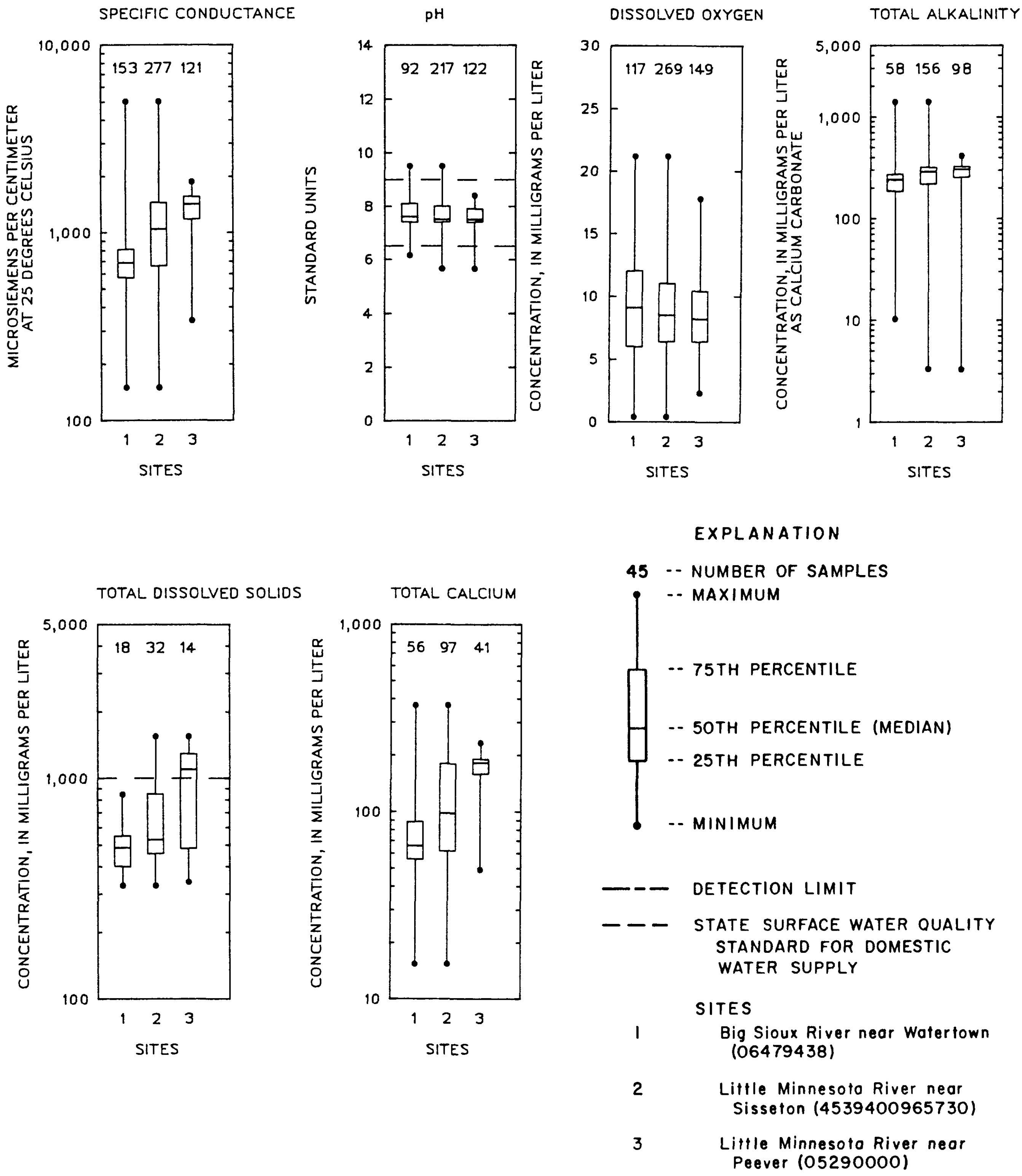


Figure 15.--Streamflow quality at three sites in and near the Lake Traverse Indian Reservation. (Source of data: South Dakota Department of Water and Natural Resources.)

Lakes

Most lakes and ponds within the reservation are located within the noncontributing part of the Big Sioux River and the James River basins. Because of large surface areas, shallow depths, and effects of evaporation and ground water, the volume of water in storage within the lakes is neither sufficient nor predictable enough for major development of dependable water supplies. Even though the total storage in 1975 was estimated to be at least 205,000 acre-ft (State Lakes Preservation Committee, 1977), no one lake has a sufficient storage capacity or a dependable inflow of water to make it economically feasible for major development (table 3).

The lakes are located within basins that may differ greatly, even from adjacent basins, in terms of geology, ground-water inflow, and inflow-outflow relations. Some of these lakes, such as Bitter, Hillebrands, and Isabella (fig. 8), are nearly or completely closed systems within glacial till (table 3). The hydrologic cycles of these lakes are dominated by surface runoff and evaporation. Other lakes, such as Pickerel, Buffalo, and Enemy Swim (fig. 8), are hydraulically connected to glacial-outwash aquifers and probably are regulated indirectly by the effect of rainfall on ground-water levels (fig. 14).

Surface-Water Quality

On the basis of an analysis of data from the South Dakota Department of Water and Natural Resources, the surface-water quality, with respect to inorganic constituents, in the Lake Traverse Indian Reservation is such that the water probably is suitable for domestic, recreational, industrial, and irrigation uses (U.S. Environmental Protection Agency, 1976, 1986a, b, c).

Streams

Data for pH, dissolved oxygen, fecal coliform bacteria, total alkalinity, total nitrate, total ammonia, and total orthophosphate appear to be similar at the Bois de Sioux River (table 4), the Little Minnesota River, and the Big Sioux River (fig. 15). Occasionally, pH values may not be within the surface-water quality standard of 6.5 to 9.0 units for domestic water supplies, nitrate concentrations may exceed the standard of 10 mg/L (milligrams per liter) as nitrogen, and total dissolved solids may exceed the standard of 1,000 mg/L (South Dakota Department of Water and Natural Resources, 1986). The large values of pH and concentrations of dissolved oxygen indicate that algal blooms occasionally may occur in all three rivers. Rapid rates of photosynthesis produce a supersaturation of dissolved oxygen and more alkaline conditions as algae take up carbon dioxide and release oxygen. The smaller concentrations of dissolved oxygen also may occur as a result of algal blooms as respiration, rather than photosynthesis, occurs during the night, or when ice cover and low-flow conditions prevail and oxygen demand for decomposition within the sediments is large. Occasional large concentrations of fecal coliform bacteria, total nitrate, total ammonia, and total orthophosphate indicate probable contamination from either feedlots, septic tanks, or sewage lagoons. Unfortunately, there are no fecal streptococcus bacteria data available to determine whether the fecal coliform bacteria are of human origin. The fecal coliform bacteria concentrations at times may exceed State standards for immersion recreation (200 colonies per 100 milliliter from May 1 to September 30) and limited contact recreation (1,000 colonies per 100 milliliter from May 1 to September 30).

Table 3.--Physical characteristics of selected lakes in and near the Lake Traverse Indian Reservation

[Source: State Lakes Preservation Committee, 1977. -- indicates data were not supplied by source]

Lake	Surface area		Depth (feet)		Watershed area (square miles)
	Acres	Square miles	Average	Maximum	
			Codington County		
Cottonwood	422	0.66	2	--	7.62
Still	416	.65	2	6	68.28
			Day County		
Blue Dog	1,498	2.34	6	8	115.33
Bitter	4,173	6.52	2	--	38.95
Enemy Swim	2,144	3.35	10	26	34.86
Hillebrands	666	1.04	5	--	2.66
Lonesome	102	.16	5	8	6.15
Pickerel	954	1.4	20	43	26.82
Spring	998	1.56	4	--	5.58
			Grant County		
Twin	205	0.32	4	8	1.24
			Marshall County		
Buffalo, North	265	0.41	10	12	28.15
Buffalo, South	1,685	2.63	7	12	26.22
Clear	1,094	1.71	12	20	58.34
Greys	141	.22	4	10	1.59
Isabella	70	.11	3	5	1.26
Long	294	.46	4	9	8.79
Mud	166	.26	4	10	1.36
Piyas	1,280	2.00	3	--	4.59
Red Iron, North	173	.27	7	11	43.75
Turtlefoot	122	.19	3	--	.77
			Roberts County		
Drywood, North	914	1.43	6	10	5.67
Drywood, Middle	2,133	3.33	7	10	([1])
Drywood, South	192	.30	4	6	1.16
Hurricane	326	.51	6	12	6.08
Oneroad	288	.45	4	7	6.61
Owl	179	.28	4	--	.61
Tahana	41	.07	4	9	.11
Traverse	10,600	18.12	7	12	1,139.07
Whitestone	262	.41	8	16	1.15

[1]Watershed area grouped with North Drywood Lake.

