VARIATIONS IN SURFACE-WATER QUALITY IN THE CHAIN OF LAKES AND ITS TRIBUTARIES, DEVILS LAKE BASIN, NORTH DAKOTA, 1957-92

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 95-4102

Prepared in cooperation with the

NORTH DAKOTA STATE WATER COMMISSION and the

DEVILS LAKE BASIN JOINT WATER RESOURCE BOARD

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Bismarck, North Dakota

1995

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
degree Celsius (°C)	([1])	degree Fahrenheit
foot (ft)	0.3048	meter
kilogram (kg)	2.205	pound avoirdupois
mile (mi)	1.609	kilometer
milligram per second (mg/s)	0.00003527	ounce avoirdupois
square mile (mi^2)	2.590	square kilometer

[1]Temp °F = 1.8 temp °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 Sea Level Datum of 1929.

Micrograms per liter (µg/L) is a unit expressing the concentration of a chemical constituent in solution as mass (micrograms) of solute per unit volume (liter) of water.

Microsiemens per centimeter at 25 degrees Celsius (µS/cm) replaces micromhos per centimeter at 25 degrees Celsius used for specific conductance in older reports. The two units are equivalent.

Milligrams per liter (mg/L) is a unit expressing the concentration of a chemical constituent in solution as mass (milligrams) of solute per unit volume (liter) of water; 1 mg/L equals 1,000 µg/L.

Variations in Surface-Water Quality in the Chain of Lakes and Its Tributaries, Devils Lake Basin, North Dakota, 1957-92

By Robert M. Lent *and* Scott D. Zainhofsky

Abstract

The chain of lakes, located in the Devils Lake Basin, North Dakota, receives and stores runoff from the northern section of the basin and recharges Devils Lake. Hydrologic and water-quality conditions can vary greatly in the basin, resulting in potential economic damage. This report describes the seasonal and spatial variations in surface-water quality in the chain of lakes and its tributaries.

Long-term trends in dissolved-solids and nutrient concentrations and instantaneous loads in tributaries upstream and downstream of the chain of lakes are not apparent. However, seasonal variations are apparent. Dissolved-solids concentrations were smaller, and nutrient concentrations were larger, during the spring than during the remainder of the year. Variations in dissolved-solids concentrations are caused by dilution and evaporation. Variations in nutrient concentrations are the result of biologic activity. Instantaneous dissolved-solids and nutrient loads were greater during the spring than during the remainder of the year because of seasonal differences in flow rates.

Only minimal long-term trends and seasonal variations in dissolved-solids and nutrient concentrations in the chain of lakes are apparent. During the period of record, dissolved-solids concentrations in Sweetwater Lake generally increased, dissolved-solids concentrations in Lake Alice and Lake Irvine varied seasonally, and dissolved phosphorus concentrations in Lake Alice generally increased.

Spatial variations in dissolved-solids and nutrient concentrations in the basin are apparent. The medians and ranges of dissolved-solids concentrations for the upstream stations were smaller than those for the lake stations and the downstream stations. Dissolved-solids concentrations were larger in Channel A than in Big Coulee, and nutrient concentrations were larger in Big Coulee than in Channel A.

INTRODUCTION

Before 1979, Sweetwater Lake, Morrison Lake, Cavanaugh Lake, Dry Lake, Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine were an interconnected chain of natural lakes located in the Devils Lake drainage basin in northeastern North Dakota (fig. 1). The chain of lakes received and stored runoff from northern sections of the Devils Lake Basin by way of Edmore Coulee, Starkweather Coulee, St. Joe Coulee, Calio Coulee, and Mauvais Coulee and recharged Devils Lake by way of Big Coulee. In 1979, when Channel A was constructed and Dry Lake was separated from Mikes Lake, the chain of lakes became two separate chains. Sweetwater Lake, Morrison Lake, Cavanaugh Lake, and Dry Lake received and

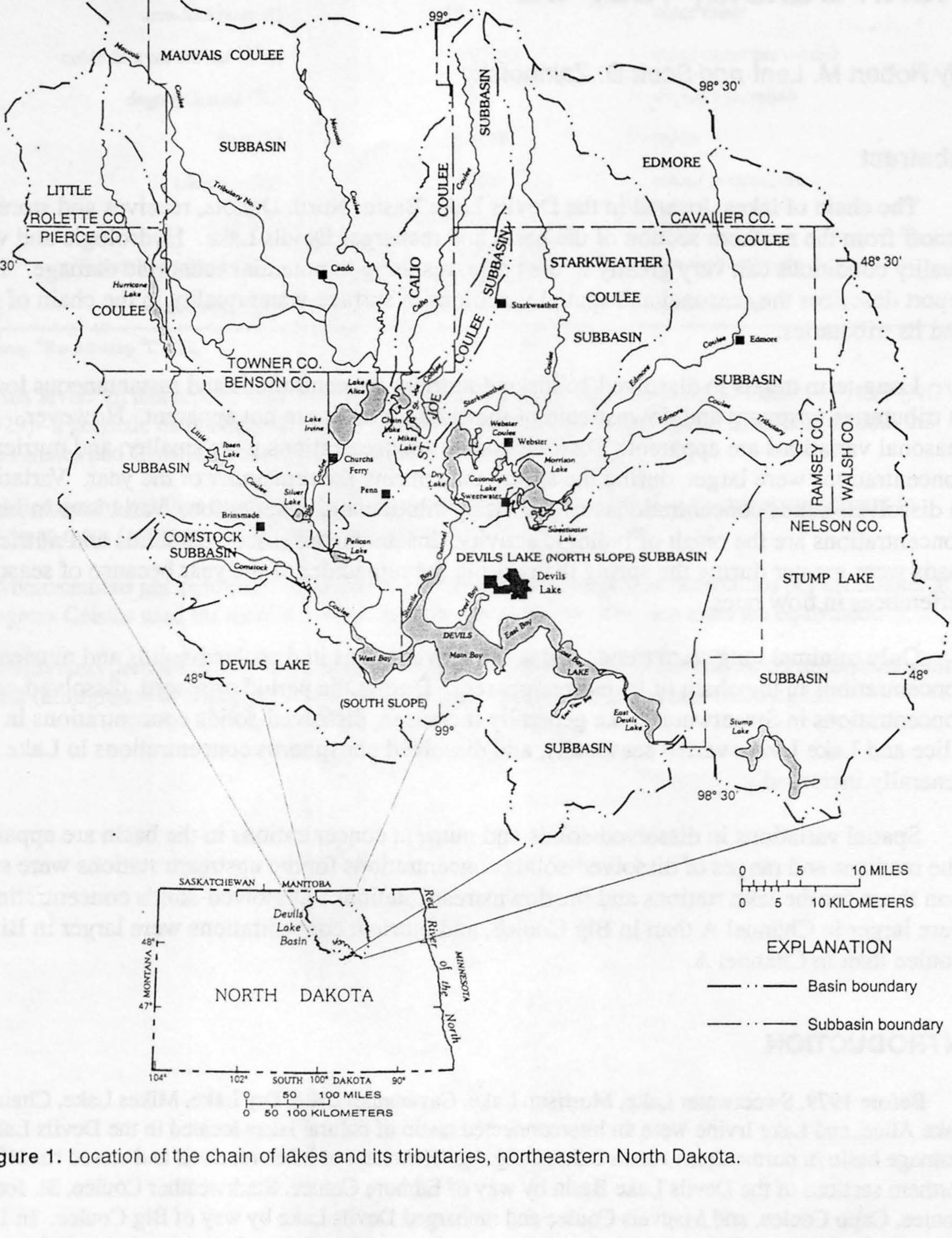


Figure 1. Location of the chain of lakes and its tributaries, northeastern North Dakota.

stored runoff by way of Edmore Coulee and Starkweather Coulee and recharged Devils Lake by way of Channel A. Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine received and stored runoff by way of St. Joe Coulee, Calio Coulee, and Mauvais Coulee and recharged Devils Lake by way of Big Coulee. Together, the two chains act as an evaporation and storage basin and can affect water-level fluctuations in Devils Lake (Wiche, 1986). However, water-quality variations between the two chains are difficult to determine.

During the early to mid-1980's, the water level of Devils Lake generally rose until it reached a maximum of 1,428.8 ft above sea level in July 1987 (fig. 2). The rising water level caused flooding of croplands and county roads. From July 1987 to October 1992, the water level generally decreased until it reached a minimum of 1,422.4 ft above sea level in October 1992. The water-level fluctuations in Devils Lake have caused water-quality variations in the lake. In 1987, dissolved-solids concentrations generally were small, but, from July 1987 to October 1992, the concentrations generally increased. Decreasing water levels and increasing dissolved-solids concentrations adversely affected the sport fishery in Devils Lake.

Artificial controls on Dry Lake and Lake Alice allow some regulation of flow from the chain of lakes to Devils Lake. In 1968, the U.S. Fish and Wildlife Service constructed a control between Lake Alice and Lake Irvine to maintain water levels and minimize water-level fluctuations to protect waterfowl habitats on Lake Alice. During the 1980's and early 1990's, many water-management plans were proposed to reduce flooding and water-quality problems in the Devils Lake Basin and in Devils Lake. To help develop management plans for the Devils Lake Basin, a thorough understanding of upstream water-quality conditions is needed.

Hydrologic and water-quality conditions have varied greatly in Devils Lake during the 125 years for which records are available. Intermittently since 1957, the U.S. Geological Survey has collected water-quality data upstream of Devils Lake for a variety of different projects. Before 1992, a comprehensive analysis of the available water-quality data had not been done. Thus, in 1993, the U.S. Geological Survey, in cooperation with the North Dakota State Water Commission and the Devils Lake Basin Joint Water Resource Board, began a study to evaluate available information for variations and trends in water quality in the chain of lakes and in tributaries upstream and downstream of the chain of lakes.

Purpose and Scope

This report describes temporal and spatial variations in surface-water quality in the chain of lakes and in tributaries upstream and downstream of the chain of lakes during October 1957 through September 1992. The report includes evaluations of:

1. Temporal and spatial variations and long-term trends in major-ion and nutrient concentrations in tributaries upstream of the chain of lakes, in the chain of lakes, and in tributaries downstream of the chain of lakes.

2. Temporal variations and long-term trends in major-ion and nutrient masses in the chain of lakes.

3. Temporal and spatial variations and long-term trends in major-ion and nutrient loads in tributaries upstream and downstream of the chain of lakes.

4. The effects of storage in the chain of lakes on water quality in tributaries downstream of the chain of lakes.

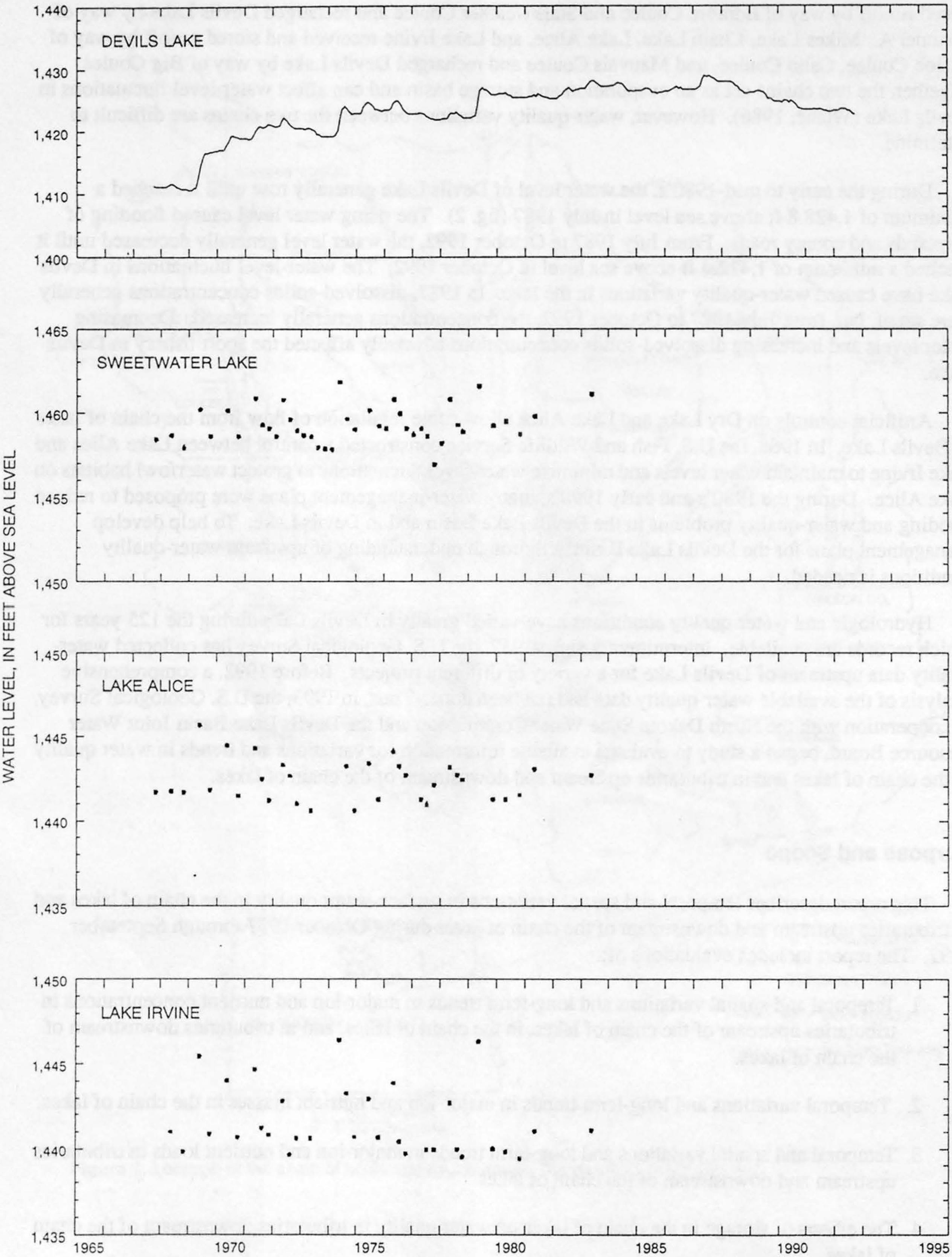
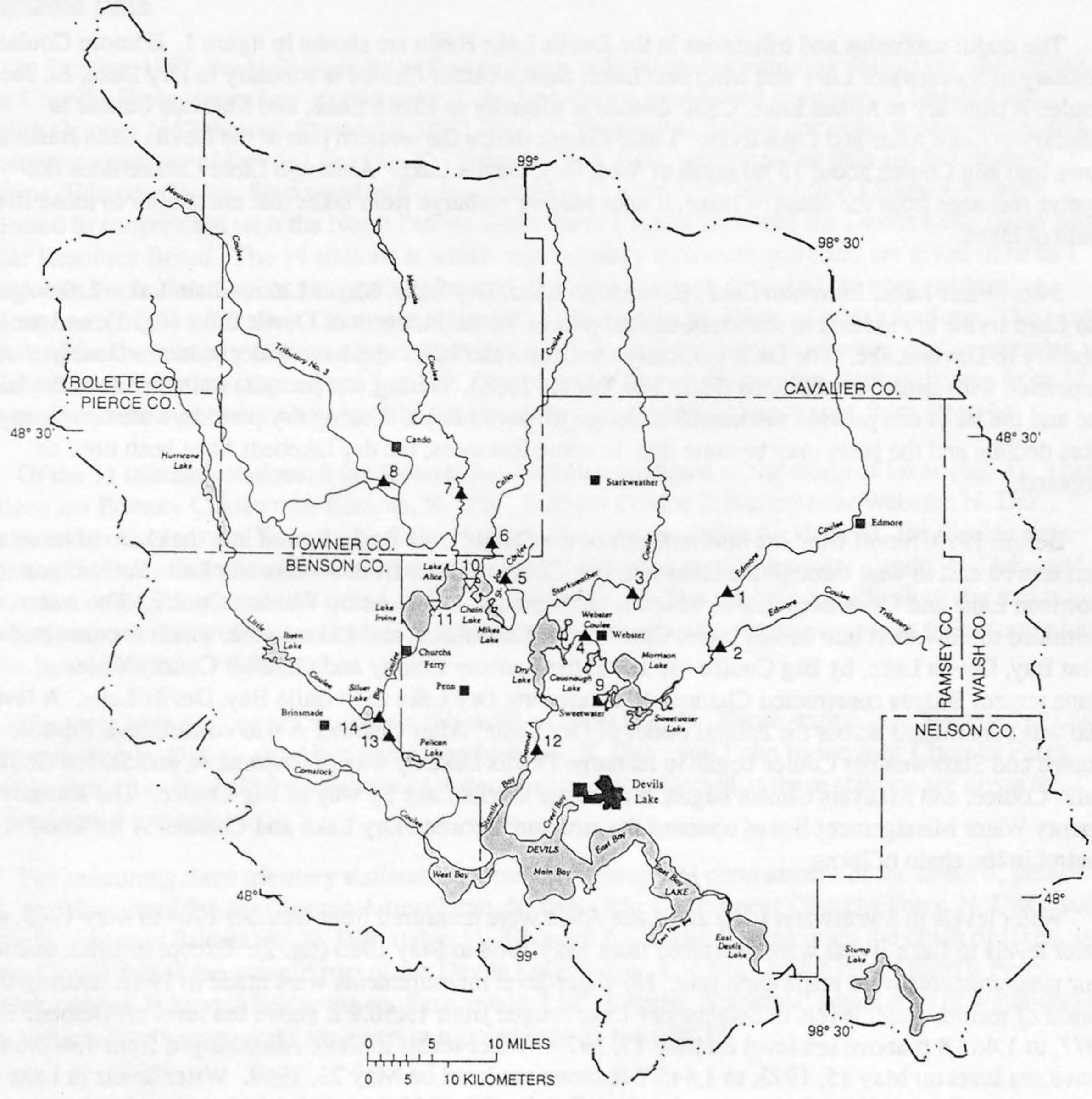


Figure 2. Water levels in Devils Lake and in selected lakes in the chain of lakes, northeastern North Dakota, 1967-92.