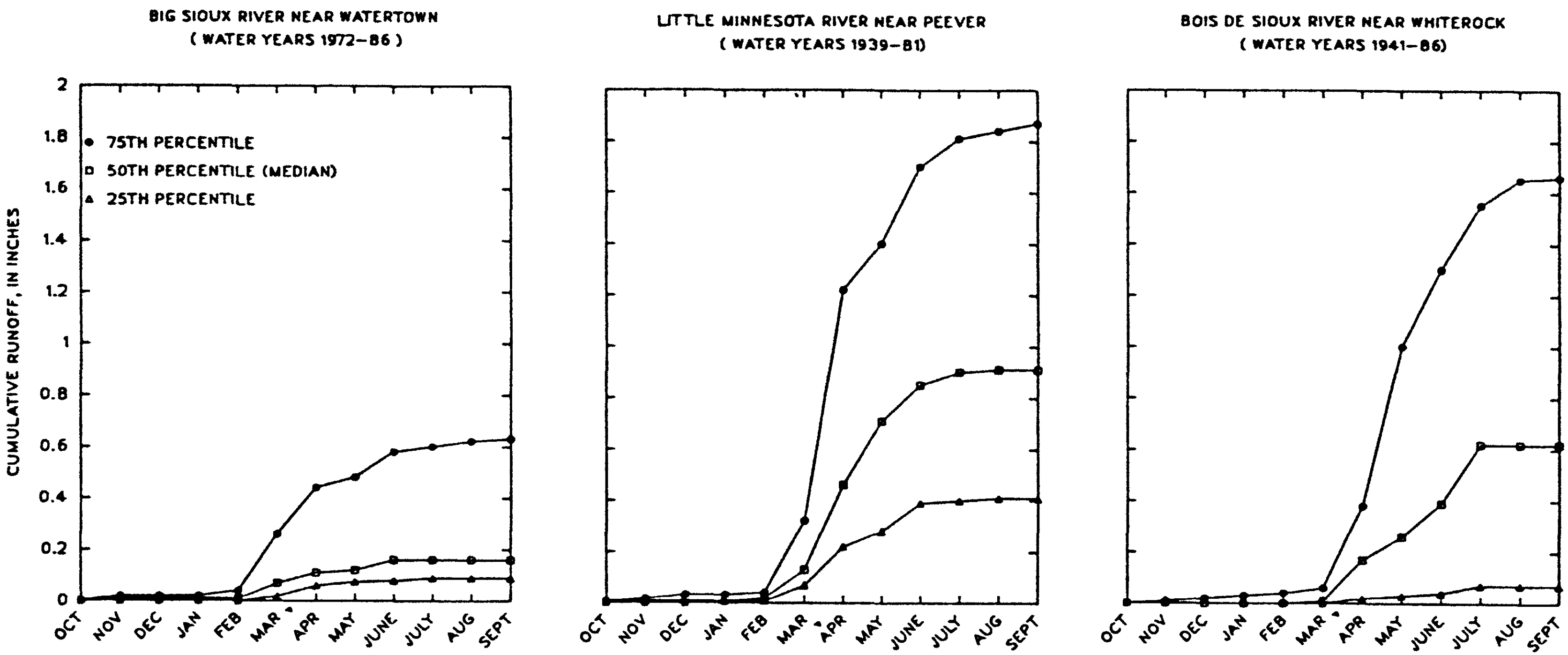


Figure 12.--Statistics of cumulative monthly runoff for the period of record at three streamflow-gaging stations in and near the Lake Traverse Indian Reservation.

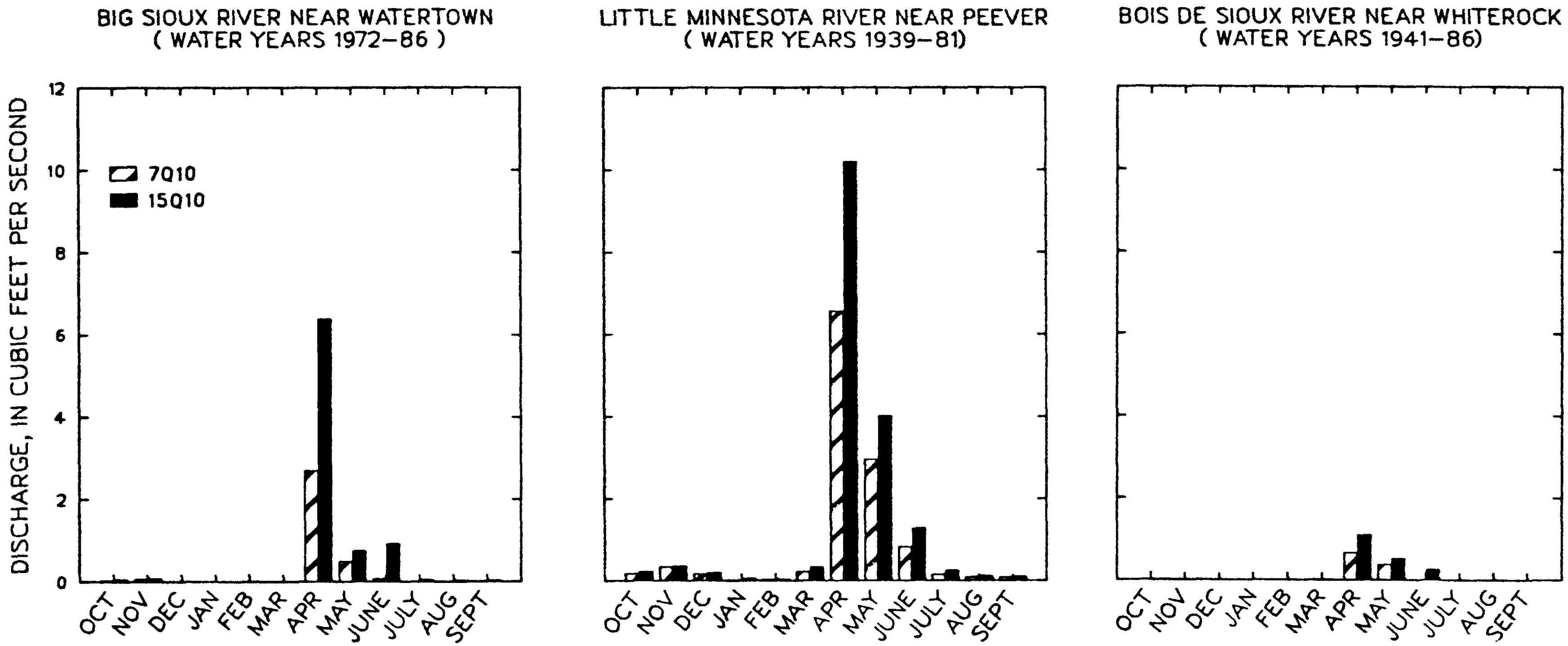


Figure 13.--The 7-day, 10-year (7Q10) and 15-day, 10-year (15Q10) minimum discharges for the period of record at three streamflow-gaging stations in and near the Lake Traverse Indian Reservation.

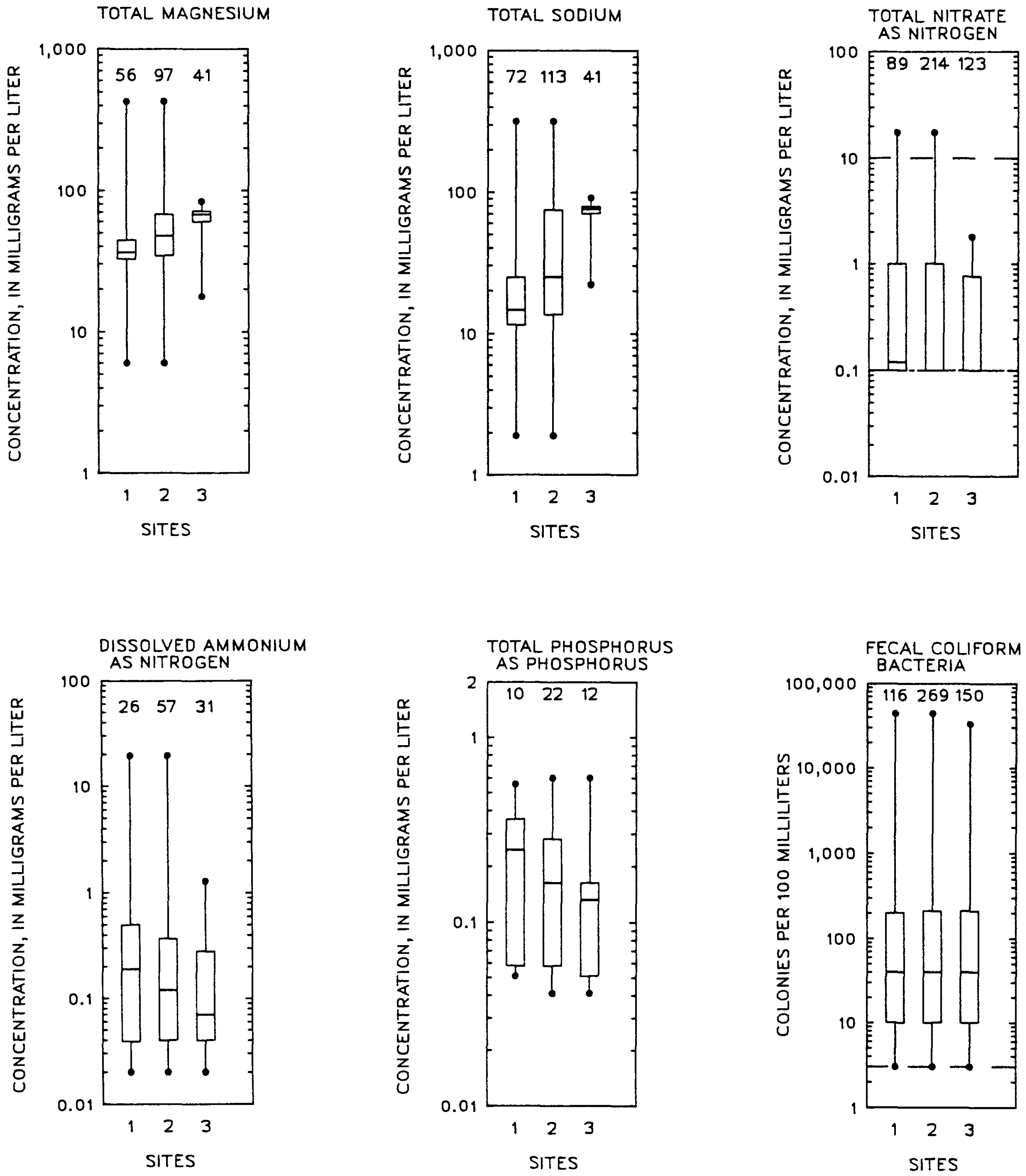

TOTAL MAGNESIUM
1,000
100
10
1
56 97 41
CONCENTRATION, IN MILLIGRAMS PER LITER
1 2 3
SITES
TOTAL SODIUM
1,000
100
10
1
72 113 41
CONCENTRATION, IN MILLIGRAMS PER LITER
1 2 3
SITES
TOTAL NITRATE AS NITROGEN
100
10
1
0.1
0.01
89 214 123
CONCENTRATION, IN MILLIGRAMS PER LITER
1 2 3
SITES
DISSOLVED AMMONIUM AS NITROGEN
100
10
1
0.1
0.01
26 57 31
CONCENTRATION, IN MILLIGRAMS PER LITER
1 2 3
SITES
TOTAL PHOSPHORUS AS PHOSPHORUS
2
1
0.1
0.01
10 22 12
CONCENTRATION, IN MILLIGRAMS PER LITER
1 2 3
SITES
FECAL COLIFORM BACTERIA
100,000
10,000
1,000
100
10
1
116 269 150
COLONIES PER 100 MILLILITERS
1 2 3
SITES

Table 4.--Summary of water-quality data for the Bois de Sioux River near White Rock

[Number of analyses = 15. Results in milligrams per liter except as indicated; °C, degrees Celsius; JTU, Jackson turbidity units; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

Property or constituent	Maximum	Mean	Minimum
Specific conductance (microsiemens per centimeter at 25 °C)	2,860	1,360	754
pH (units)	8.4	7.7	7.4
Temperature, water (°C)	26.9	15.8	0.6
Turbidity (JTU)	130	90	8
Dissolved oxygen	11	7.2	2.6
Biochemical oxygen demand	15	6.6	2.0
Total coliform bacteria (colonies per 100 milliliters)	3,300	800	200
Fecal coliform bacteria (colonies per 100 milliliters)	400	200	20
Hardness, total as $CaCO_3$	1,600	670	350
Hardness, noncarbonate as $CaCO_3$	520	177	18
Calcium, dissolved	300	130	68
Magnesium, dissolved	210	86	47
Sodium, dissolved	140	64	25
Sodium-adsorption ratio	1.6	1.0	0.6
Potassium, dissolved	21	14	8
Bicarbonate	480	330	220
Sulfate, dissolved	1,400	510	200
Chloride, dissolved	35	17	6.8
Fluoride, dissolved	0.6	0.3	0.2
Silica	34	18	7.7
Dissolved solids, residue at 180 °C	2,370	1,020	529
Nitrate, dissolved as NO_3	5.8	2.9	1.0
Un-ionized ammonia as NH_4	1.3	0.3	<0.01
Orthophosphate, dissolved as P	0.55	0.33	0.15
Boron, dissolved (micrograms per liter)	320	220	90
Iron, dissolved (micrograms per liter)	950	120	30
Manganese, dissolved (micrograms per liter)	310	100	10

The Big Sioux River near Watertown has somewhat less mineralized water than the Little Minnesota River near Peever and near Sisseton, which may be a result of the glacial-outwash sediments that dominate the Big Sioux River basin. The influence of surficial outwash deposits is greatest in the headwaters of the Little Minnesota River and minimal for the Bois de Sioux River. Specific-conductance values and calcium, magnesium, sodium, and dissolved-solids concentrations generally are smaller in the Big Sioux River than those at the other two stations. The Little Minnesota River near Peever has the narrowest range of specific-conductance values and calcium, sodium, and magnesium concentrations. The reason for this is unknown. Although specific conductance and dissolved solids can give a general indication of water quality, a more specific description of surface-water quality cannot be given because data for chloride, sulfate, potassium, trace metals, and organic compounds are not available for the stations in the reservation.

Lakes

Because of the considerable variation in the geology and other factors governing the hydrologic cycle of lakes within the reservation, a variety of water-quality regimes occur. A listing of lakes divided into general water-quality categories by dissolved-solids concentrations is given in table 5. A detailed summary of the water quality of four lakes from three of the four categories in table 5 is given in figure 16. There were not enough data to adequately summarize other lakes given in table 5, particularly for lakes with dissolved-solids concentrations ranging from 500 to 1,000 mg/L.

Bitter Lake, just west of the reservation, was used as a representative of the group of lakes with dissolved-solids concentrations greater than 4,000 mg/L because Bitter Lake had the most data for lakes within that group. This group of lakes is located within basins composed of glacial till; therefore, the lakes have little ground-water inflow and have large losses of water from evaporation. The water quality of Bitter Lake is characterized by a large concentration of dissolved solids due primarily to the concentration of solutes within the lake by evaporation (fig. 16). Maximum concentrations of calcium, magnesium, sodium, sulfate, chloride, and dissolved solids were measured in February when the lake was covered by ice. Large concentrations of dissolved solids may occur during winter ice cover when the formation of ice pulls water molecules into the ice layer, leaving dissolved ions in the water, which progressively concentrates minerals within the unfrozen part of the lake. Water with a large concentration of dissolved solids has a freezing point less than 0 °C.

Because of the large concentration of dissolved solids in the lake, it is probable that precipitation of calcium carbonate is occurring. The small calcium and alkalinity concentrations relative to magnesium, sodium, and chloride concentrations tend to support this hypothesis. The water quality within Bitter Lake is, therefore, dominated by magnesium sulfate (fig. 16). It seems likely that similar reactions and processes occur to varying degrees within Hillebrands Lake and Lake Isabella. Water in Bitter Lake is not suitable for domestic uses because of taste and cathartic effects; for agricultural uses because of salt buildup in soils that results in a detrimental effect on plants and because of excessive constituents that may have a possible unhealthy effect on livestock; and for most, if not all, industrial uses because of mineral buildup in pipes, and corrosion of machinery.