The report also includes water-quality data collected by the U.S. Geological Survey during October 1957 through September 1992. Data were collected at 14 stations in the Devils Lake Basin (fig. 3). Of the 14 stations, 8 are located on tributaries upstream of the chain of lakes, 3 are located on the chain of lakes, 2 are located on tributaries downstream of the chain of lakes, and 1 is located on Little Coulee, a tributary to Big Coulee. Water-quality data for Devils Lake are not included in this report.



EXPLANATION

Devils Lake Basin boundary

▲ 1 Tributary station and site number (See table 1 for site number list)

▽ 9 Lake station and site number (See table 1 for site number list)

Figure 3. Location of surface-water stations on the chain of lakes and its tributaries in the Devils Lake Basin, northeastern North Dakota.

Hydrologic Setting

The Devils Lake Basin in northeastern North Dakota is a large, closed basin located in the drainage of the Red River of the North (fig. 1). About 3,320 mi^2 of the basin (87 percent) is tributary to Devils Lake, and the remaining 490 mi^2 (13 percent) is tributary to Stump Lake (fig. 1). The area around Devils Lake is blanketed by glacial sediments that are characterized by hummocky surfaces, shallow depressions, and poorly defined water divides (Callender, 1968; Hobbs and Bluemle, 1987). The till is comprised primarily of material from the Cretaceous Pierre Shale, a shale-rich formation underlying much of eastern North Dakota.

The major subbasins and tributaries in the Devils Lake Basin are shown in figure 1. Edmore Coulee is tributary to Sweetwater Lake and Morrison Lake, Starkweather Coulee is tributary to Dry Lake, St. Joe Coulee is tributary to Mikes Lake, Calio Coulee is tributary to Chain Lake, and Mauvais Coulee is tributary to Lake Alice and Lake Irvine. Little Coulee drains the western part of the Devils Lake Basin and flows into Big Coulee about 15 mi north of West Bay, Devils Lake. Although Little Coulee does not receive recharge from the chain of lakes, it does receive recharge from lakes that are similar to those in the chain of lakes.

Sweetwater Lake, Morrison Lake, Cavanaugh Lake, Dry Lake, Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine are located in the south-central part of the basin, north of Devils Lake (fig. 1), and are tributary to Devils Lake. The lakes generally are freshwater lakes and have water volumes closely associated with climatic conditions (Ryan and Wiche, 1988). During wet periods, water levels in the lakes rise and the lakes can provide substantial recharge to Devils Lake. During dry periods, water levels in the lakes decline and the lakes may become dry. In some instances, the dry lakebeds have been used as cropland.

Before 1979, runoff from the northern part of the Devils Lake Basin flowed into the chain of lakes and then flowed east to west through the lakes into Big Coulee. Water from Sweetwater Lake flowed west into Morrison Lake and Cavanaugh Lake, which is connected to Dry Lake by Webster Coulee. The water continued to flow west into Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine, which is connected to West Bay, Devils Lake, by Big Coulee. In 1979, the Ramsey County and Cavalier County Water Management Boards constructed Channel A, connecting Dry Lake to Sixmile Bay, Devils Lake. A levee also was constructed across the natural outlet of Dry Lake. After Channel A was constructed, Edmore Coulee and Starkweather Coulee began to recharge Devils Lake by way of Channel A, and St. Joe Coulee, Calio Coulee, and Mauvais Coulee began to recharge Devils Lake by way of Big Coulee. The Ramsey County Water Management Board operates the structure between Dry Lake and Channel A for flood control in the chain of lakes.

Water levels in Sweetwater Lake and Lake Alice were measured from October 1967 to May 1983, and water levels in Lake Irvine were measured from May 1968 to May 1983 (fig. 2). Except in 1982, one to four measurements were made each year. No water-level measurements were made in 1982. During the period of record, water levels in Sweetwater Lake ranged from 1,456.9 ft above sea level on October 17, 1977, to 1,461.8 ft above sea level on May 17, 1979. Water levels in Lake Alice ranged from 1,440.6 ft above sea level on May 15, 1973, to 1,445.7 ft above sea level on May 23, 1969. Water levels in Lake Irvine ranged from 1,439.4 ft above sea level on October 30, 1980, to 1,446.4 ft above sea level on May 24, 1974. Because of the small amount of available data, the hydrographs shown in figure 2 should not be considered detailed.

Water-level fluctuations in the chain of lakes generally were seasonal (fig. 2). Maximum annual water levels occurred during the spring and early summer as a result of spring runoff, and minimum annual water levels occurred during the fall and winter as a result of discharge to Devils Lake and loss by evaporation. In contrast, water-level fluctuations in Devils Lake generally were long term (fig. 2).

During the period of record, the water volume in Sweetwater Lake ranged from 15,500 acre-ft on October 17, 1977, to 47,400 acre-ft on May 17, 1979. The water volume in Lake Alice ranged from 2,200 acre-ft on May 15, 1973, to 23,550 acre-ft on May 23, 1969. The water volume in Lake Irvine ranged from 550 acre-ft on October 30, 1980, to 28,500 acre-ft on May 24, 1974.

Available Data

In October 1957, the U.S. Geological Survey began collecting water-quality data at the Big Coulee near Churchs Ferry streamflow-gaging station, the first station established upstream of Devils Lake. During October 1957 through September 1992, the U.S. Geological Survey collected water-quality data at 14 stations upstream of Devils Lake (fig. 3). From 1986 to 1992, water-quality data for five of these stations (Edmore Coulee, Starkweather Coulee, Mauvais Coulee, Big Coulee, and Channel A) were collected in cooperation with the North Dakota State Water Commission and the Devils Lake Basin Joint Water Resource Board. The 14 stations at which water-quality data were collected are given in table 1 along with the station number, the period of record, the total drainage area, and the noncontributing drainage area of the subbasins. Data were collected at 11 tributary stations and 3 lake stations. The period of record for the tributary stations ranges from 3 to 36 years, and the number of water-quality samples collected at each station ranges from 3 to 169. The period of record for the lake stations ranges from 22 to 27 years, and the number of water-quality samples collected at each station ranges from 49 to 64.

Of the 11 tributary stations, 8 are located on tributaries upstream of the chain of lakes (fig. 3). These stations are Edmore Coulee near Edmore, N. Dak.; Edmore Coulee Tributary near Webster, N. Dak.; Starkweather Coulee near Webster, N. Dak.; Webster Coulee at Webster, N. Dak.; St. Joe Coulee near Webster, N. Dak.; Calio Coulee near Starkweather, N. Dak.; Mauvais Coulee near Cando, N. Dak.; and Mauvais Coulee Tributary No. 3 near Cando, N. Dak. (table 1). The stations include all of the major tributaries to the chain of lakes. Statistical summaries of water-quality data collected at these stations are given in supplements 1 through 8.

The three lake stations are located on the chain of lakes (fig. 3). These stations are Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak. (table 1). Statistical summaries of water-quality data collected at these stations are given in supplements 9 through 11.

The remaining three tributary stations are located on tributaries downstream of the chain of lakes (fig. 3). These stations are Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak. (table 1). Channel A and Big Coulee drain the chain of lakes, and Little Coulee drains the western part of the Devils Lake Basin. The Big Coulee near Churchs Ferry, N. Dak., station is located below the confluence with Little Coulee. Statistical summaries of water-quality data collected at these stations are given in supplements 12 through 14.

Analytical Methods

Water-quality data used in this report were retrieved from the U.S. Geological Survey's National Water Information System (NWIS) data base. The entire record for each station was retrieved, the number of samples was determined, and the maximum, minimum, mean, and summary statistics (supplements 1

Table 1. Stations at which water-quality data were collected in the Devils Lake Basin, northeastern North Dakota

Station number	Site number	Station name	Period of record	Total drainage area (square miles)	Noncontributing drainage area (square miles)
Stations located on tributaries upstream of the chain of lakes (east)					
05056200	1	Edmore Coulee near Edmore, North Dakota	1971-92	382	100
05056215	2	Edmore Coulee Tributary near Webster, North Dakota	1986-92	148	44
05056239	3	Starkweather Coulee near Webster, North Dakota	1980-92	310	--
05056225	4	Webster Coulee at Webster, North Dakota	1980-86	670	--
Stations located on tributaries upstream of the chain of lakes (west)					
05056244	5	St. Joe Coulee near Webster, North Dakota	1986-88	91	--
05056247	6	Calio Coulee near Starkweather, North Dakota	1986-88	130	--
05056100	7	Mauvais Coulee near Cando, North Dakota	1971-92	387	10
05056060	8	Mauvais Coulee Tributary No. 3 near Cando, North Dakota	1986-92	60.2	--
Stations located on the chain of lakes					
05056220	9	Sweetwater Lake at Sweetwater, North Dakota	1960-86	670	290
05056250	10	Lake Alice near Churchs Ferry, North Dakota	1960-86	2,100	500
05056260	11	Lake Irvine near Churchs Ferry, North Dakota	1965-86	2,120	500
Station located on tributary downstream of the chain of lakes (east)					
05056410	12	Channel A near Penn, North Dakota	1984-92	930	--
Station located on tributary downstream of the chain of lakes (west)					
05056400	13	Big Coulee near Churchs Ferry, North Dakota	1957-92	1,620	158
Station located downstream of the chain of lakes (nontributary station analyzed with stations located on tributaries downstream of the chain of lakes)					
05056390	14	Little Coulee near Brinsmade, North Dakota	1976-89	350	160

through 14) were calculated for all water-quality properties and constituents. The original data then were processed according to the following procedures.

Values for certain water-quality properties, including specific conductance, pH, and alkalinity, were determined using both field and laboratory methods. As a result, different parameter codes were used to store data in the NWIS data base. Before data analysis, the field and laboratory data were combined into one file. If both field and laboratory values were reported for the same water-quality sample, the field value was used.

The reporting units for certain water-quality constituents, such as the nitrogen- and phosphorus-species constituents, have changed through time. Therefore, all nitrogen-species concentrations were converted to concentrations in milligrams per liter as nitrogen, and all phosphorus-species concentrations were converted to concentrations in milligrams per liter as phosphorus. If both dissolved nitrite plus nitrate and dissolved nitrate concentrations were available, the dissolved nitrite plus nitrate concentrations were used. If dissolved nitrite plus nitrate concentrations were unavailable but dissolved nitrate concentrations were available, the dissolved nitrate concentrations were used and reported as dissolved nitrite plus nitrate.

Dissolved-solids concentrations were used to determine variations in major-ion concentrations. The dissolved-solids concentrations were calculated as the sum of calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, and silica. Alkalinity concentrations were converted from concentrations in milligrams per liter as calcium carbonate to concentrations in milligrams per liter as bicarbonate. The effects of carbon-dioxide volatilization during evaporation were not considered.

Instantaneous load is a measure of the mass of a chemical constituent being transported by a stream and is equal to the concentration of the chemical constituent in the stream times the volumetric flow rate of the stream. If sufficient water-quality data are available, instantaneous load measurements can be used to calculate long-term (daily, weekly, or annual) loads for chemical mass-balance comparisons. Because of the small amount of water-quality data available for this study, instantaneous loads cannot be used to calculate long-term loads of a chemical constituent in a stream. Major-ion and nutrient concentrations in a stream vary with flow rate and with season. Therefore, to calculate long-term major-ion and nutrient loads accurately, water-quality samples must be collected at varying flow rates throughout the year. Instantaneous loads of selected major ions, nutrients, and dissolved solids (in milligrams per second) were calculated for the tributary stations by converting instantaneous discharge in cubic feet per second to instantaneous discharge in liters per second and multiplying by the concentration of the selected chemical constituent (in milligrams per liter). Hereinafter, instantaneous loads (in milligrams per second) will be referred to as loads.

Variations in the mass of a chemical constituent in a lake result from disequilibrium between the sum of the inputs of the chemical constituent to the lake and the sum of the outputs of the chemical constituent from the lake. The mass of a chemical constituent in a lake at a given time is equal to the water volume in the lake times the concentration of the chemical constituent in the lake. To determine the mass of selected major ions, nutrients, and dissolved solids in Sweetwater Lake, Lake Alice, and Lake Irvine, the water volume in each lake was calculated from existing elevation-capacity tables, converted to liters, and multiplied by the concentration of the selected chemical constituent.

Surface-water flow in the Devils Lake Basin is seasonal. At each station, the largest discharge during any year occurred in the spring (March, April, and May). The average spring discharge for the period of record also was larger than the average remainder-of-the-year discharge except at Big Coulee, where the averages were approximately equal. However, during the period of record, considerable overlap exists between spring discharge and remainder-of-the-year discharge. Water-quality data for streams in the Devils Lake Basin generally were collected once each year during high flow and once each year during low flow. Occasionally, however, more than one sample was collected during high flow to characterize water-quality conditions during high-flow periods. To determine seasonal variations, data collected during the spring high-flow months were separated from data collected during the remainder-of-the-year low-flow months (water samples were not collected during the winter).

Graphical Methods

Piper diagrams were used to plot the cation and anion concentrations in water samples and to identify the general water-type classification. Detailed descriptions of the construction and use of Piper diagrams are given in Briel (1993) and Fetter (1994). Piper diagrams have two triangular fields in the lower part of the diagram and a quadrangular field in the center of the upper part of the diagram (fig. 4). Each apex of the triangular fields represents 100-percent concentration of one of six constituents.

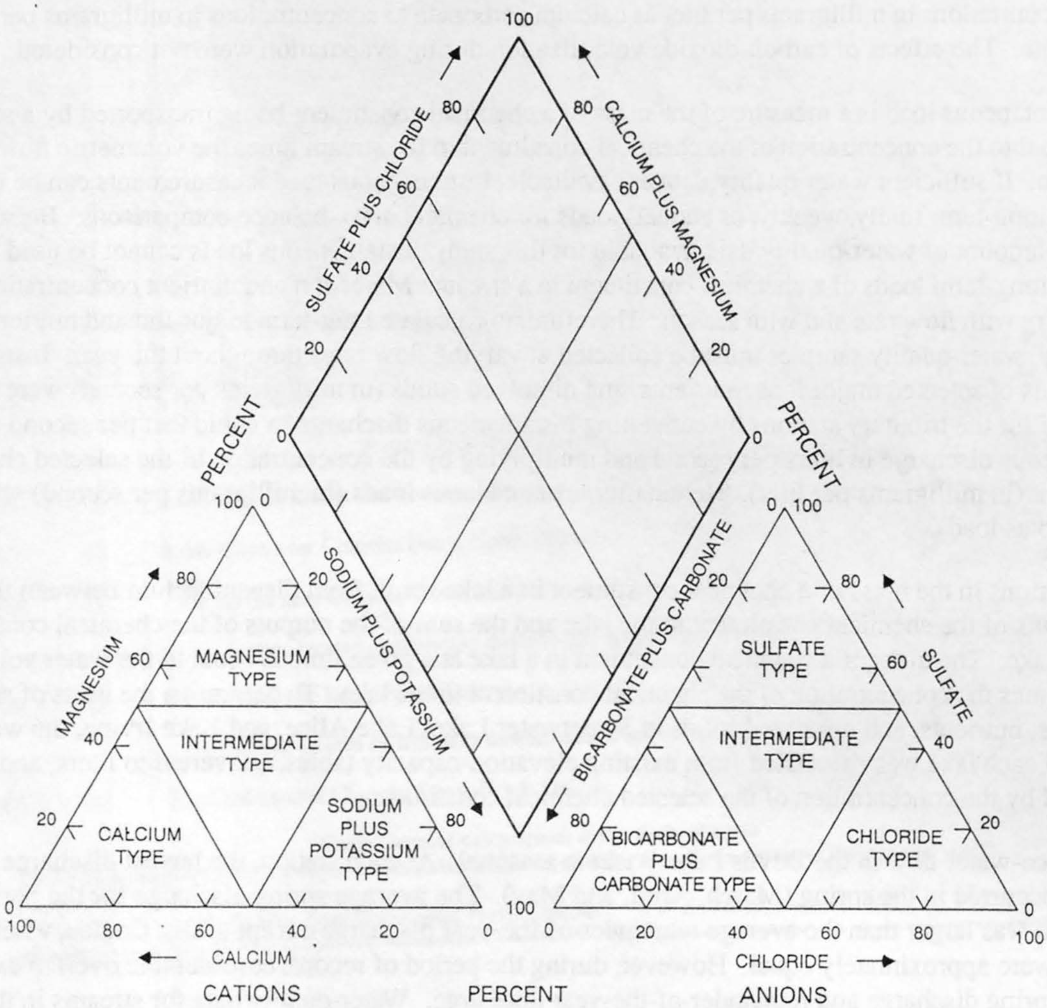


Figure 4. Generalized Piper diagram used for cation and anion water-type classification.