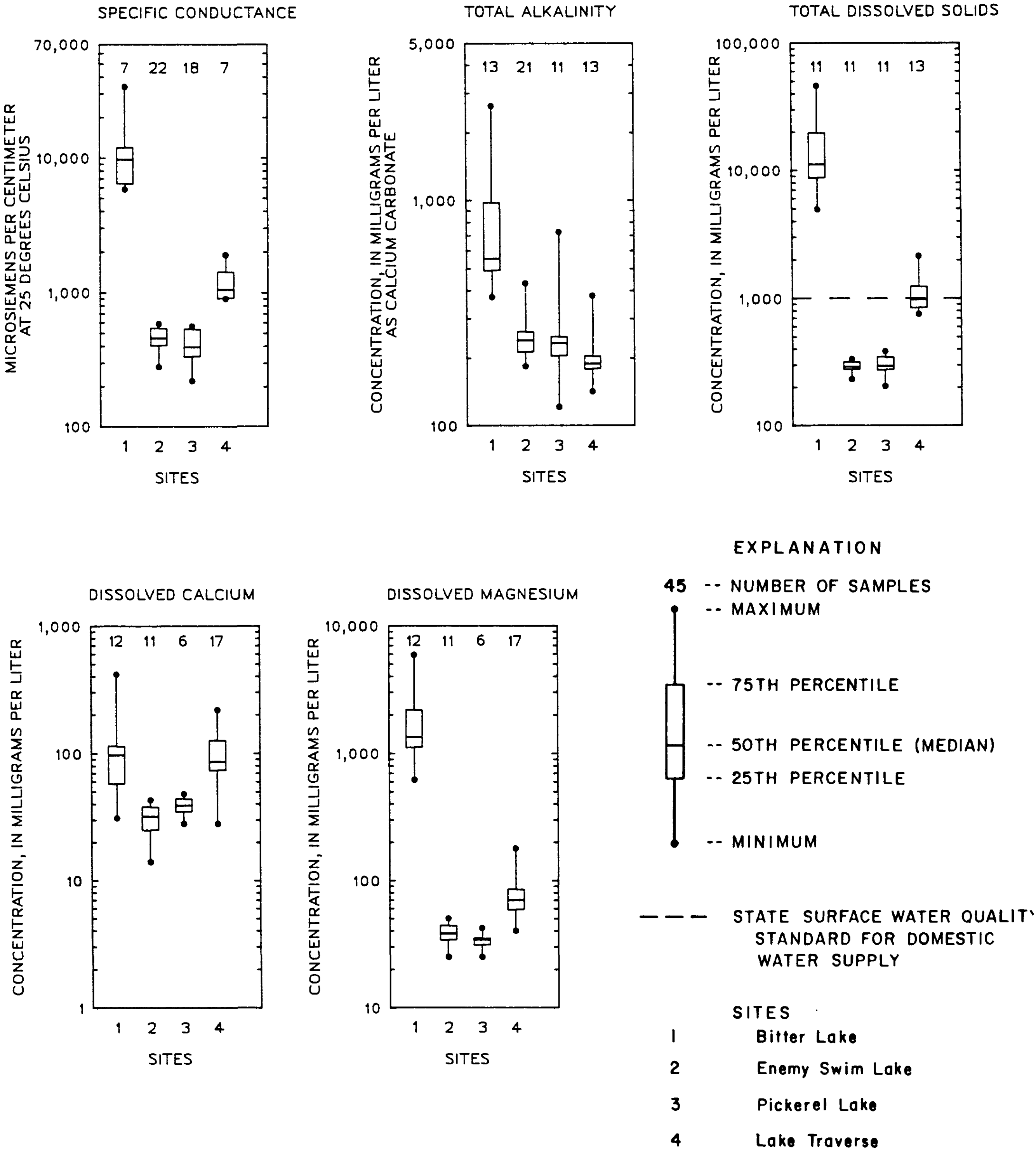


Figure 16.--Water quality of four lakes in and near the Lake Traverse Indian Reservation. (Source of data: State Lakes Preservation Committee, 1977.)

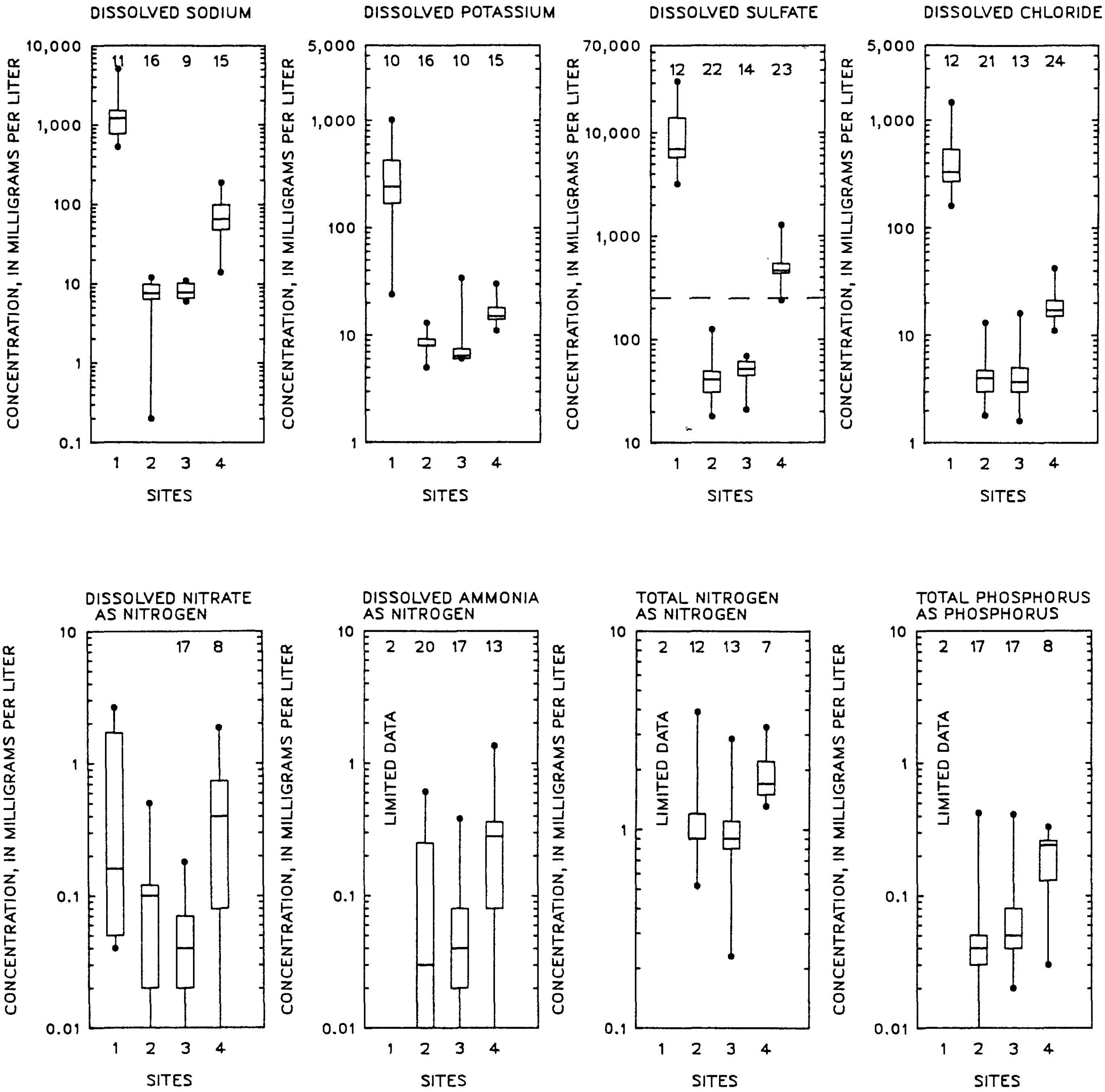

DISSOLVED SODIUM
11 16 9 15
DISSOLVED POTASSIUM
10 16 10 15
DISSOLVED SULFATE
12 22 14 23
DISSOLVED CHLORIDE
12 21 13 24
DISSOLVED NITRATE AS NITROGEN
17 8
DISSOLVED AMMONIA AS NITROGEN
2 20 17 13
TOTAL NITROGEN AS NITROGEN
2 12 13 7
TOTAL PHOSPHORUS AS PHOSPHORUS
2 17 17 8
LIMITED DATA
CONCENTRATION, IN MILLIGRAMS PER LITER
SITES

Table 5.-- Lakes in and near the Lake Traverse Indian Reservation grouped by median concentrations of dissolved solids

---

Lakes with median dissolved-solids concentration less than 500 milligrams per liter

Blue Dog
Hurricane
Enemy Swim
Pickerel
Oneroad
North and South Red Iron

Lakes with median dissolved-solids concentration between 500 and 1,000 milligrams per liter

Long
Clear
Whitestone
North and South Buffalo
Greys
Mud

Lakes with median dissolved-solids concentration between 1,000 and 4,000 milligrams per liter

Piyas
North and South Drywood
Tahana
Turtlefoot
Traverse

Lakes with median dissolved-solids concentration greater than 4,000 milligrams per liter

Bitter
Hillebrands
Isabella

Water-quality data for Lake Traverse are in many respects more similar to data for Bitter Lake than to data for Enemy Swim or Pickerel Lake because of the limited hydraulic connection of Lake Traverse with ground water (fig. 16). Lake Traverse is dominated by calcium, magnesium, and sulfate, and has more calcium and less sulfate than does Bitter Lake. Even though some precipitation of calcium carbonate probably occurs in Lake Traverse, particularly during droughts, it is not a dominant process within the lake.

The water quality of Pickerel and Enemy Swim Lakes provides a marked contrast between the Bitter Lake and Lake Traverse water-quality regime, and represents the quality of lakes with a dissolved-solids concentration less than 500 mg/L (table 5). These lakes have the least mineralized water of lakes within the reservation (fig. 16). Pickerel and Enemy Swim Lakes are hydraulically connected to a glacial-outwash aquifer, and their water levels reflect the water table of that aquifer. Therefore, levels of these lakes should rise and fall independently of evaporation. According to the South Dakota Department of Water and Natural Resources (1986), Pickerel and Enemy Swim Lakes (Leap, 1972) are hydraulically connected to areas where the Coteau Lakes aquifer is thick and may also be recharge areas for the aquifer. Water quality in these lakes probably reflects the water quality of the aquifers sustaining them.

Concentrations of dissolved nitrate, organic nitrogen, and phosphorous fluctuate greatly in all four lakes. It is difficult to establish a reason for this fluctuation without additional data and interpretation. However, because most of the lakes tend to be sinks for nutrients, nutrient concentrations would be expected to be greater than those in streams. Feedlots, septic tanks, and agricultural fertilizers have been identified as sources of nutrients for many of these lakes (State Lakes Preservation Committee, 1977). Therefore, lakes within the reservation tend to be eutrophic to varying degrees, some to the extent that nuisance blooms of algae are common, requiring remedial measures to eliminate blooms and preserve the esthetic quality of the lakes (State Lakes Preservation Committee, 1977).

With the exception of a few lakes, surface water within the reservation generally is suitable for domestic, agricultural, and industrial uses. Significant development of this resource is limited by the lack of dependable quantities and a lack of potential storage capacity. The potential uses of lakes within the reservation may be impaired because of large nutrient concentrations and subsequent algal blooms, which degrade the water quality and the esthetic quality of the lakes. Additional data and interpretation are needed to determine the hydrologic processes and sources of nutrients affecting water quality of the lakes. Bitter Lake and Lake Hillebrands are potential sites for studying hydrogeochemical processes and controls of those processes within a closed-basin lake.

GROUND WATER

Even though ground water is being used by the city of Sisseton and by individual farmers and homeowners, the distribution, quantity, and quality of ground water in the reservation is not well known. Therefore, in order to determine whether sufficient water of acceptable quality is available for agriculture and housing developments, an analysis of the ground-water supplies and hydrogeology is needed. The following narrative will summarize what is known about the ground-water resources in the reservation.

Hydrogeology

The substantial differences in physiography within the boundaries of the reservation also are paralleled by differences in hydrogeology in the Minnesota River-Red River lowlands and the Coteau des Prairies. Within the Coteau, deposits of sand and gravel, commonly containing interbedded layers of till, occur at various depths from the land surface to depths of 230 ft or greater below land surface. According to Koch (1975), several aquifers can be delineated within the Marshall County part of the reservation. These aquifers include the Coteau Lakes, Marday, and Eden aquifers. The Prairie Coteau, Eastern Lakes, Lonesome Lake, and Big Sioux aquifers also underlie the Coteau des Prairies. Koch (1975) identified an additional aquifer, the Veblen aquifer, in Marshall County that extends from the northeastern toe of the Coteau north into North Dakota and east and southeast into the Minnesota River-Red River lowlands. Because of the lack of ground-water data within the reservation, this study did not attempt to address the delineation of aquifers identified within the reservation in other studies (Leap, 1972; Koch, 1975). More detailed data and interpretation are needed to establish the definite boundaries and extent of aquifers in the reservation.

The depth from land surface to the first sand and gravel deposits thicker than 3 ft in the reservation is illustrated in figure 17. Large areas of sand and gravel deposits are at or near land surface, and probably are areas of water recharge to or water discharge from those deposits. This map was developed to generally indicate how deep a driller could expect to drill before encountering the first significant sand and gravel deposits. The map is not suitable for delineating the extent of aquifers. Such an effort will require additional data and numerous cross sections to determine elevations and possible continuity of sand and gravel deposits. Those analyses were beyond the scope of this study.

The thickness of sand and gravel deposits also is shown in figure 17. Surficial sand and gravel deposits in the Coteau range in thickness from less than 3 ft to 70 ft, and average 25 ft. Shallow sand and gravel deposits in the Minnesota River-Red River lowlands range in thickness from less than 3 ft to 70 ft near the Minnesota-South Dakota border (fig. 17). These thicknesses of sand and gravel should provide some indication of the location of substantial quantities of water within those deposits, although in a few instances the first significant sand and gravel deposits penetrated were dry.

Multiple layers of sand and gravel deposits underlie the Coteau, but are particularly prevalent in the Minnesota River-Red River lowlands. Many of these layers in the lowlands of the reservation tend to be deep (90 to 250 ft below land surface) and may be 10 to 60 ft thick. Some deep sand and gravel deposits underlying the Minnesota River-Red River lowlands may directly overlie Cretaceous sedimentary rocks.

Ground-water within the reservation generally tends to flow west and east-northeast from a topographic divide located along the eastern edge of the Coteau. Water levels for various wells are shown in figure 18. In several areas, water may flow from areas where sand and gravel deposits are within 5 ft of the land surface, indicating possible areas of recharge. The available water-level data precluded the development of a ground-water flow regime.

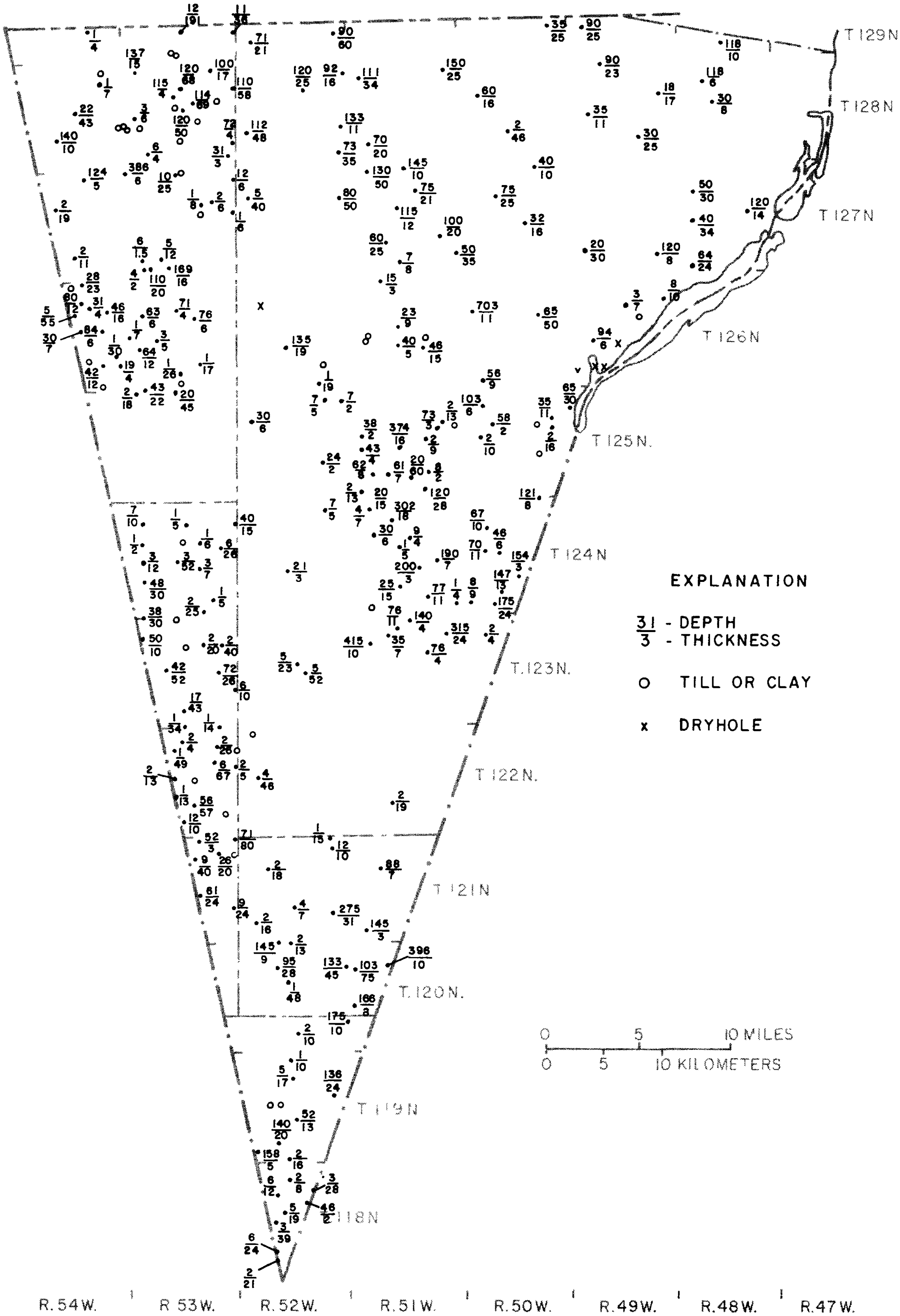


Figure 17.--Depth below land surface and thickness of sand and gravel deposits in the Lake Traverse Indian Reservation.