The triangular field in the lower left corner of the Piper diagram is used to plot the cation (calcium, magnesium, and sodium plus potassium) concentrations in a sample, and the triangular field in the lower right corner of the diagram is used to plot the anion (bicarbonate plus carbonate, sulfate, and chloride) concentrations in a sample. The cation triangle is divided into four fields that represent calcium, magnesium, sodium plus potassium (hereinafter referred to as sodium), and intermediate water types, and the anion triangle is divided into four fields that represent bicarbonate plus carbonate (hereinafter referred to as bicarbonate), sulfate, chloride, and intermediate water types. The positions at which the cation and anion concentrations are plotted on the two triangular fields identify the general water-type classification.

Data from the two triangular fields can be projected to a single point on the quadrangular field. The relative position of individual points on each of the three fields can be used to evaluate variations in major-ion compositions and to identify geochemical processes occurring in the system.

Standard X-Y plots were used with two general types of paired data to determine water-quality variations in the chain of lakes and its tributaries. For the first type of paired data, the concentration, load, or mass of selected water-quality constituents was plotted versus time. The time was plotted on the X-axis, or abscissa, and the concentration, load, or mass was plotted on the Y-axis, or ordinate. A linear scale was used for the X-axis, and either a linear or log scale was used for the Y-axis, depending on the range of values for the water-quality constituent. For the second type of paired data, the concentration of selected water-quality constituents was plotted versus the concentration of other selected water-quality constituents. Either linear or log scales were used on both axes.

Box plots, or box and whisker plots, were used to compare concentrations of selected water-quality constituents between stations. A detailed description of the construction and use of box plots is given in Briel (1993). Station names were plotted on the X-axis, and concentrations for that station were plotted on the Y-axis. Generalized box plots (fig. 5) were used to illustrate the range of concentrations of a particular

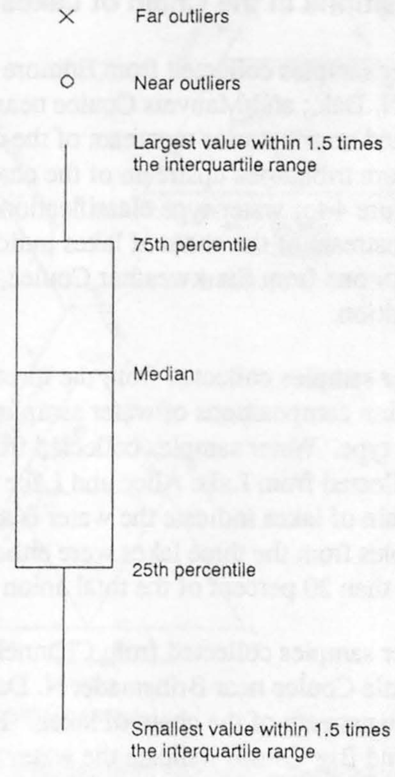


Figure 5. Generalized box plot.

water-quality constituent at a station. The central range, called the interquartile range, is represented by the box and contains 50 percent of the concentrations. The median concentration is defined by the horizontal line in the box. The vertical lines (whiskers) that extend from the boxes represent the range in which 99 percent of the concentrations will plot. The remaining 1 percent of the concentrations are divided into two groups--near outliers and far outliers. Concentrations that are within 1.5 to 3 times the interquartile range are designated as near outliers. Concentrations that are greater than 3 times the interquartile range are designated as far outliers.

The individual box plots in each diagram were positioned according to the relative position of the surface-water station in the drainage basin. Stations located on tributaries upstream of the chain of lakes are shown on the left side of the diagrams, stations located on the chain of lakes are shown in the center of the diagrams, and stations located on tributaries downstream of the chain of lakes are shown on the right side of the diagrams.

VARIATIONS IN SURFACE-WATER QUALITY IN THE CHAIN OF LAKES AND ITS TRIBUTARIES

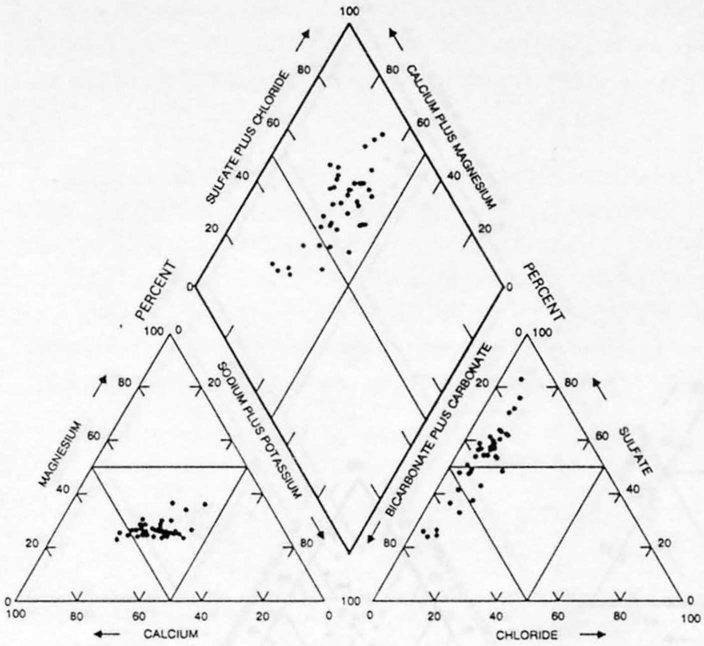
In the chain of lakes and its tributaries, seasonal variations for many water-quality constituents appear to be quite ambiguous. However, spatial variation between tributaries upstream of the chain of lakes and the chain of lakes is fairly apparent for most water-quality constituents. Water quality in the chain of lakes and in tributaries downstream of the chain of lakes generally is quite similar, indicating that the lakes greatly influence the chemical budget of the Devils Lake Basin.

Variations in Major-Ion Compositions in the Chain of Lakes and Its Tributaries

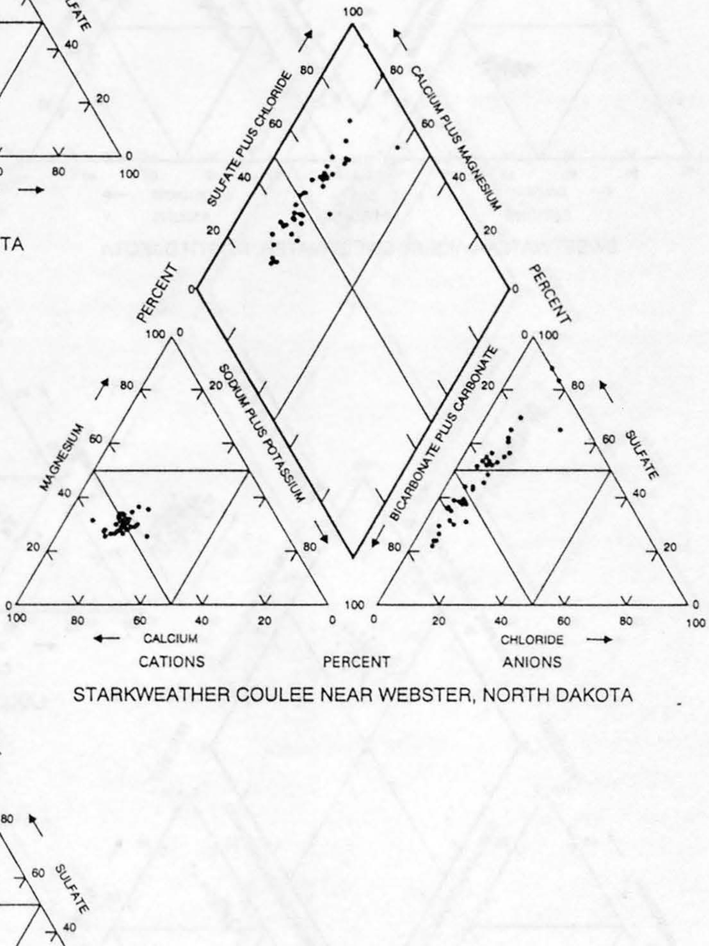
Major-ion compositions of water samples collected from Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 6. The three stations are located on tributaries upstream of the chain of lakes. The cation compositions of water samples collected from tributaries upstream of the chain of lakes indicate the water is a calcium to intermediate type (see figure 4 for water-type classification). The anion compositions of water samples collected from tributaries upstream of the chain of lakes indicate the water is a bicarbonate to sulfate type. In all samples except for one from Starkweather Coulee, chloride comprised less than 20 percent of the total anion composition.

Major-ion compositions of water samples collected from the three stations located on the chain of lakes are shown in figure 7. The cation compositions of water samples collected from the three lakes indicate the water is an intermediate type. Water samples collected from Sweetwater Lake have relatively more sodium than water samples collected from Lake Alice and Lake Irvine. The anion compositions of water samples collected from the chain of lakes indicate the water is a bicarbonate to intermediate to sulfate type. Most of the water samples from the three lakes were either an intermediate or sulfate type. In all samples, chloride comprised less than 20 percent of the total anion composition.

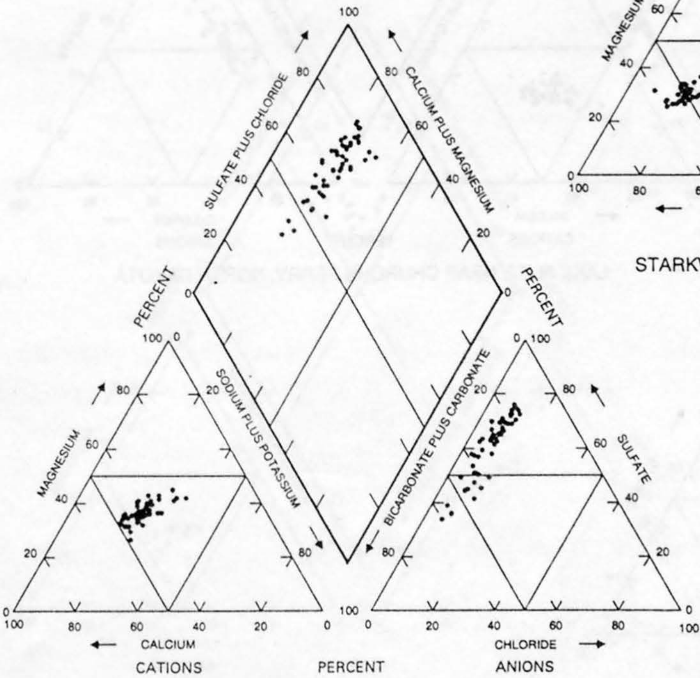
Major-ion compositions of water samples collected from Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak., are shown in figure 8. The three stations are located on tributaries downstream of the chain of lakes. The cation compositions of water samples collected from Channel A and Big Coulee indicate the water is an intermediate to sodium type. One water sample collected from Big Coulee was a calcium type. The cation compositions of water samples collected from Little Coulee indicate the water is an intermediate type. The anion compositions



EDMORE COULEE NEAR EDMORE, NORTH DAKOTA



STARKWEATHER COULEE NEAR WEBSTER, NORTH DAKOTA



MAUVAIS COULEE NEAR CANDO, NORTH DAKOTA

Figure 6. Major-ion composition of water samples from selected surface-water stations on tributaries upstream of the chain of lakes.

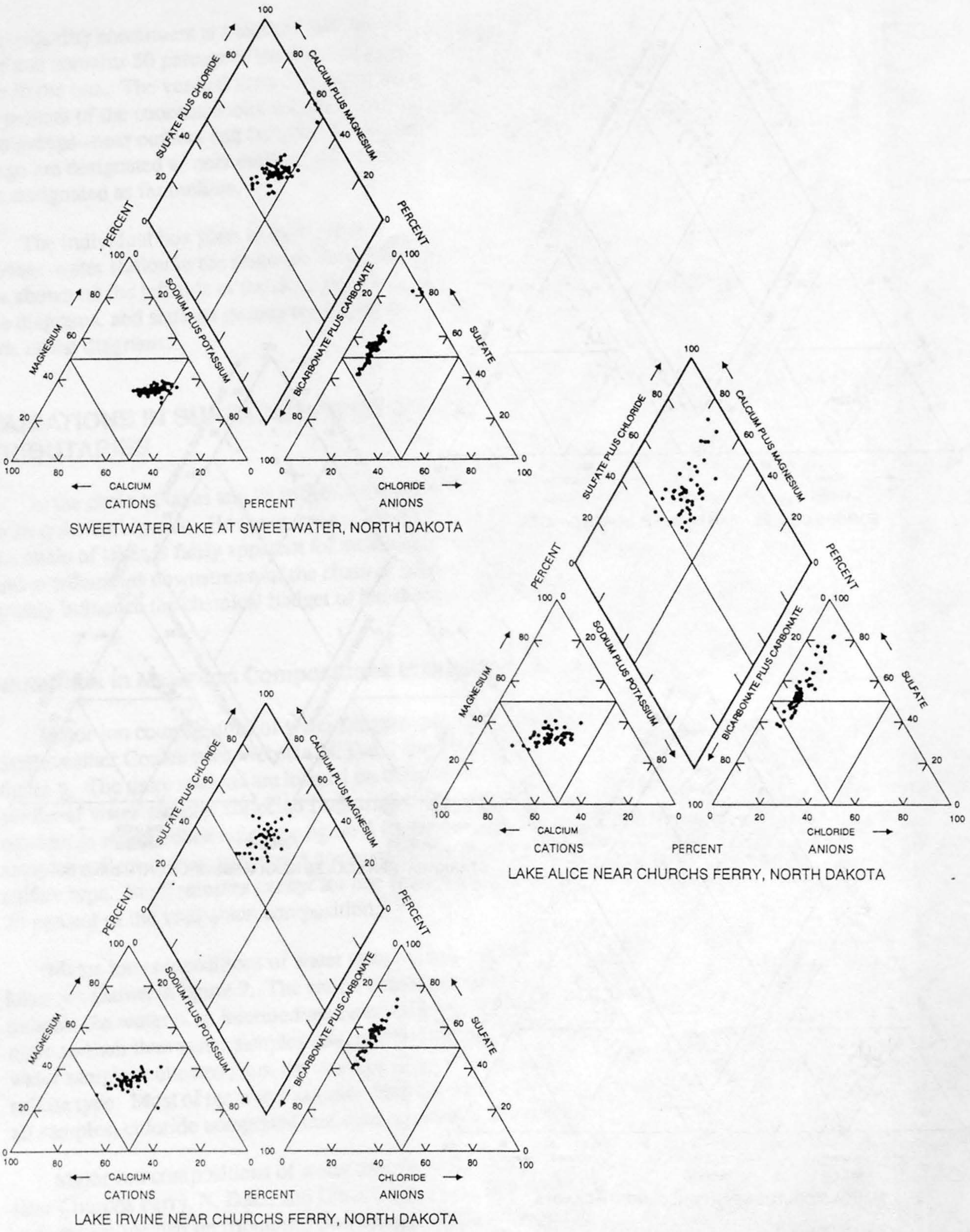


Figure 7. Major-ion composition of water samples from surface-water stations on the chain of lakes.

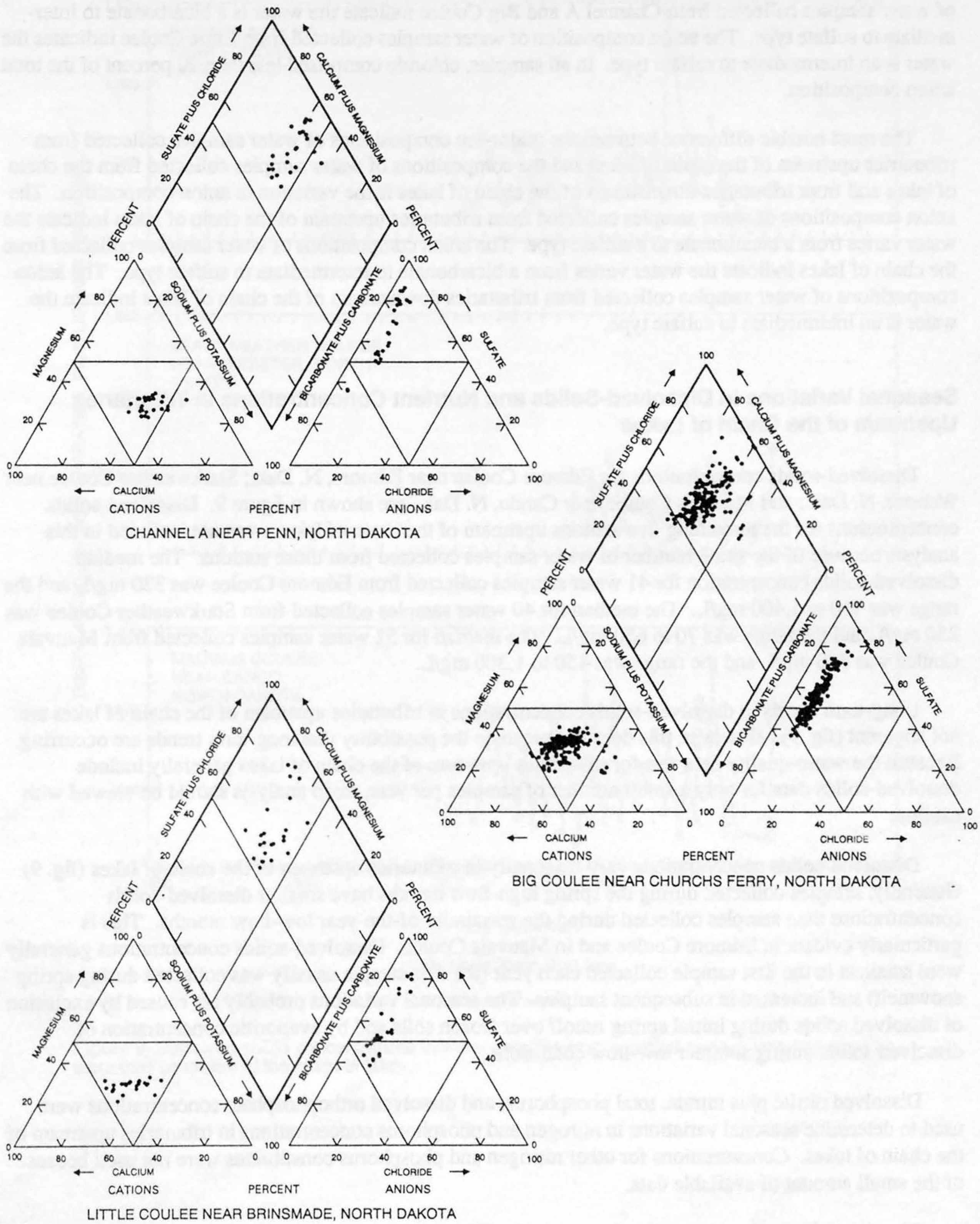


Figure 8. Major-ion composition of water samples from surface-water stations on tributaries downstream of the chain of lakes.

of water samples collected from Channel A and Big Coulee indicate the water is a bicarbonate to intermediate to sulfate type. The anion composition of water samples collected from Little Coulee indicates the water is an intermediate to sulfate type. In all samples, chloride comprised less than 20 percent of the total anion composition.

The most notable difference between the major-ion compositions of water samples collected from tributaries upstream of the chain of lakes and the compositions of water samples collected from the chain of lakes and from tributaries downstream of the chain of lakes is the variation in anion composition. The anion compositions of water samples collected from tributaries upstream of the chain of lakes indicate the water varies from a bicarbonate to a sulfate type. The anion compositions of water samples collected from the chain of lakes indicate the water varies from a bicarbonate to intermediate to sulfate type. The anion compositions of water samples collected from tributaries downstream of the chain of lakes indicate the water is an intermediate to sulfate type.

Seasonal Variations in Dissolved-Solids and Nutrient Concentrations in Tributaries Upstream of the Chain of Lakes

Dissolved-solids concentrations for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 9. Dissolved-solids concentrations for the remaining five stations upstream of the chain of lakes were not included in this analysis because of the small number of water samples collected from those stations. The median dissolved-solids concentration for 41 water samples collected from Edmore Coulee was 320 mg/L and the range was 110 to 1,400 mg/L. The median for 40 water samples collected from Starkweather Coulee was 250 mg/L and the range was 70 to 650 mg/L. The median for 52 water samples collected from Mauvais Coulee was 540 mg/L and the range was 150 to 1,300 mg/L.

Long-term trends in dissolved-solids concentrations in tributaries upstream of the chain of lakes are not apparent (fig. 9). However, this does not preclude the possibility that long-term trends are occurring. Because the water-quality data sets for tributaries upstream of the chain of lakes generally include dissolved-solids data for only a small number of samples per year, trend analysis should be viewed with caution.

Dissolved-solids concentrations vary seasonally in tributaries upstream of the chain of lakes (fig. 9). Generally, samples collected during the spring high-flow months have smaller dissolved-solids concentrations than samples collected during the remainder-of-the-year low-flow months. This is particularly evident in Edmore Coulee and in Mauvais Coulee. Dissolved-solids concentrations generally were smallest in the first sample collected each year (the first sample usually was collected during spring snowmelt) and increased in subsequent samples. The seasonal variations probably are caused by exclusion of dissolved solids during initial spring runoff over frozen soils and by evaporitic concentration of dissolved solids during summer low-flow conditions.

Dissolved nitrite plus nitrate, total phosphorus, and dissolved orthophosphate concentrations were used to determine seasonal variations in nitrogen and phosphorus concentrations in tributaries upstream of the chain of lakes. Concentrations for other nitrogen and phosphorus constituents were not used because of the small amount of available data.

Dissolved nitrite plus nitrate concentrations for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 10. The median dissolved nitrite plus nitrate concentration for 29 water samples collected from Edmore Coulee was 0.29 mg/L and the range was <0.01 to 2.7 mg/L. The median for 29 water samples collected from

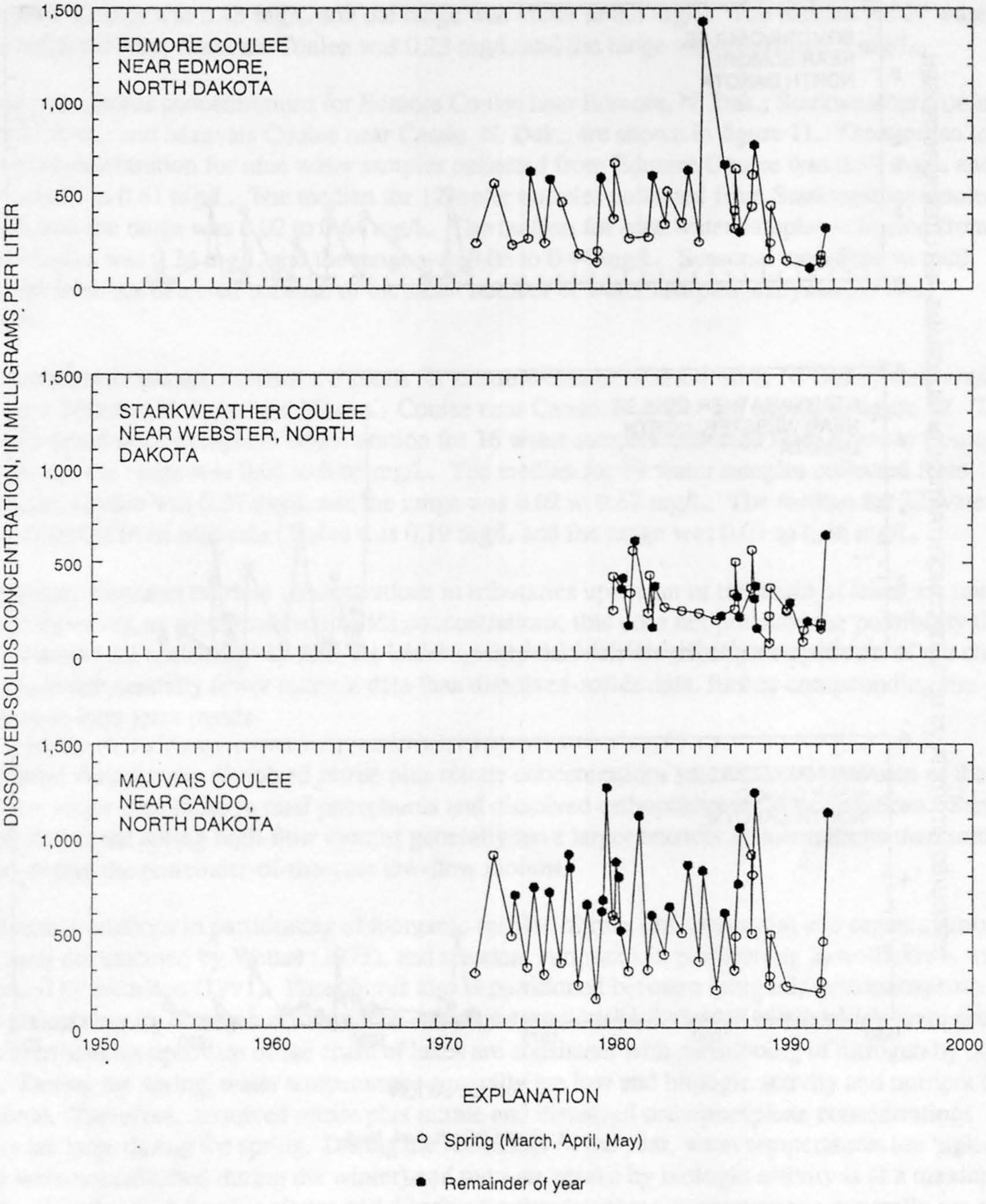


Figure 9. Dissolved-solids concentrations in water samples from selected surface-water stations on tributaries upstream of the chain of lakes.

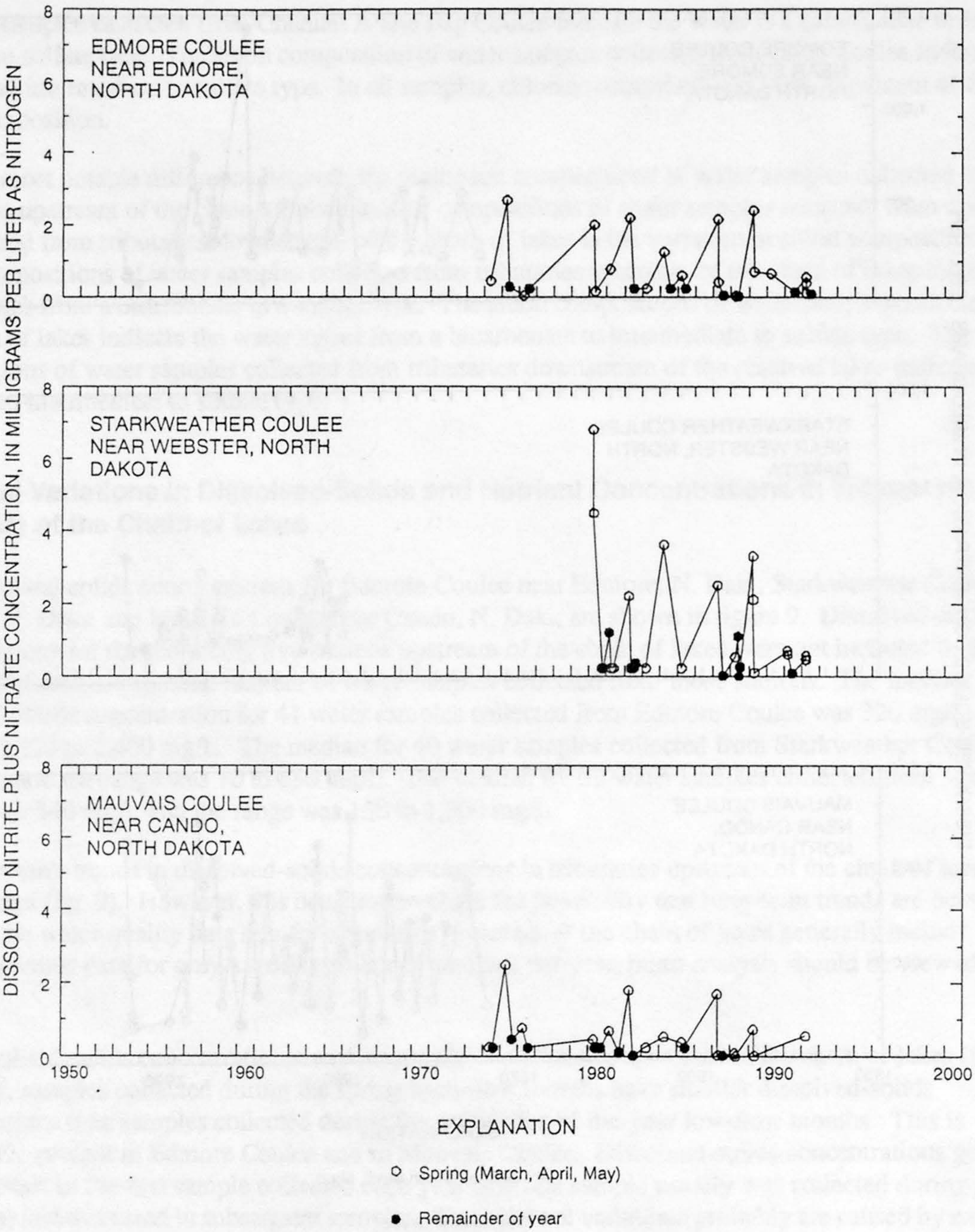


Figure 10. Dissolved nitrite plus nitrate concentrations in water samples from selected surface-water stations on tributaries upstream of the chain of lakes.

Starkweather Coulee was 0.45 mg/L and the range was <0.01 to 6.8 mg/L. The median for 27 water samples collected from Mauvais Coulee was 0.23 mg/L and the range was <0.01 to 2.5 mg/L.

Total phosphorus concentrations for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 11. The median total phosphorus concentration for nine water samples collected from Edmore Coulee was 0.39 mg/L and the range was 0.25 to 0.61 mg/L. The median for 12 water samples collected from Starkweather Coulee was 0.33 mg/L and the range was 0.02 to 0.64 mg/L. The median for nine water samples collected from Mauvais Coulee was 0.24 mg/L and the range was 0.06 to 0.44 mg/L. Seasonal variations in total phosphorus were not detected because of the small number of water samples analyzed for total phosphorus.

Dissolved orthophosphate concentrations for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 12. The median dissolved orthophosphate concentration for 16 water samples collected from Edmore Coulee was 0.27 mg/L and the range was 0.01 to 0.85 mg/L. The median for 19 water samples collected from Starkweather Coulee was 0.27 mg/L and the range was 0.02 to 0.62 mg/L. The median for 22 water samples collected from Mauvais Coulee was 0.19 mg/L and the range was 0.01 to 0.46 mg/L.

Long-term trends in nutrient concentrations in tributaries upstream of the chain of lakes are not apparent. However, as with dissolved-solids concentrations, this does not preclude the possibility that long-term trends are occurring. In fact, the water-quality data sets for tributaries upstream of the chain of lakes include substantially fewer nutrient data than dissolved-solids data, further compounding the uncertainty in long-term trends.

Seasonal variations in dissolved nitrite plus nitrate concentrations in tributaries upstream of the chain of lakes are larger than those in total phosphorus and dissolved orthophosphate concentrations. Samples collected during the spring high-flow months generally have larger nutrient concentrations than samples collected during the remainder-of-the-year low-flow months.

Seasonal variations in partitioning of inorganic (nitrite, nitrate, and ammonia) and organic nitrogen in lakes is well documented by Wetzel (1975), and seasonal variations in partitioning in wetlands is well documented by Johnston (1991). Phosphorus also is partitioned between inorganic orthophosphate and organic phosphorus by biologic activity. The seasonal variations in dissolved nitrite plus nitrate concentrations in tributaries upstream of the chain of lakes are consistent with partitioning of nitrogen by biologic activity. During the spring, water temperatures generally are low and biologic activity and nutrient uptake are minimal. Therefore, dissolved nitrite plus nitrate and dissolved orthophosphate concentrations generally are large during the spring. During the remainder of the year, water temperatures are high (water samples were not collected during the winter) and nutrient uptake by biologic activity is at a maximum. Therefore, dissolved nitrite plus nitrate and dissolved orthophosphate concentrations generally are small during the remainder of the year.

Seasonal Variations in Dissolved-Solids and Nutrient Loads in Tributaries Upstream of the Chain of Lakes

Dissolved-solids loads calculated for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 13. The median dissolved-solids load calculated for Edmore Coulee was 330,000 mg/s and the range was 400 to 9.6 million mg/s. The median for Starkweather Coulee was 47,000 mg/s and the range was 370 to 3.9 million mg/s. The median for Mauvais Coulee was 50,000 mg/s and the range was 180 to 18 million mg/s.