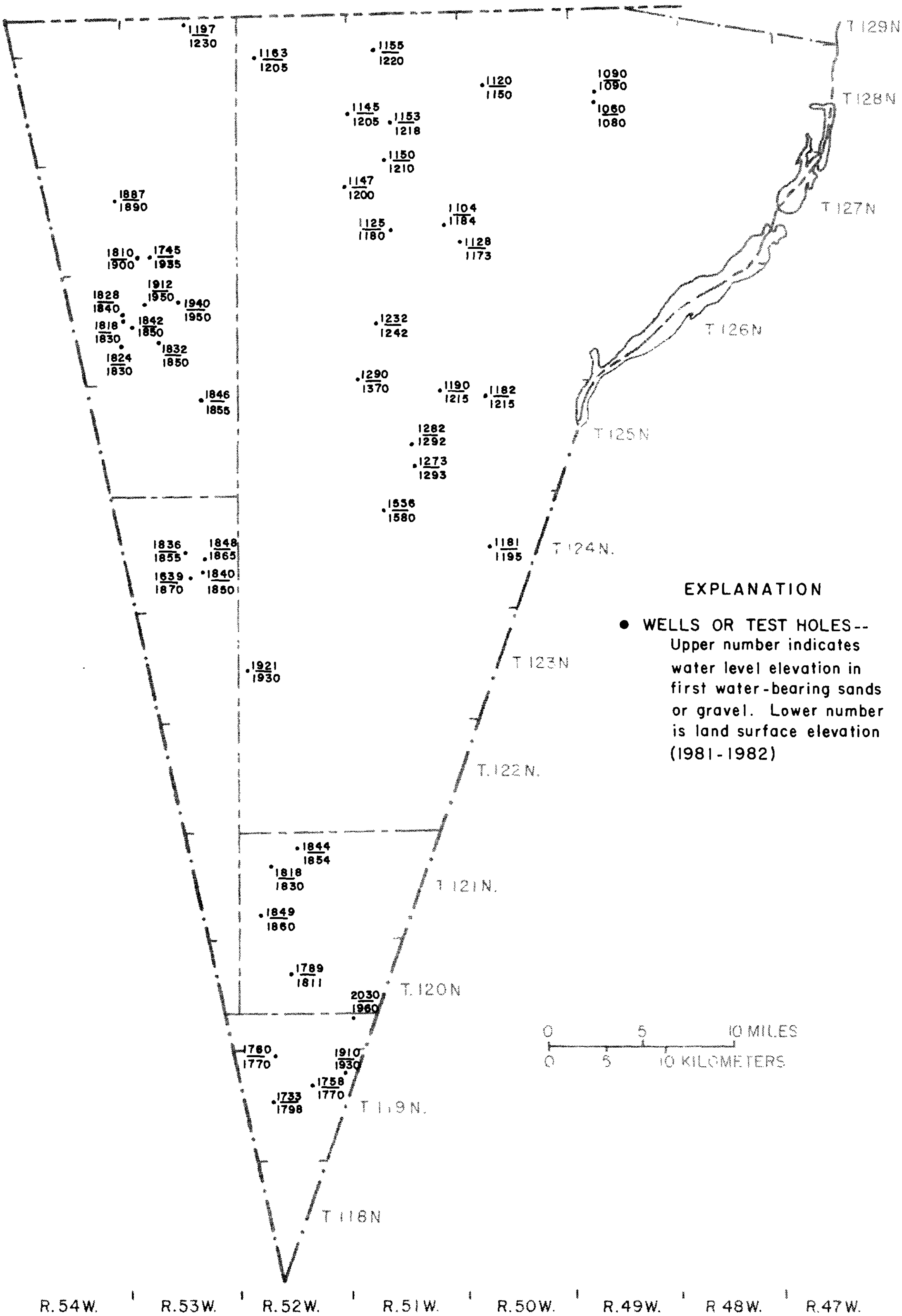


Figure 18.--Water-table altitude in surficial sand or gravel in the Lake Traverse Indian Reservation.

Ground-Water Quality

In most instances, ground water is more mineralized than surface water. Reasons for this include longer contact time with water-soluble minerals, increased solubility of minerals because of higher temperature, and contact with clay layers with exchangeable ions.

Analyses of water samples from wells in the reservation indicate that significant increases in dissolved-solids concentrations generally occur as well depth increases (fig. 19). Median specific-conductance values range from about 1,400 μS/cm (microsiemens per centimeter at 25 °C) in wells with depths ranging from 30 to 60 ft to 3,200 μS/cm for wells with depths greater than 500 ft. Many of the wells deeper than 500 ft may be completed just above Cretaceous sedimentary rocks. Sodium, potassium, sulfate, chloride, fluoride, iron, manganese, and dissolved-solids concentrations also generally increase with well depth. Since censored data (data with less than a minimum value) were present (specifically iron, manganese, and nitrate), a maximum-likelihood procedure was used to provide estimates of means and 25th, 50th, and 75th percentiles (Helsel and Gilliom, 1985). Concentrations of chloride in water samples from shallower wells only occasionally exceed South Dakota drinking-water standards (South Dakota Department of Water and Natural Resources, 1986), whereas concentrations of sulfate from wells frequently exceeded those standards (fig. 19). It is unknown whether the water quality in deeper wells is affected by recharge from the Dakota aquifer or if concentrations are larger because of the longer contact time between water and the deeper glacial-aquifer materials.

Although nitrate concentrations tend to be larger in water from the shallower wells, those samples infrequently exceeded the drinking-water standard for nitrate of 10 mg/L as nitrogen (fig. 19) (South Dakota Department of Water and Natural Resources, 1986). Infants may develop the disorder methemoglobinemia (blue-baby disease) when nitrate concentrations equal or exceed 10 mg/L as nitrogen. Although nitrate concentrations tend to decrease with well depth, water from the deeper wells contains nitrate in a concentration range similar to that in water from the shallower wells. It is possible that inadequate construction of the deeper wells could allow nitrate-enriched water from the shallow wells to flow down the outside of the well casing and into the deep sandstone aquifer (Dakota Sandstone).

Water in the shallow wells can become contaminated with large concentrations of nitrate through the placement of wells downgradient from livestock areas and septic-tank leach fields. It is unlikely that water with large nitrate concentrations would seep through the many layers of sand, gravel, and glacial till to reach the water in the deep wells; however, if the water could seep to deeper depths, the anoxic conditions of deep ground water would facilitate the denitrification of nitrate in the water by facultative micro-organisms to produce reduced-nitrogen compounds including nitrogen gas and result in depletion of nitrate in the water.

In general, proportions of dominant cations changed little in water samples from wells with depths less than 500 ft below land surface. Calcium and magnesium proportions were stable at all well depths except the greatest depths. Calcium and magnesium consisted of at least 86 percent (on an equivalent basis) of the total cations at all well depths except the greatest depths.

Proportions of dominant anions were much more variable. Bicarbonate and sulfate were the predominant anions in most instances. However, in a few samples, chloride concentrations were a greater proportion of the anions than bicarbonate or sulfate.

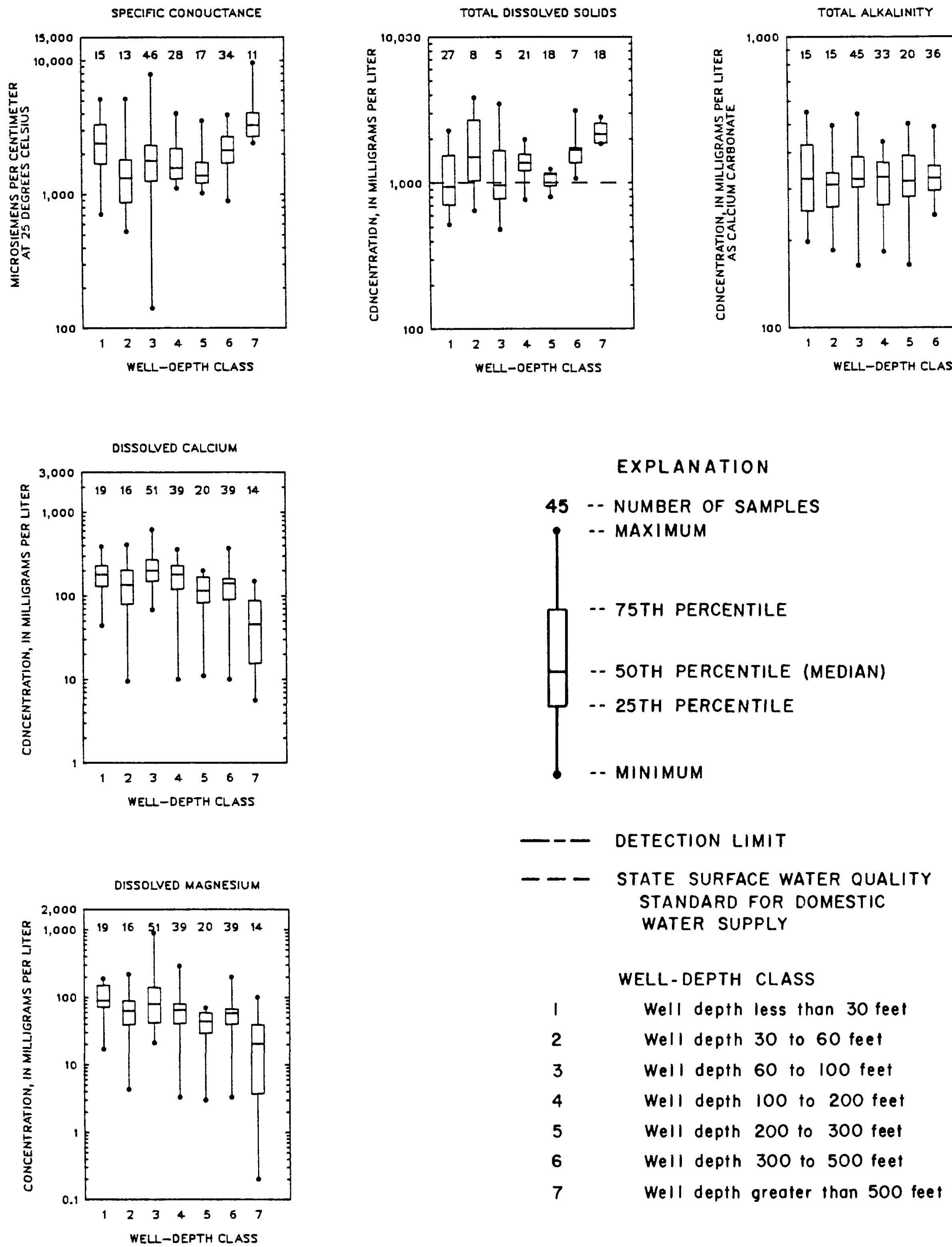
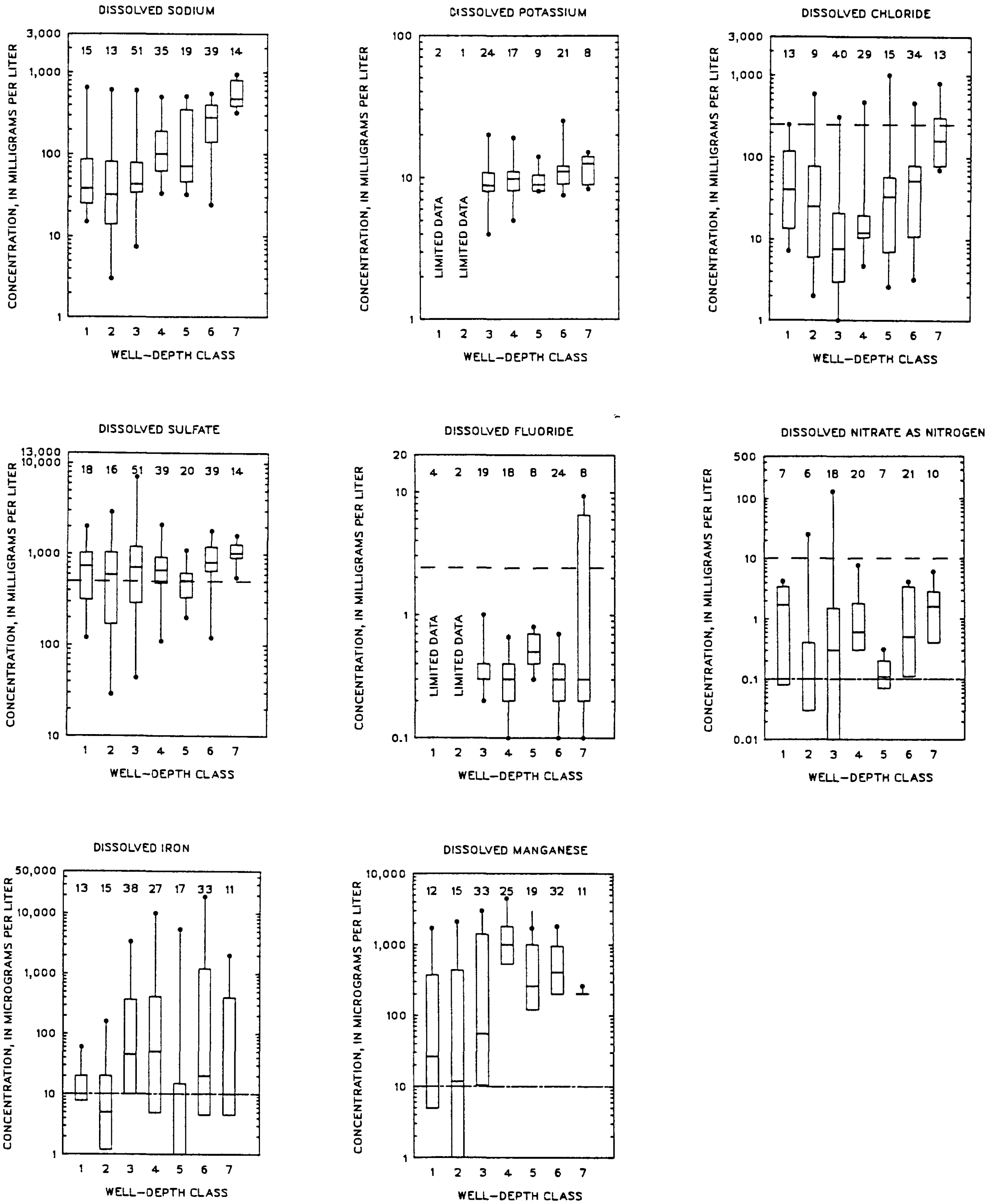


Figure 19.--Water quality of ground water by well depth in the Lake Traverse Indian Reservation.


DISSOLVED SODIUM
CONCENTRATION, IN MILLIGRAMS PER LITER
3,000
1,000
100
10
1
15 13 51 35 19 39 14
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED POTASSIUM
CONCENTRATION, IN MILLIGRAMS PER LITER
100
10
1
2 1 24 17 9 21 8
LIMITED DATA
LIMITED DATA
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED CHLORIDE
CONCENTRATION, IN MILLIGRAMS PER LITER
3,000
1,000
100
10
1
13 9 40 29 15 34 13
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED SULFATE
CONCENTRATION, IN MILLIGRAMS PER LITER
13,000
10,000
1,000
100
10
18 16 51 39 20 39 14
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED FLUORIDE
CONCENTRATION, IN MILLIGRAMS PER LITER
20
10
1
0.1
4 2 19 18 8 24 8
LIMITED DATA
LIMITED DATA
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED NITRATE AS NITROGEN
CONCENTRATION, IN MILLIGRAMS PER LITER
500
100
10
1
0.1
0.01
7 6 18 20 7 21 10
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED IRON
CONCENTRATION, IN MICROGRAMS PER LITER
50,000
10,000
1,000
100
10
1
13 15 38 27 17 33 11
1 2 3 4 5 6 7
WELL-DEPTH CLASS
DISSOLVED MANGANESE
CONCENTRATION, IN MICROGRAMS PER LITER
10,000
1,000
100
10
1
12 15 33 25 19 32 11
1 2 3 4 5 6 7
WELL-DEPTH CLASS

Water samples from wells less than about 180 ft deep had two different water types--a calcium bicarbonate type and a calcium sulfate type--and probably reflect water in the glacial aquifers or perhaps some intrusion of water from underlying Cretaceous sedimentary rocks through improperly constructed or corroded wells. Water from these wells is very hard (hardness greater than 180 mg/L as $CaCO_3$) and, although suitable for domestic and agricultural uses, many users prefer softer water.

Wells at a depth of greater than 500 ft below land surface generally are completed in the Cretaceous Dakota Sandstone and yield water that generally is too mineralized for most uses. The water generally is soft with predominant ions being sodium and sulfate (figs. 19 and 20). Two other water types are evident from wells in this grouping, calcium bicarbonate and calcium sulfate. It is likely that wells with those two water types are completed in deep glacial-outwash deposits with water quality similar to that in shallower glacial-outwash deposits. However, some intrusion of water from overlying glacial formations may produce local dilution of water from the Dakota Sandstone. Such intrusion results from improperly constructed deep wells that are cased through glacial sands and gravels and allow water to flow into the sandstone aquifer. However, no data are available to confirm that hypothesis.

Data pertaining to ground-water quality within the reservation are lacking for numerous areas. In addition, at least 50 percent of the water-quality samples for all aquifers could not be used to determine the dominant ions because of incomplete analyses. Additional water-quality samples could be collected at wells that now do not have complete analyses. It is possible that additional data on dominant ions could help delineate aquifer boundaries or determine if water is moving from one aquifer to another through improperly constructed wells or other avenues. Nitrate plus nitrite, dissolved-fluoride, dissolved-iron, and dissolved-manganese data are especially needed. Nitrate plus nitrite data are needed particularly from the glacial-outwash aquifers. Because these aquifers are close to land surface and are commonly used for private water supplies, they are particularly susceptible to contamination by nitrate plus nitrite in runoff from feedlots, septic tanks, and fertilizer storage areas.

NEEDED ADDITIONAL STUDIES

Although numerous data are available for surface and ground water within the reservation, and have been used in this investigation, key pieces of data are missing. This investigation has established that the quantity, timing, and storage of surface water within the reservation is not sufficient to meet large-scale beneficial uses. Lakes generally are too shallow and too affected by the vagaries of climate to be used as a large-scale water supply. Streamflow is not dependable for most of the year except during spring when the winter snowpack melts. Additional gaging stations could be used to monitor streams flowing from the reservation into Minnesota (Jorgenson River) and North Dakota (Shortfoot Creek).