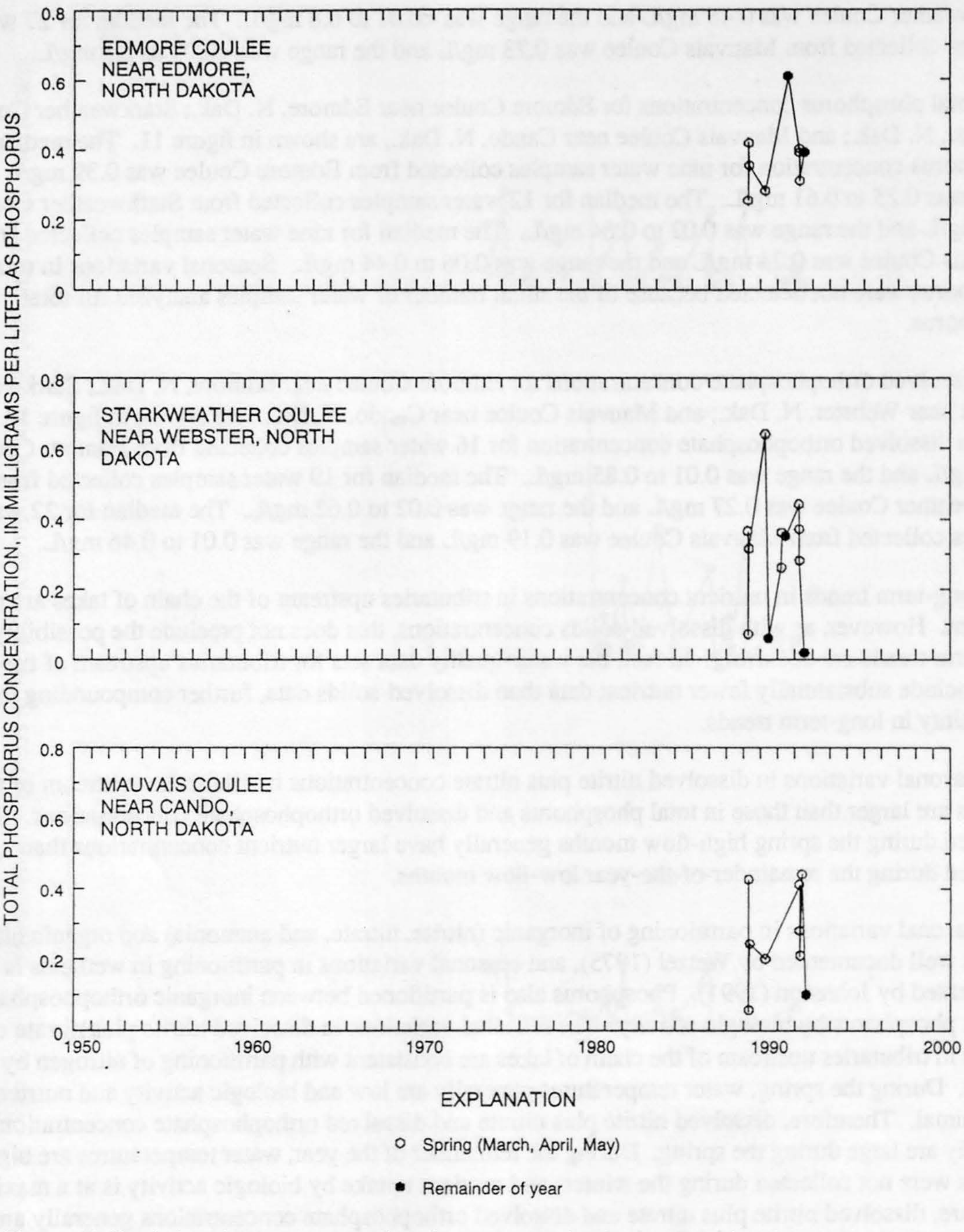


Figure 11. Total phosphorus concentrations in water samples from selected surface-water stations on tributaries upstream of the chain of lakes.

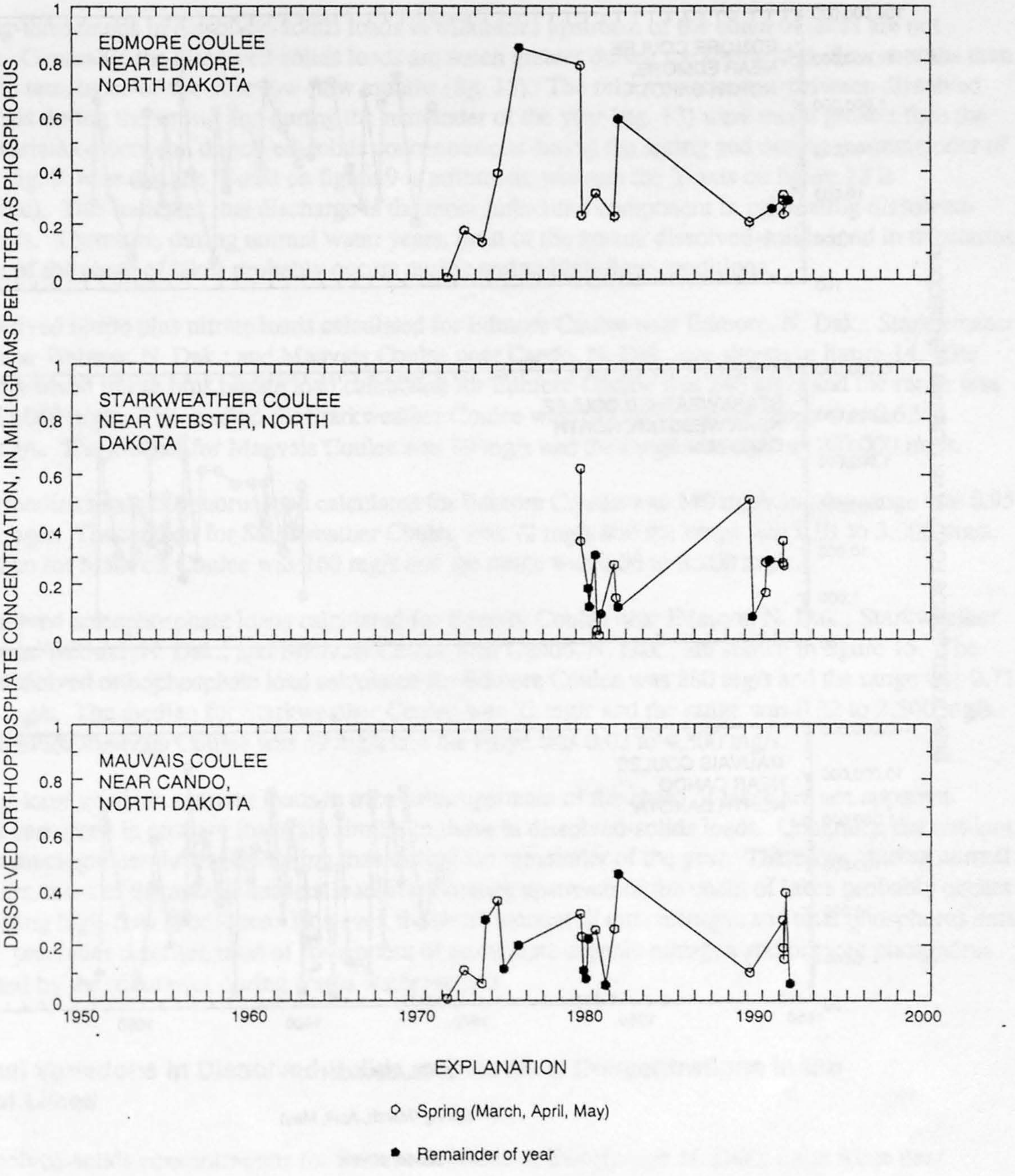


Figure 12. Dissolved orthophosphate concentrations in water samples from selected surface-water stations on tributaries upstream of the chain of lakes.

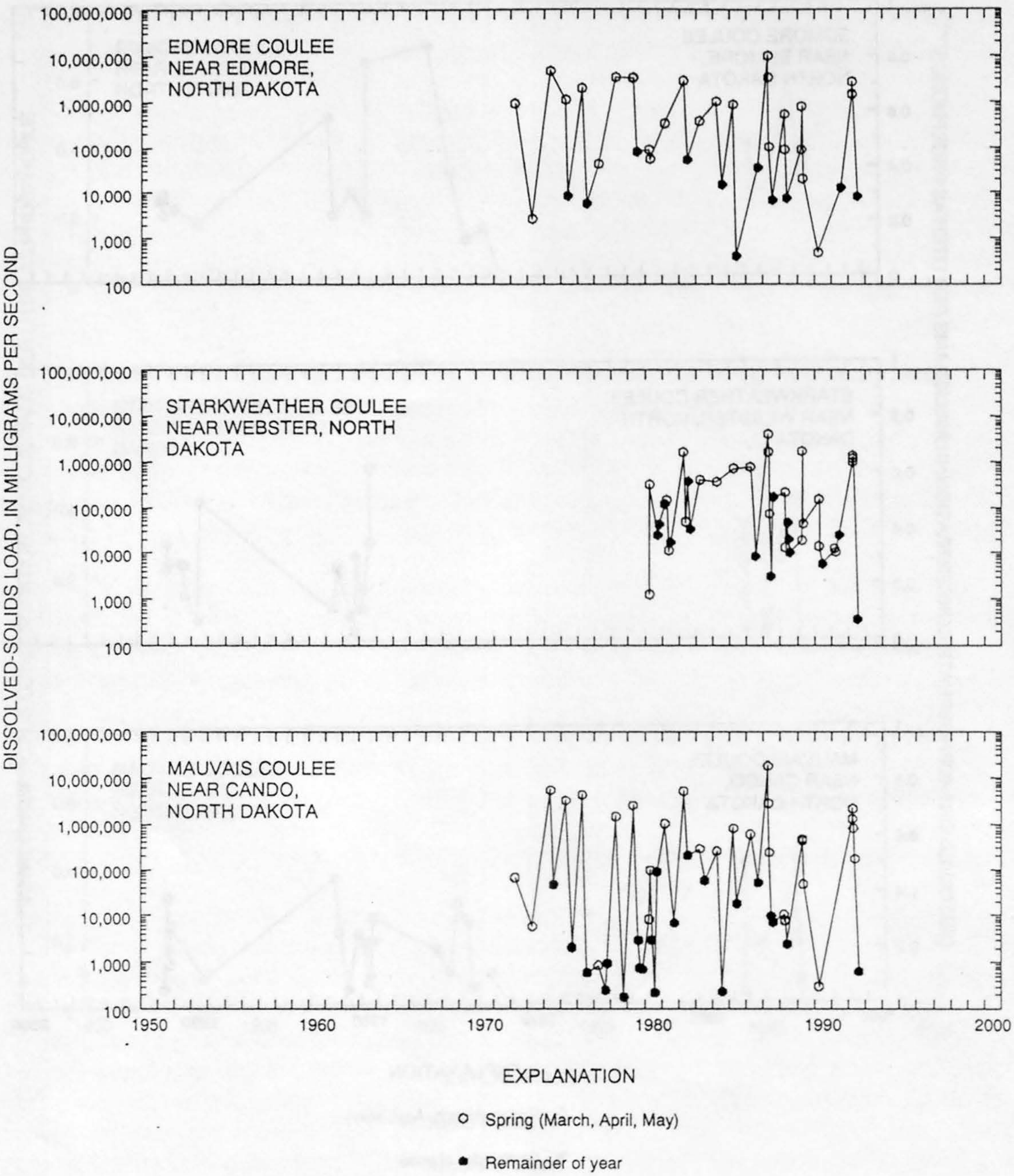


Figure 13. Dissolved-solids loads calculated for selected surface-water stations on tributaries upstream of the chain of lakes.

Long-term trends in dissolved-solids loads in tributaries upstream of the chain of lakes are not apparent. Generally, the dissolved-solids loads are much greater during the spring high-flow months than during the remainder-of-the-year low-flow months (fig. 13). The relative variations between dissolved-solids loads during the spring and during the remainder of the year (fig. 13) were much greater than the relative variations between dissolved-solids concentrations during the spring and during the remainder of the year (fig. 9; note that the Y-axis on figure 9 is arithmetic whereas the Y-axis on figure 13 is logarithmic). This indicates that discharge is the more influential component in calculating dissolved-solids loads. Therefore, during normal water years, most of the annual dissolved-solids load in tributaries upstream of the chain of lakes probably occurs during spring high-flow conditions.

Dissolved nitrite plus nitrate loads calculated for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 14. The median dissolved nitrite plus nitrate load calculated for Edmore Coulee was 240 mg/s and the range was 0.06 to 65,000 mg/s. The median for Starkweather Coulee was 170 mg/s and the range was 0.53 to 39,000 mg/s. The median for Mauvais Coulee was 39 mg/s and the range was 0.07 to 100,000 mg/s.

The median total phosphorus load calculated for Edmore Coulee was 140 mg/s and the range was 0.95 to 6,800 mg/s. The median for Starkweather Coulee was 72 mg/s and the range was 0.01 to 3,000 mg/s. The median for Mauvais Coulee was 160 mg/s and the range was 0.06 to 3,200 mg/s.

Dissolved orthophosphate loads calculated for Edmore Coulee near Edmore, N. Dak.; Starkweather Coulee near Webster, N. Dak.; and Mauvais Coulee near Cando, N. Dak., are shown in figure 15. The median dissolved orthophosphate load calculated for Edmore Coulee was 280 mg/s and the range was 0.71 to 5,200 mg/s. The median for Starkweather Coulee was 32 mg/s and the range was 0.32 to 2,500 mg/s. The median for Mauvais Coulee was 39 mg/s and the range was 0.02 to 4,300 mg/s.

Long-term trends in nutrient loads in tributaries upstream of the chain of lakes are not apparent. Seasonal variations in nutrient loads are similar to those in dissolved-solids loads. Generally, the nutrient loads are much greater during the spring than during the remainder of the year. Therefore, during normal water years, most of the annual nutrient load in tributaries upstream of the chain of lakes probably occurs during spring high-flow conditions. However, the small amount of total nitrogen and total phosphorus data available precludes determination of the amount of particulate organic nitrogen and organic phosphorus transported by the tributaries during warm-water months.

Seasonal Variations in Dissolved-Solids and Nutrient Concentrations in the Chain of Lakes

Dissolved-solids concentrations for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 16. The median dissolved-solids concentration for 64 water samples collected from Sweetwater Lake was 500 mg/L and the range was 290 to 940 mg/L. The median for 52 water samples collected from Lake Alice was 540 mg/L and the range was 200 to 2,700 mg/L. The median for 48 water samples collected from Lake Irvine was 540 mg/L and the range was 230 to 1,300 mg/L.

Dissolved-solids concentrations in Sweetwater Lake generally increased during the period of record. In 1960, the dissolved-solids concentration was about 300 mg/L (fig. 16). During the 1980's, the concentrations ranged from about 400 to 700 mg/L. Dissolved-solids concentrations in samples collected during the spring were similar to those in samples collected during the remainder of the year. However, many of the largest dissolved-solids concentrations were in samples collected during the remainder of the year rather than during the spring.

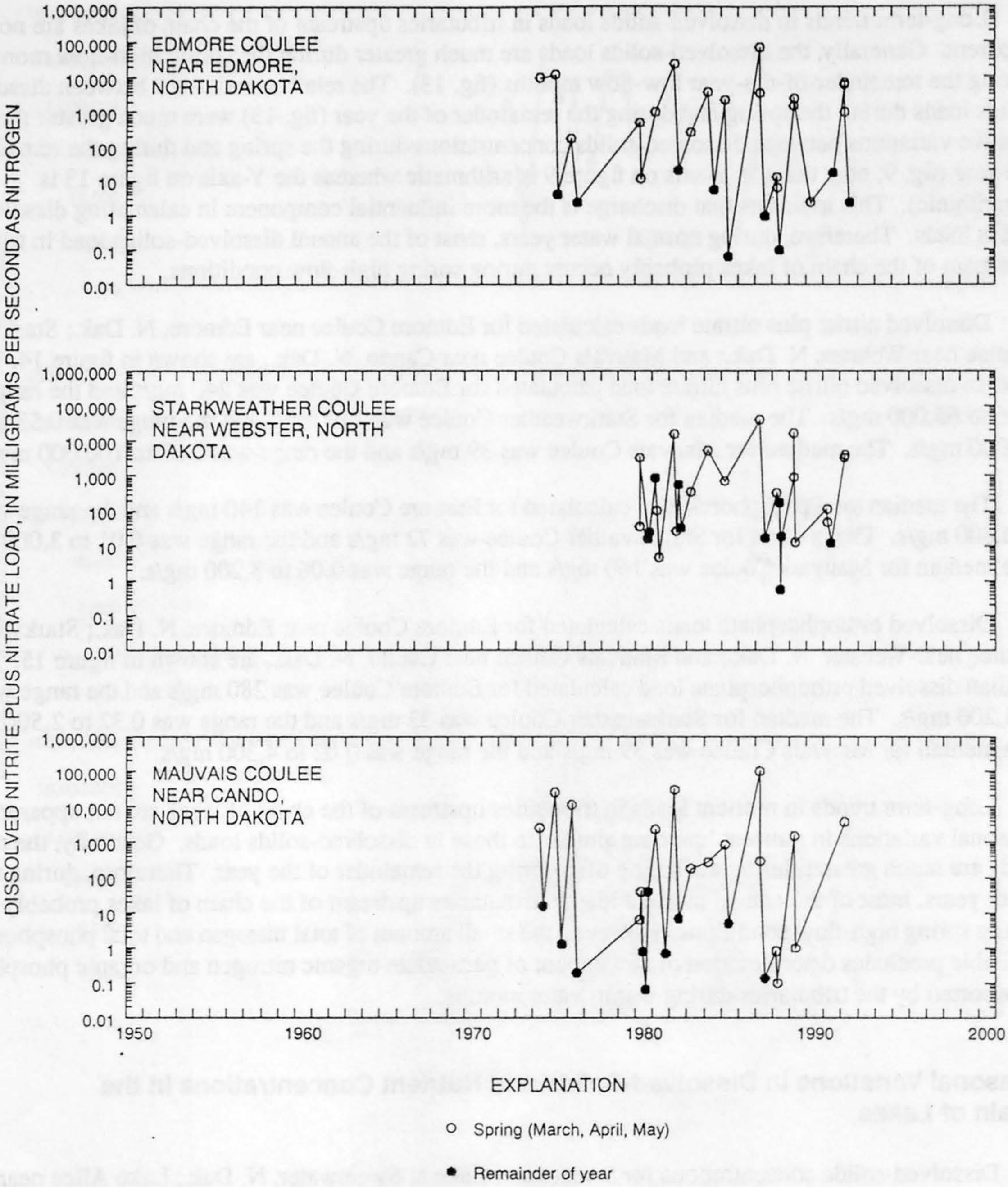


Figure 14. Dissolved nitrite plus nitrate loads calculated for selected surface-water stations on tributaries upstream of the chain of lakes.

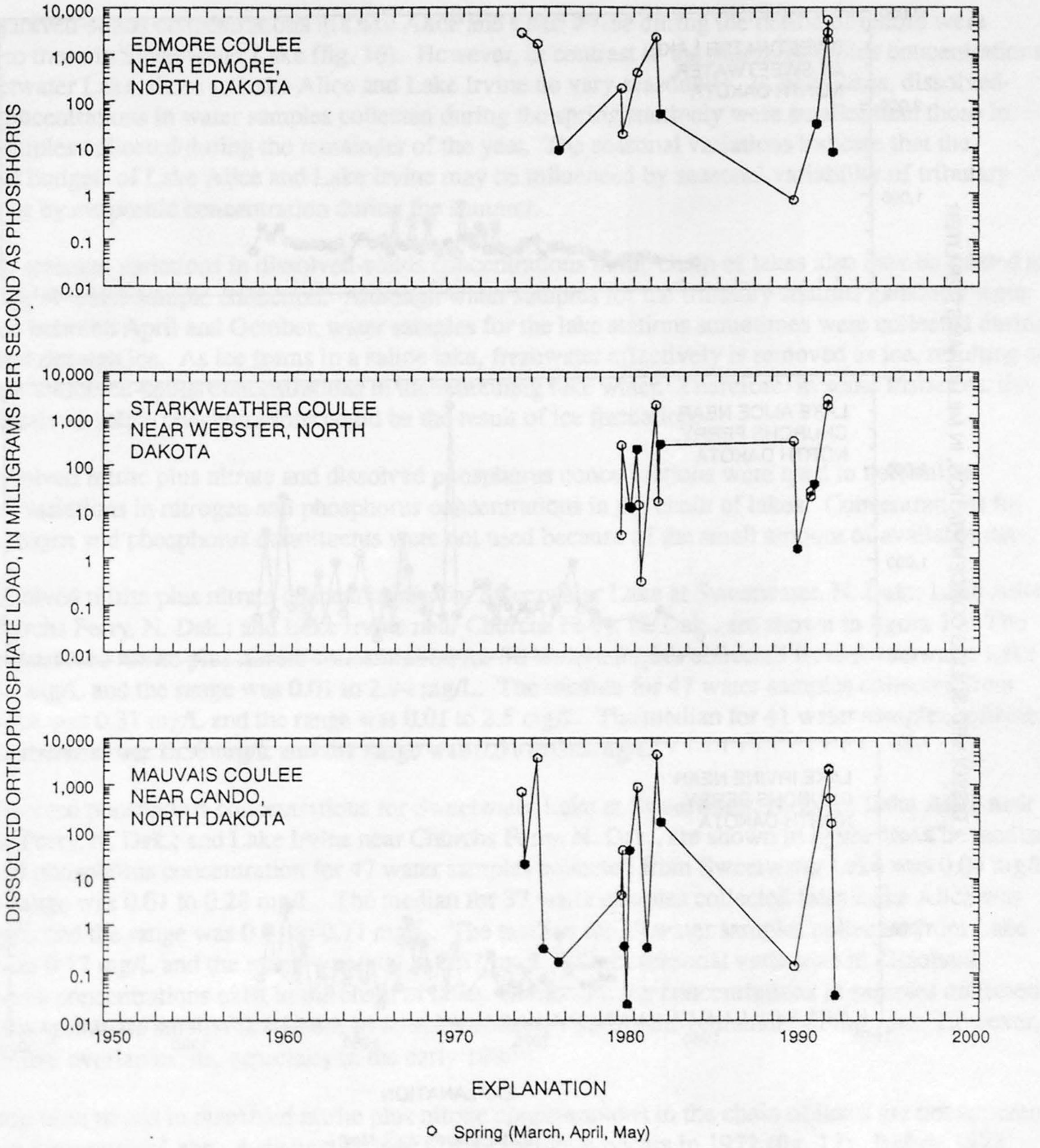


Figure 15. Dissolved orthophosphate loads calculated for selected surface-water stations on tributaries upstream of the chain of lakes.

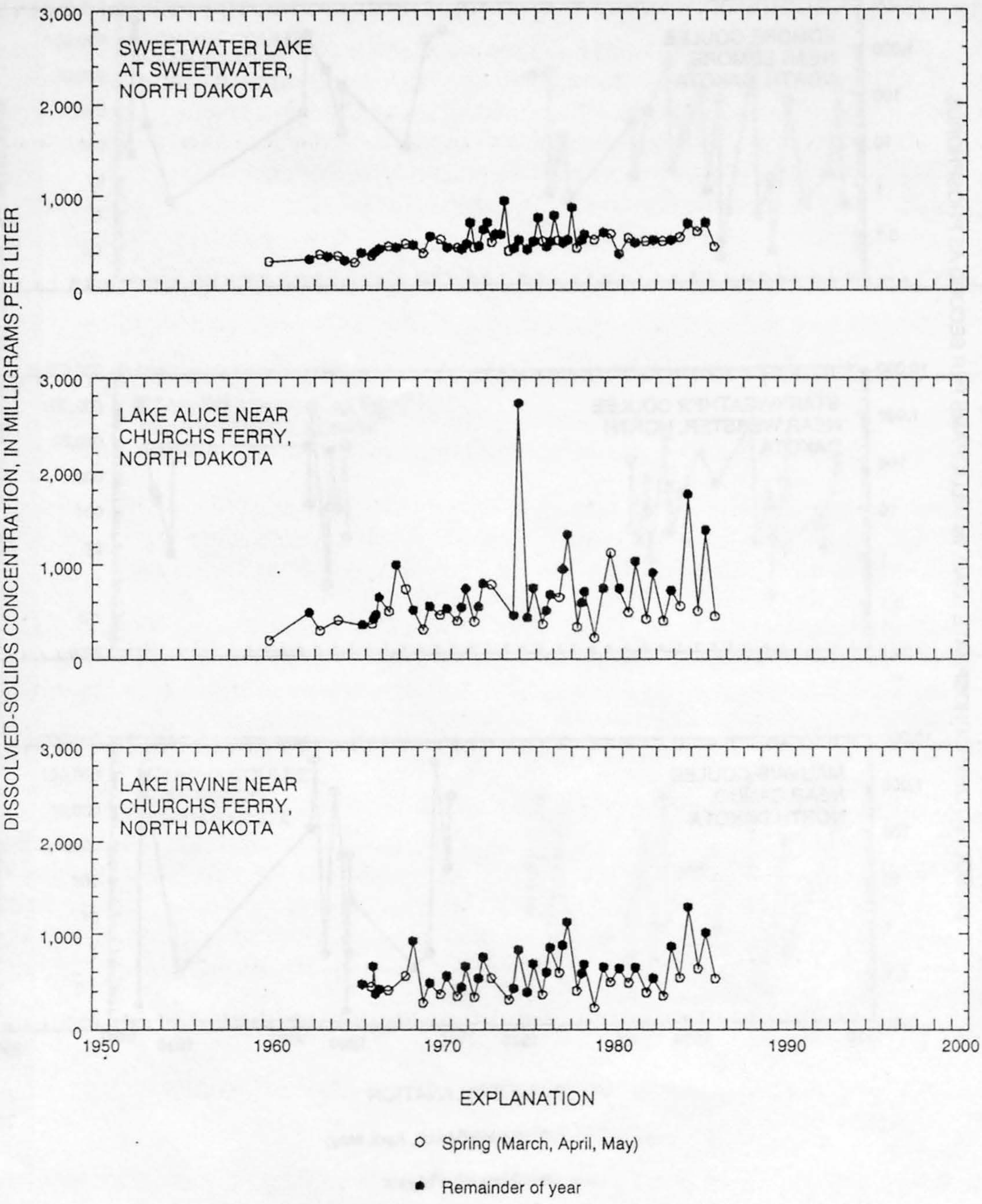


Figure 16. Dissolved-solids concentrations in water samples from surface-water stations on the chain of lakes.

Dissolved-solids concentrations in Lake Alice and Lake Irvine during the period of record were similar to those in Sweetwater Lake (fig. 16). However, in contrast to the dissolved-solids concentrations in Sweetwater Lake, those in Lake Alice and Lake Irvine do vary seasonally. In both lakes, dissolved-solids concentrations in water samples collected during the spring routinely were smaller than those in water samples collected during the remainder of the year. The seasonal variations indicate that the chemical budgets of Lake Alice and Lake Irvine may be influenced by seasonal variability of tributary inflows or by evaporitic concentration during the summer.

The seasonal variations in dissolved-solids concentrations in the chain of lakes also may be related to the timing of water-sample collection. Although water samples for the tributary stations generally were collected between April and October, water samples for the lake stations sometimes were collected during the winter through ice. As ice forms in a saline lake, freshwater effectively is removed as ice, resulting in increased dissolved-solids concentrations in the remaining lake water. Therefore, in some instances, the large dissolved-solids concentrations could be the result of ice formation.

Dissolved nitrite plus nitrate and dissolved phosphorus concentrations were used to determine seasonal variations in nitrogen and phosphorus concentrations in the chain of lakes. Concentrations for other nitrogen and phosphorus constituents were not used because of the small amount of available data.

Dissolved nitrite plus nitrate concentrations for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 17. The median dissolved nitrite plus nitrate concentration for 50 water samples collected from Sweetwater Lake was 0.12 mg/L and the range was 0.01 to 2.94 mg/L. The median for 47 water samples collected from Lake Alice was 0.31 mg/L and the range was 0.01 to 2.5 mg/L. The median for 41 water samples collected from Lake Irvine was 0.38 mg/L and the range was 0.01 to 3.6 mg/L.

Dissolved phosphorus concentrations for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 18. The median dissolved phosphorus concentration for 47 water samples collected from Sweetwater Lake was 0.04 mg/L and the range was 0.01 to 0.28 mg/L. The median for 37 water samples collected from Lake Alice was 0.17 mg/L and the range was 0.01 to 0.71 mg/L. The median for 39 water samples collected from Lake Irvine was 0.17 mg/L and the range was 0.01 to 0.67 mg/L. Slight seasonal variations in dissolved phosphorus concentrations exist in the chain of lakes. Generally, the concentrations in samples collected during the spring are smaller than those in samples collected during the remainder of the year. However, considerable overlap exists, especially in the early 1980's.

Long-term trends in dissolved nitrite plus nitrate concentrations in the chain of lakes are not apparent except in Sweetwater Lake. A distinct change in concentration occurs in 1972 (fig. 17). Before 1972, dissolved nitrite plus nitrate concentrations ranged from <0.01 to 3 mg/L. After 1972, the concentrations consistently approached zero. The reason for this change is unknown.

Dissolved phosphorus concentrations in water samples collected from Lake Alice during the spring (fig. 18) generally increased during the period of record. The concentrations increased from <0.1 mg/L in the early 1970's to about 0.3 mg/L in the mid 1980's. During the same period, dissolved nitrite plus nitrate concentrations in Lake Alice did not vary systematically (fig. 17). The reason for this upward trend in dissolved phosphorus concentrations in Lake Alice is unclear.

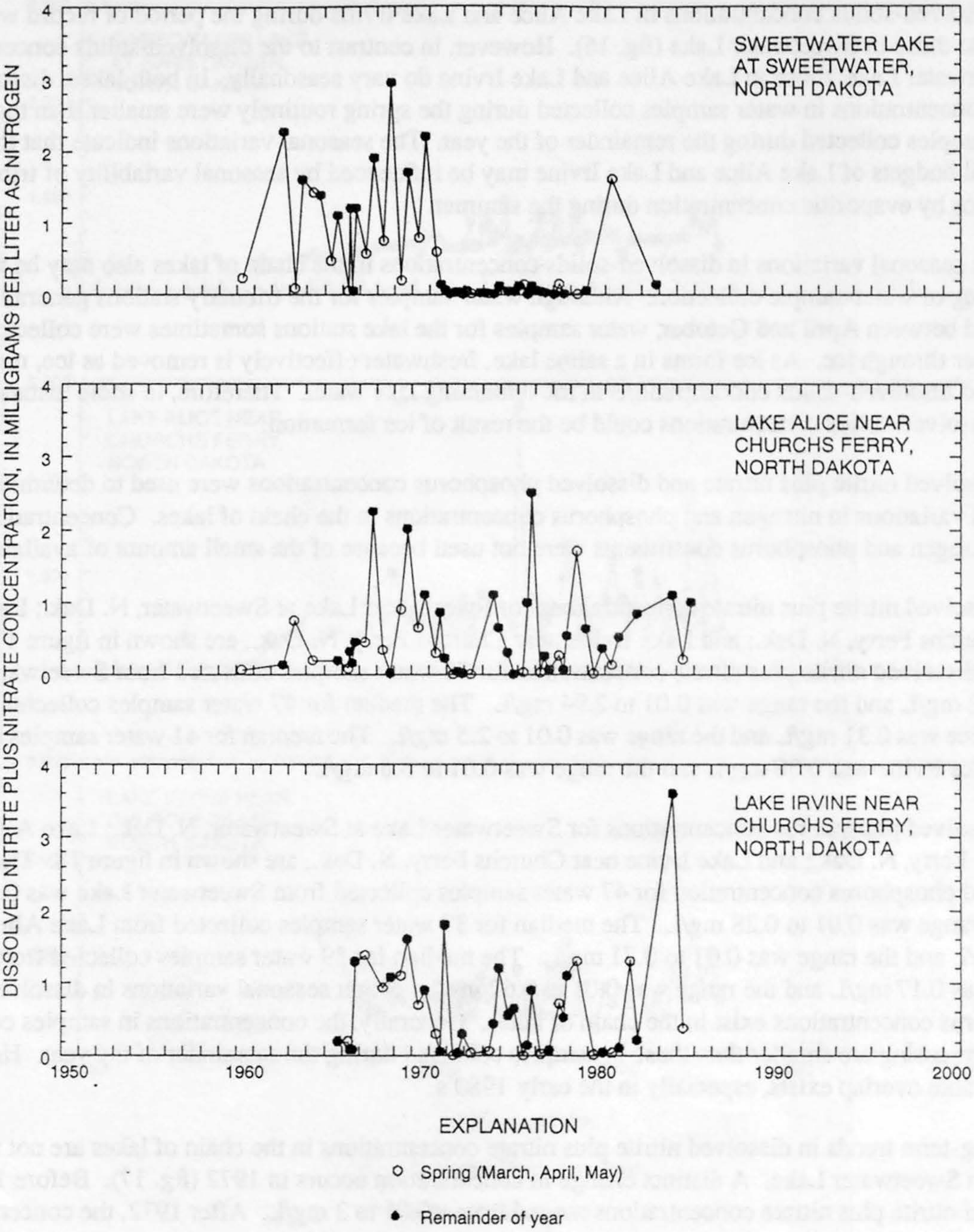


Figure 17. Dissolved nitrite plus nitrate concentrations in water samples from surface-water stations on the chain of lakes.