Surface water generally is suitable for most uses. Because the streams and most lakes in the reservation are hydraulically connected to glacial-outwash aquifers, the water is suitable for domestic, industrial, and agricultural supplies. However, additional chloride, sulfate, nutrient, trace-element, fecal coliform and fecal streptococcus bacteria, and sediment-transport data are needed for streams and lakes in the reservation. An in-depth study of Bitter Lake and Lake Hillebrands could provide insight into hydrogeochemical processes in lakes within closed basins.

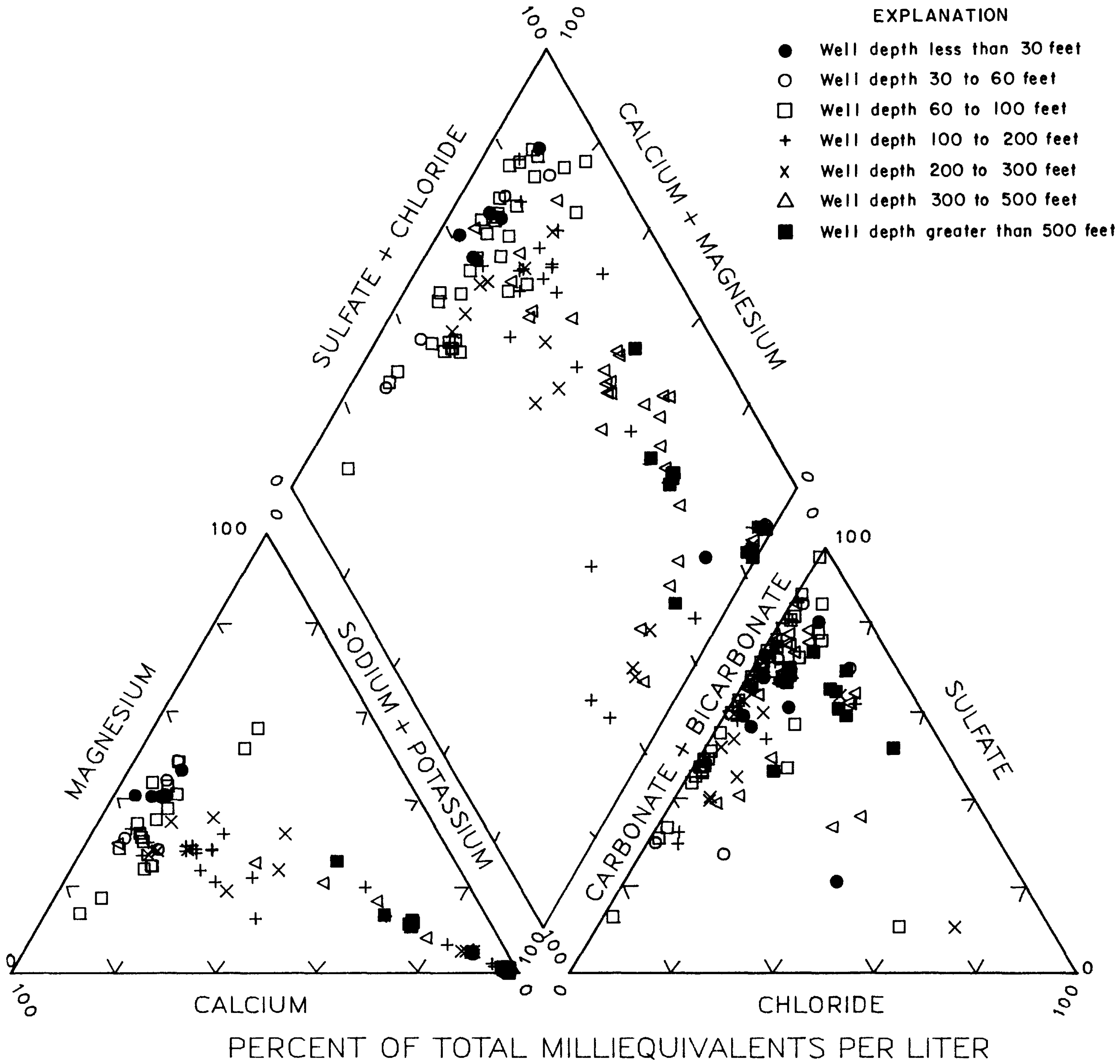


Figure 20.--Trilinear plot of water chemistry by well depth for wells in and near the Lake Traverse Indian Reservation.

Because the quantity, timing, and storage capacity of surface water in the reservation preclude large-scale development, the ground-water resource becomes an important component in the reservation's use of water. Available data are not sufficient to describe with accuracy the direction of regional ground-water flow and the thickness of regional sand and gravel deposits in the reservation. Furthermore, additional water-level data are needed to further define areas of recharge and discharge; additional well logs are needed to further define elevation, thickness, areal extent of sand and gravel deposits, and delineation of aquifers. This additional data, plus tests to determine aquifer transmissivity and specific yield, will provide information that allows a more predictable and more efficient means of finding significant quantities of usable ground water. Additional data pertaining to the quality of ground water in the reservation are needed to ensure that available water meets drinking-water standards.

Although the data and interpretations in this report are sufficient to provide a general overview of ground water in the reservation, considerable additional data and interpretations are needed in order to efficiently develop the resource. Specifically:

1. Additional well-log data, which can be obtained either through surveys of existing wells or by drilling of observation wells, are needed in parts of the reservation to develop multiple lithologic sections of sand and gravel deposits for defining specific aquifers.

2. Measurement of water levels in as many wells as possible during a 6-month period are needed to determine potentiometric surfaces of the aquifers and direction of ground-water flow on a local scale.

3. Tests are needed to determine aquifer transmissivity, specific yield, and storage coefficient.

SUMMARY

The Lake Traverse Indian Reservation in the northeast part of South Dakota occupies a triangular area within the Central Lowlands physiographic province. The topography is generally glacially derived and is characterized by two physiographic divisions--the Coteau des Prairies (a prominent plateau) and the Minnesota River-Red River lowlands. Geologically, the area is underlaid by layers of glacial till and outwash, and alluvial deposits of sand and gravel. These deposits are underlaid by Cretaceous sedimentary rocks and Precambrian granite.

The glacial-outwash and alluvial deposits generally are layers of fine to coarse sand and gravel with poor to moderate sorting that are commonly interlayered with till. The thickness of sand and gravel deposits ranges from less than 3 ft to 70 ft; these deposits may extend from the land surface to depths greater than 230 ft below land surface. Cretaceous sedimentary rocks containing a sandstone aquifer underlie the reservation at depths greater than 500 ft below land surface.

Surface water within the reservation consists of intermittent streams and numerous lakes and wetlands. The reservation is located in parts of three major river basins: the Missouri River basin, represented by the Big Sioux and James River basins; the Souris-Red-Rainy River basin, represented by the Bois de Sioux River basin; and the Upper Mississippi River basin, represented by the Little Minnesota and Jorgenson River basins. The flow regimes of the Big Sioux, Bois de Sioux, and Little Minnesota Rivers have distinct seasonal trends. Most of the annual streamflow occurs from March through June in response to the melting winter snow pack and to thunderstorms. Spring is the period of most dependable flow for the three rivers, but ground-water inflow in the basins of the Big Sioux and Little Minnesota Rivers provides a small but dependable flow during the fall. Periods of zero flow may occur during the winter and late summer.

Numerous lakes, ponds, and wetlands are located in the reservation, particularly within internally drained, noncontributing areas of the basins of the Big Sioux and James Rivers. These lakes store large quantities of water during wet periods (205,000 acre-ft in 1975); however, because of large surface areas, shallow depths, effects of evaporation, and lack of sustained ground-water inflow, the lakes cannot store dependable supplies of water for large-scale domestic or agricultural uses. Many of the lakes are hydraulically connected to glacial-outwash aquifers and lake levels tend to rise or fall with the water table.

Streamflow generally is suitable for most uses; dissolved-solids concentrations only occasionally exceed 1,000 mg/L in the Big Sioux, Bois de Sioux, and Little Minnesota Rivers. Other properties and constituents, such as pH, dissolved oxygen, and fecal coliform bacteria may exceed drinking-water standards and, in the case of bacteria, recreational standards. Nutrient concentrations may at times be large, indicating some enrichment from feedlots or septic tanks.

The lakes in the reservation may have dissolved-solids concentrations less than 500 mg/L (lakes in contact with glacial-outwash aquifers) or greater than 4,000 mg/L (lakes in contact with glacial till in closed basins). The water quality of many of the lakes indicates nutrient enrichment due to feedlot and other agricultural runoff; such enrichment accelerates eutrophication.

Ground water in the reservation generally is suitable for most uses; dissolved-solids concentrations commonly are less than 1,500 mg/L. The quality of water from the sand and gravel deposits generally is similar even to depths of 250 ft. However, nitrate may be a serious problem because concentrations approach the drinking-water standard of 10 mg/L as nitrogen. Water from the deep sandstone aquifer is too mineralized for domestic, irrigation, or industrial uses without treatment.

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