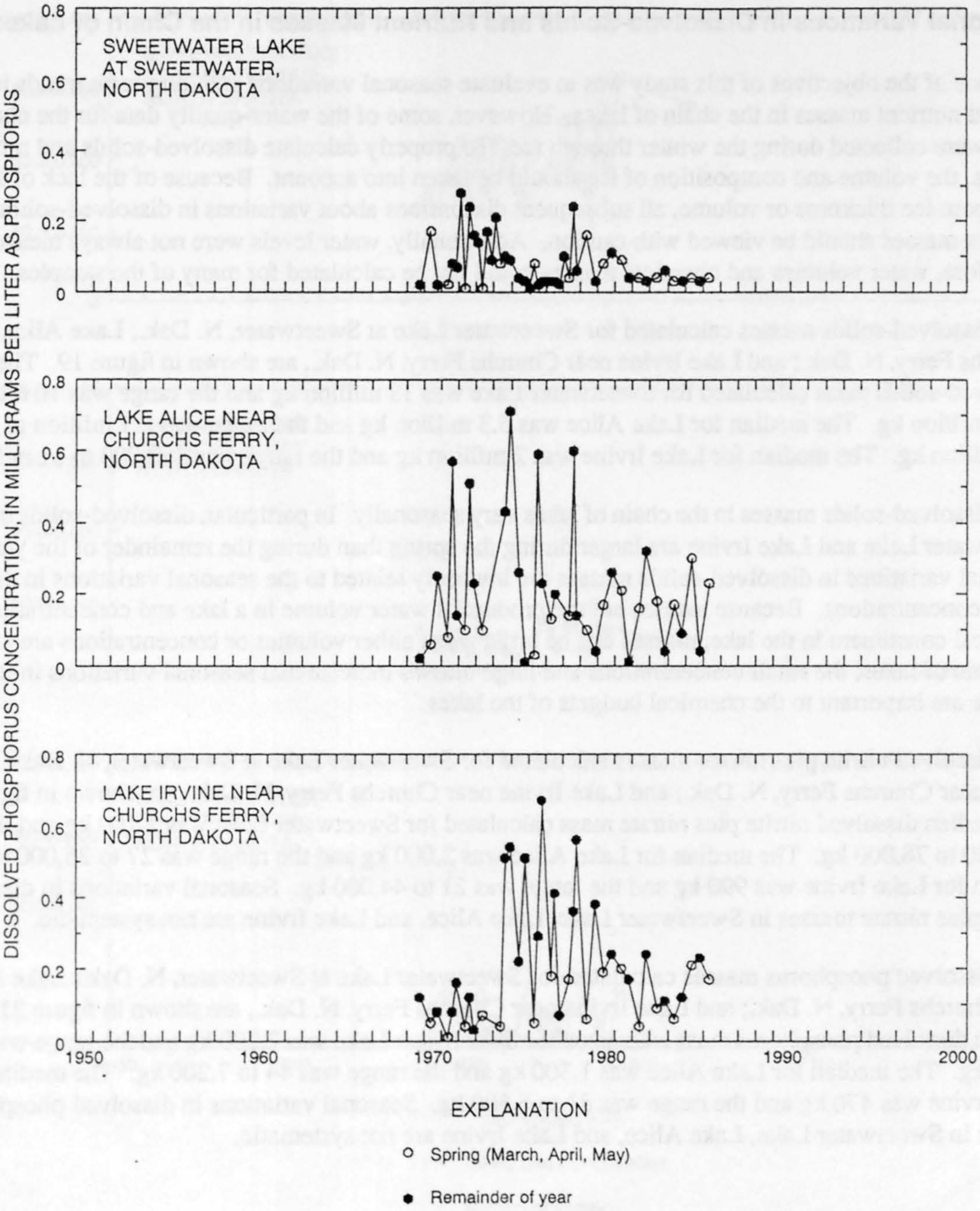


Figure 18. Dissolved phosphorus concentrations in water samples from surface-water stations on the chain of lakes.

Seasonal Variations in Dissolved-Solids and Nutrient Masses in the Chain of Lakes

One of the objectives of this study was to evaluate seasonal variations and long-term trends in major-ion and nutrient masses in the chain of lakes. However, some of the water-quality data for the chain of lakes were collected during the winter through ice. To properly calculate dissolved-solids and nutrient masses, the volume and composition of ice should be taken into account. Because of the lack of information about ice thickness or volume, all subsequent discussions about variations in dissolved-solids and nutrient masses should be viewed with caution. Additionally, water levels were not always measured. Therefore, water volumes and chemical masses could not be calculated for many of the samples.

Dissolved-solids masses calculated for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 19. The median dissolved-solids mass calculated for Sweetwater Lake was 18 million kg and the range was 10 million to 31 million kg. The median for Lake Alice was 5.3 million kg and the range was 2.1 million to 9.9 million kg. The median for Lake Irvine was 2 million kg and the range was 460,000 to 11 million kg.

Dissolved-solids masses in the chain of lakes vary seasonally. In particular, dissolved-solids masses in Sweetwater Lake and Lake Irvine are larger during the spring than during the remainder of the year. The seasonal variations in dissolved-solids masses are inversely related to the seasonal variations in dissolved-solids concentrations. Because masses are the product of water volume in a lake and concentration of a chemical constituent in the lake, masses can be large when either volumes or concentrations are large. In the chain of lakes, the small concentrations and large masses indicate that seasonal variations in the water volume are important to the chemical budgets of the lakes.

Dissolved nitrite plus nitrate masses calculated for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 20. The median dissolved nitrite plus nitrate mass calculated for Sweetwater Lake was 2,100 kg and the range was 280 to 78,000 kg. The median for Lake Alice was 2,000 kg and the range was 27 to 26,000 kg. The median for Lake Irvine was 990 kg and the range was 21 to 44,000 kg. Seasonal variations in dissolved nitrite plus nitrate masses in Sweetwater Lake, Lake Alice, and Lake Irvine are not systematic.

Dissolved phosphorus masses calculated for Sweetwater Lake at Sweetwater, N. Dak.; Lake Alice near Churchs Ferry, N. Dak.; and Lake Irvine near Churchs Ferry, N. Dak., are shown in figure 21. The median dissolved phosphorus mass calculated for Sweetwater Lake was 2,200 kg and the range was 310 to 9,400 kg. The median for Lake Alice was 1,300 kg and the range was 44 to 7,200 kg. The median for Lake Irvine was 470 kg and the range was 81 to 6,500 kg. Seasonal variations in dissolved phosphorus masses in Sweetwater Lake, Lake Alice, and Lake Irvine are not systematic.

Seasonal Variations in Dissolved-Solids and Nutrient Concentrations in Tributaries Downstream of the Chain of Lakes

Dissolved-solids concentrations for Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak., are shown in figure 22. The median dissolved-solids concentration for 28 water samples collected from Channel A was 760 mg/L and the range was 290 to 2,200 mg/L. The median for 170 water samples collected from Big Coulee was 520 mg/L and the range was 120 to 1,800 mg/L. The median for 24 water samples collected from Little Coulee was 530 mg/L and the range was 120 to 2,100 mg/L.

Long-term trends in dissolved-solids concentrations in tributaries downstream of the chain of lakes are not apparent. Seasonal variations in dissolved-solids concentrations in Channel A, Big Coulee, and Little

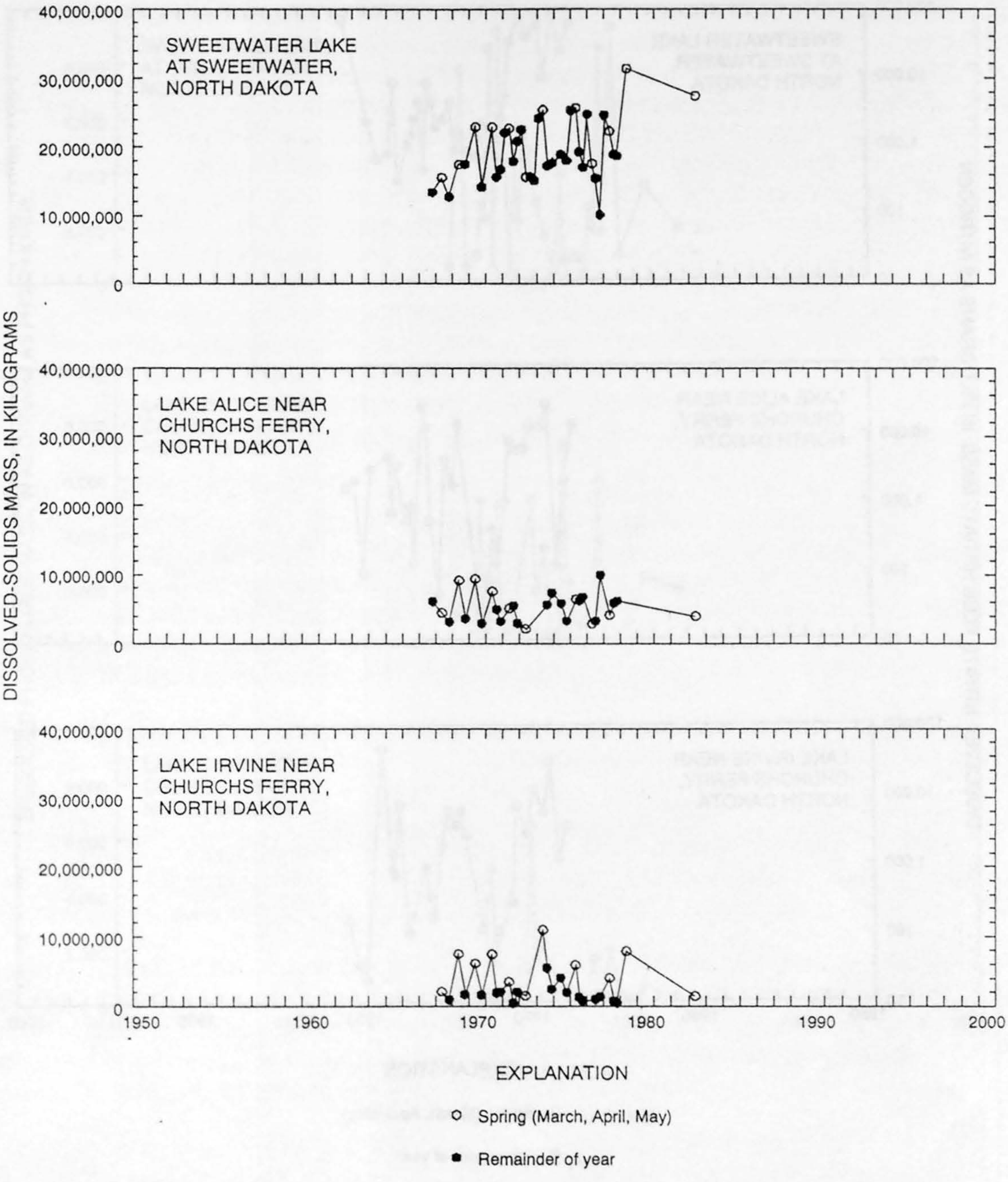


Figure 19. Dissolved-solids masses calculated for surface-water stations on the chain of lakes.

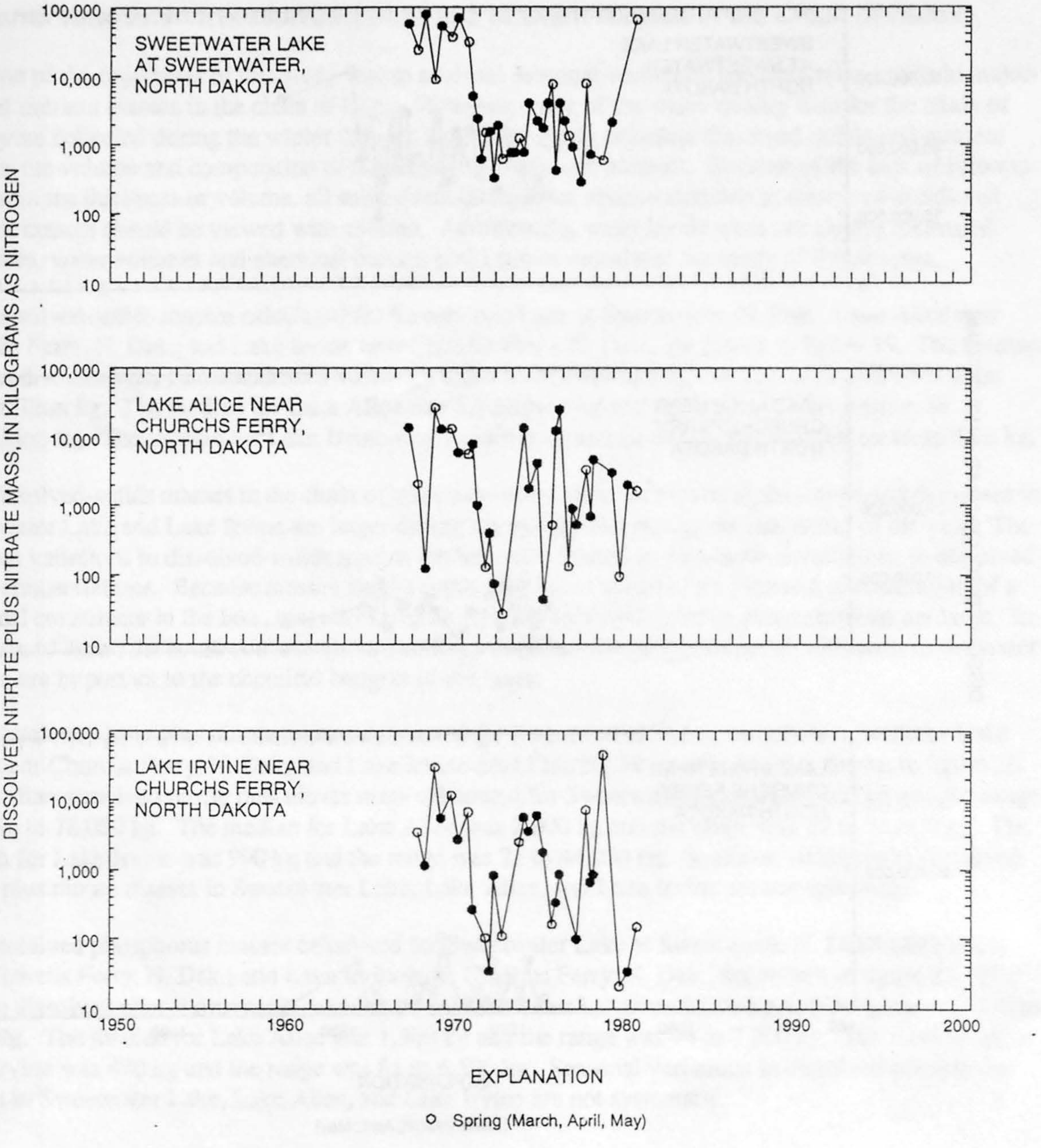


Figure 20. Dissolved nitrite plus nitrate masses calculated for surface-water stations on the chain of lakes.

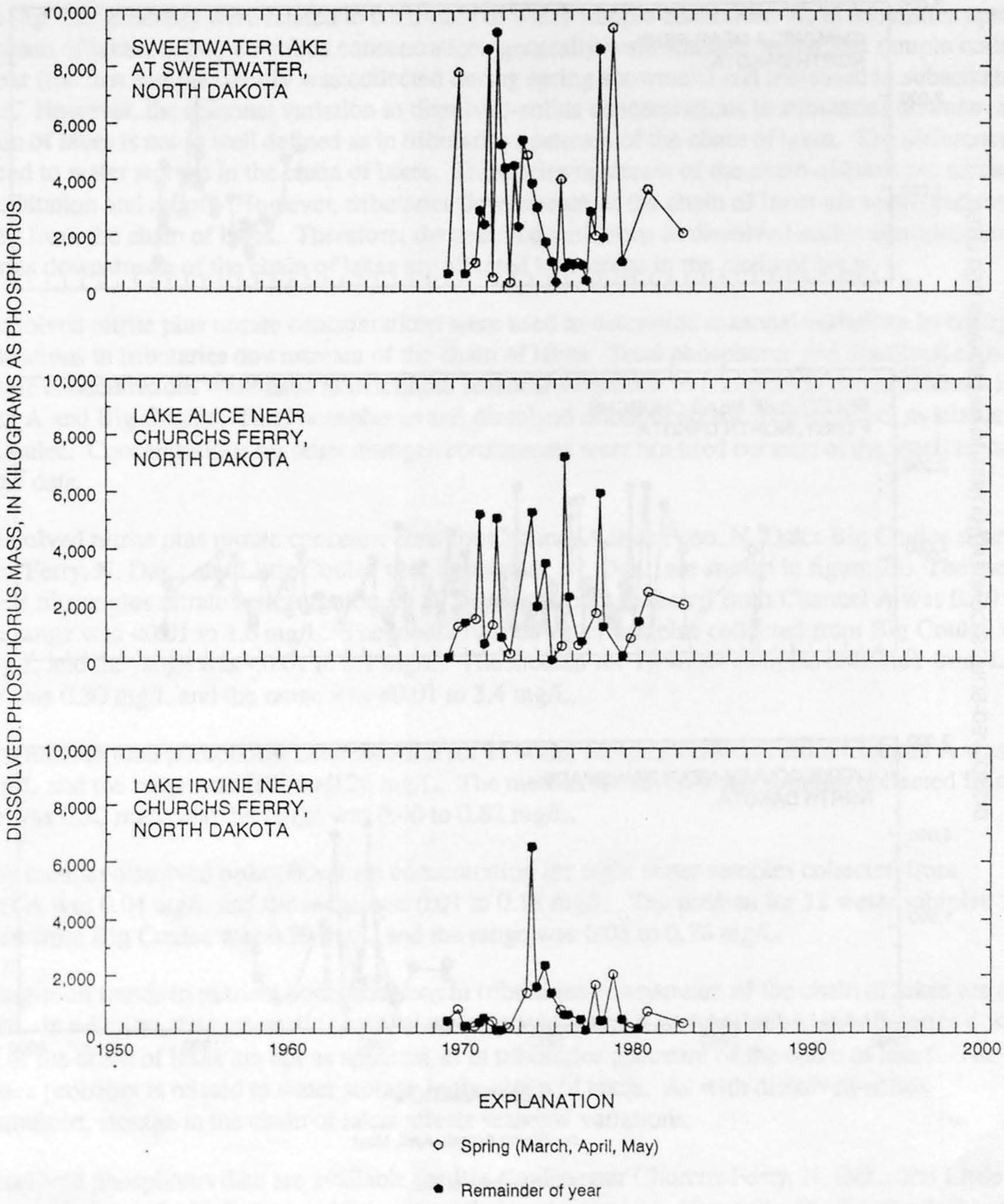


Figure 21. Dissolved phosphorus masses calculated for surface-water stations on the chain of lakes.

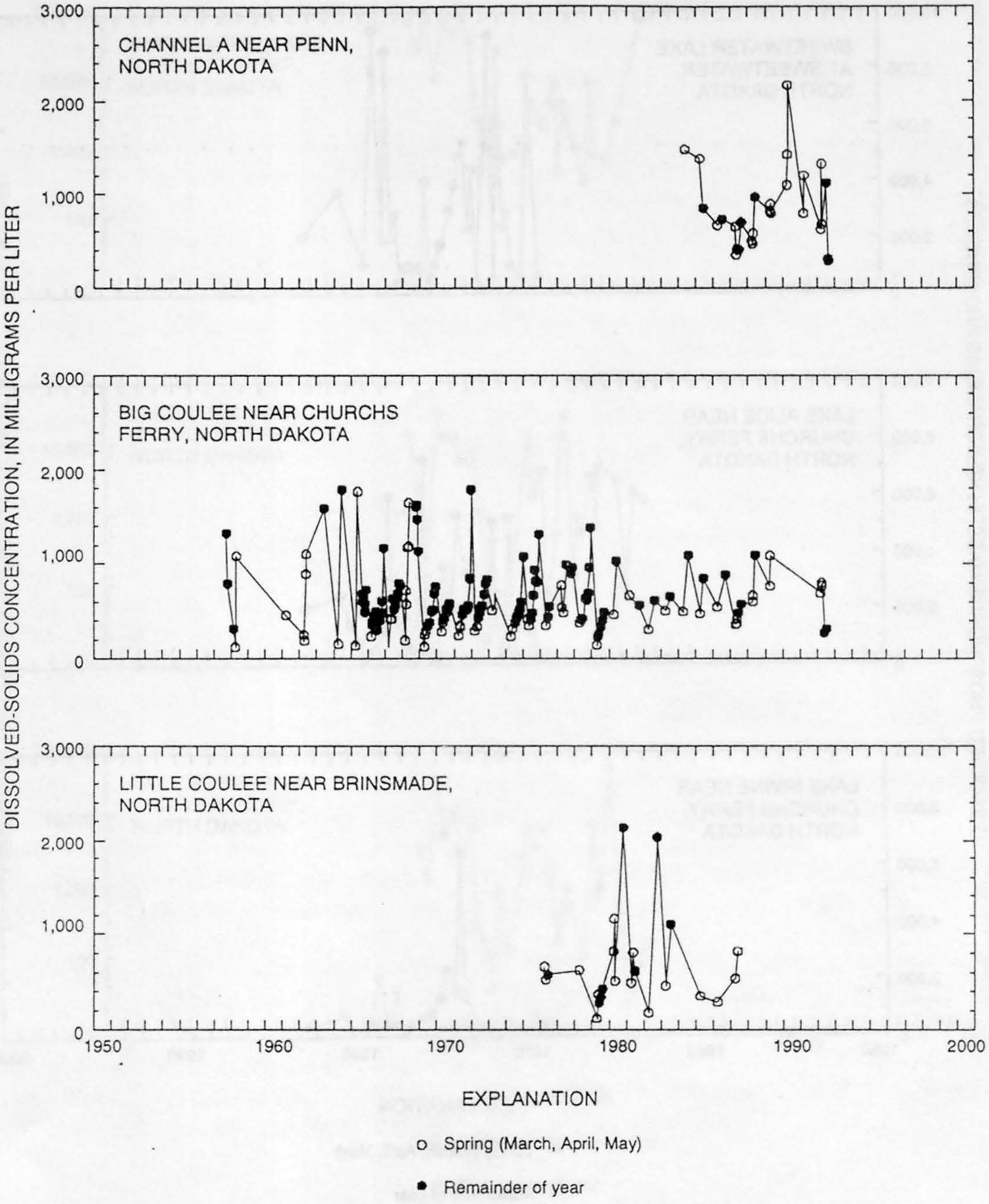


Figure 22. Dissolved-solids concentrations in water samples from surface-water stations on tributaries downstream of the chain of lakes.

Coulee (fig. 22) generally were related to the timing of water-sample collection. As in tributaries upstream of the chain of lakes, dissolved-solids concentrations generally were smallest in the first sample collected each year (the first sample usually was collected during spring snowmelt) and increased in subsequent samples. However, the seasonal variation in dissolved-solids concentrations in tributaries downstream of the chain of lakes is not as well defined as in tributaries upstream of the chain of lakes. The difference may be related to water storage in the chain of lakes. Tributaries upstream of the chain of lakes are recharged by precipitation and runoff. However, tributaries downstream of the chain of lakes are recharged mostly by water from the chain of lakes. Therefore, the seasonal variations in dissolved-solids concentrations in tributaries downstream of the chain of lakes are affected by storage in the chain of lakes.

Dissolved nitrite plus nitrate concentrations were used to determine seasonal variations in nitrogen concentrations in tributaries downstream of the chain of lakes. Total phosphorus and dissolved orthophosphate concentrations were used to determine seasonal variations in phosphorus concentrations in Channel A and Big Coulee. Total phosphorus and dissolved orthophosphate data were not available for Little Coulee. Concentrations for other nitrogen constituents were not used because of the small amount of available data.

Dissolved nitrite plus nitrate concentrations for Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak., are shown in figure 23. The median dissolved nitrite plus nitrate concentration for 17 water samples collected from Channel A was 0.10 mg/L and the range was <0.01 to 1.6 mg/L. The median for 60 water samples collected from Big Coulee was 0.68 mg/L and the range was <0.01 to 3.1 mg/L. The median for 19 water samples collected from Little Coulee was 0.30 mg/L and the range was <0.01 to 3.4 mg/L.

The median total phosphorus concentration for 11 water samples collected from Channel A was 0.11 mg/L and the range was 0.07 to 0.26 mg/L. The median for seven water samples collected from Big Coulee was 0.50 mg/L and the range was 0.40 to 0.82 mg/L.

The median dissolved orthophosphate concentration for eight water samples collected from Channel A was 0.04 mg/L and the range was 0.01 to 0.18 mg/L. The median for 12 water samples collected from Big Coulee was 0.39 mg/L and the range was 0.05 to 0.76 mg/L.

Long-term trends in nutrient concentrations in tributaries downstream of the chain of lakes are not apparent. In addition, the systematic seasonal variations in nutrient concentrations in tributaries downstream of the chain of lakes are not as apparent as in tributaries upstream of the chain of lakes. The difference probably is related to water storage in the chain of lakes. As with dissolved-solids concentrations, storage in the chain of lakes affects seasonal variations.

Dissolved phosphorus data are available for Big Coulee near Churchs Ferry, N. Dak., and Little Coulee near Brinsmade, N. Dak., in addition to total phosphorus data. Generally, the dissolved phosphorus data were collected during 1969-80. A total of 76 measurements were available for Big Coulee and a total of 16 measurements were available for Little Coulee. However, the data were of limited value to this study because of the small amount of spatial coverage in the basin. The total phosphorus and dissolved phosphorus concentrations for Big Coulee are shown in figure 24. Neither systematic long-term trends nor systematic seasonal variations in phosphorus concentrations in Big Coulee are apparent.

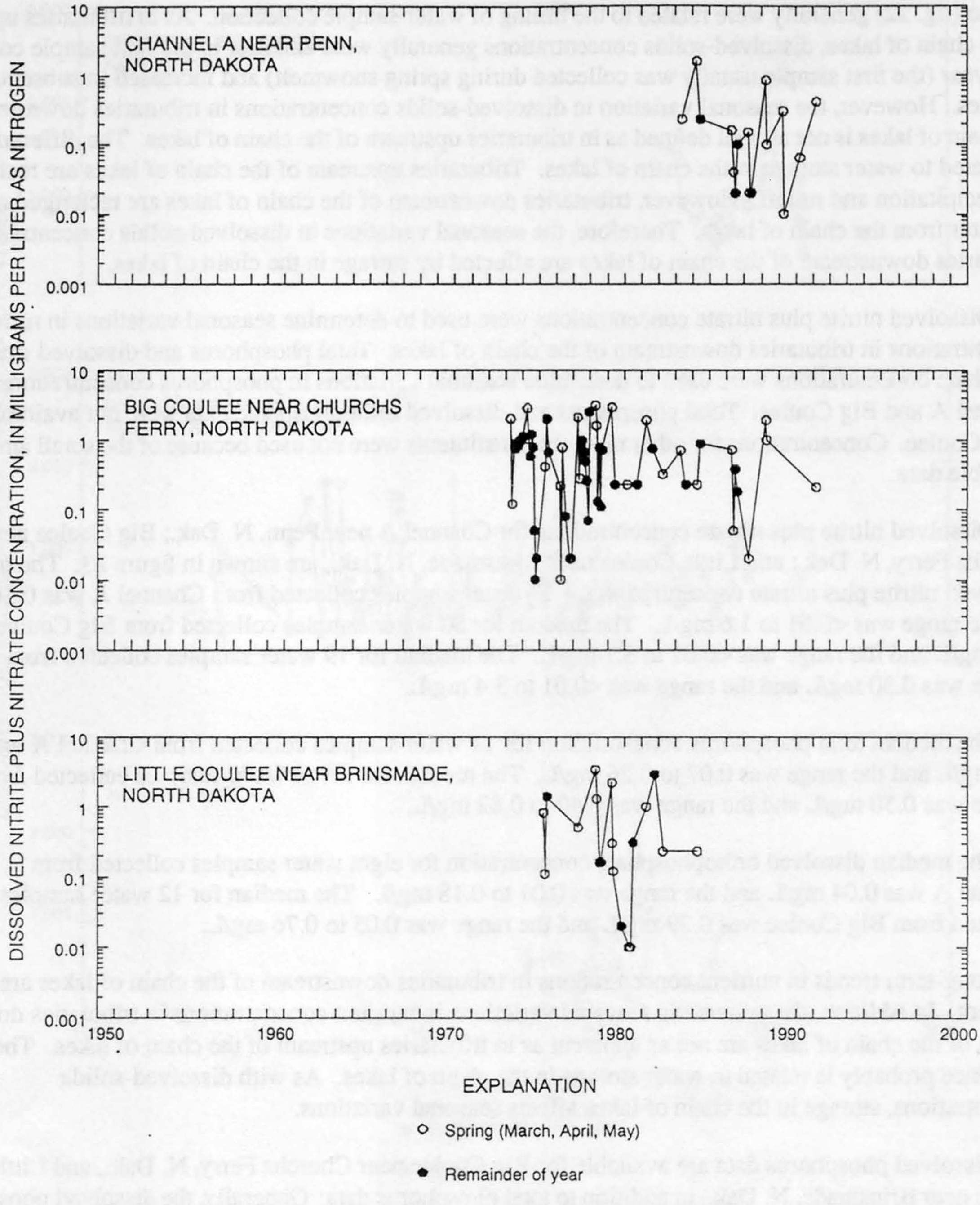


Figure 23. Dissolved nitrite plus nitrate concentrations in water samples from surface-water stations on tributaries downstream of the chain of lakes.

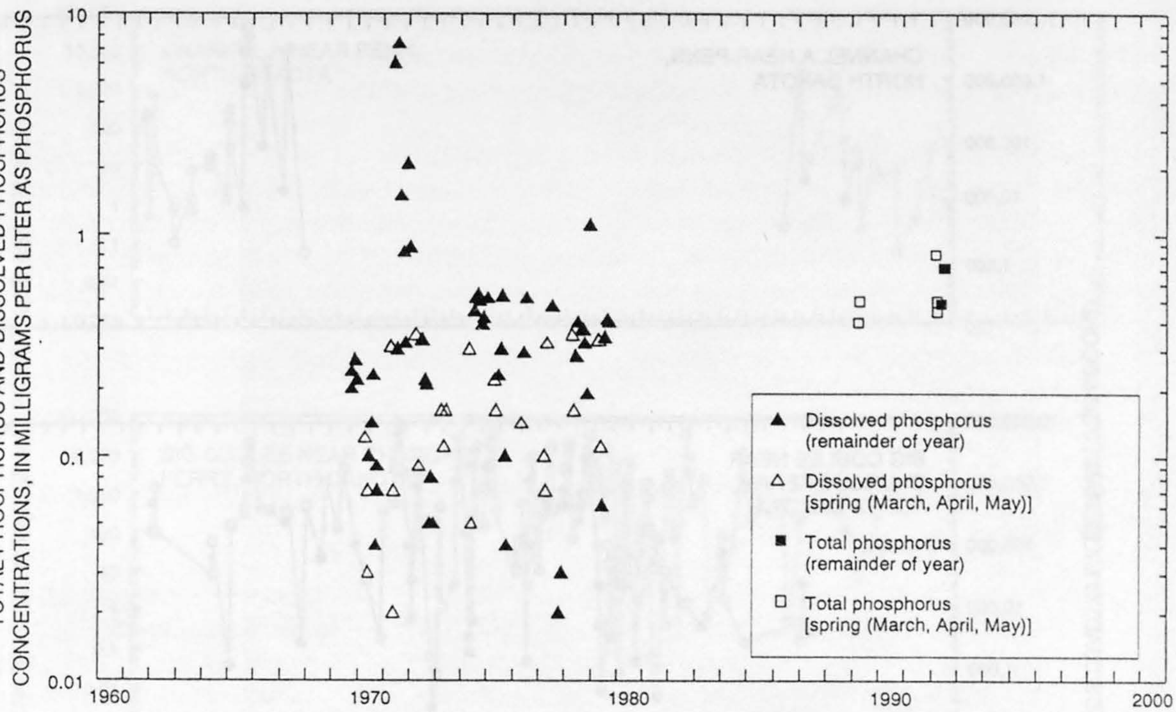


Figure 24. Total phosphorus and dissolved phosphorus concentrations in water samples from Big Coulee near Churchs Ferry, North Dakota.

Seasonal Variations in Dissolved-Solids and Nutrient Loads in Tributaries Downstream of the Chain of Lakes

Dissolved-solids loads calculated for Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak., are shown in figure 25. The median dissolved-solids load calculated for Channel A was 63,000 mg/s and the range was 1,700 to 7 million mg/s. The median for Big Coulee was 210,000 mg/s and the range was 260 to 8.6 million mg/s. The median for Little Coulee was 81,000 mg/s and the range was 230 to 2.2 million mg/s.

Long-term trends and seasonal variations in dissolved-solids loads in tributaries downstream of the chain of lakes are not apparent. Dissolved-solids loads generally were larger during the spring than during the remainder of the year. However, considerable overlap exists between the two periods.

Dissolved nitrite plus nitrate loads calculated for Channel A near Penn, N. Dak.; Big Coulee near Churchs Ferry, N. Dak.; and Little Coulee near Brinsmade, N. Dak., are shown in figure 26. The median dissolved nitrite plus nitrate load calculated for Channel A was 9.3 mg/s and the range was 0.06 to 3,500 mg/s. The median for Big Coulee was 570 mg/s and the range was 0.005 to 58,000 mg/s. The median for Little Coulee was 24 mg/s and the range was 0.003 to 7,700 mg/s.

The median total phosphorus load calculated for Channel A was 5.5 mg/s and the range was 0.40 to 69 mg/s. The median for Big Coulee was 200 mg/s and the range was 16 to 940 mg/s. Total phosphorus was not routinely measured in samples from Little Coulee during the study period.

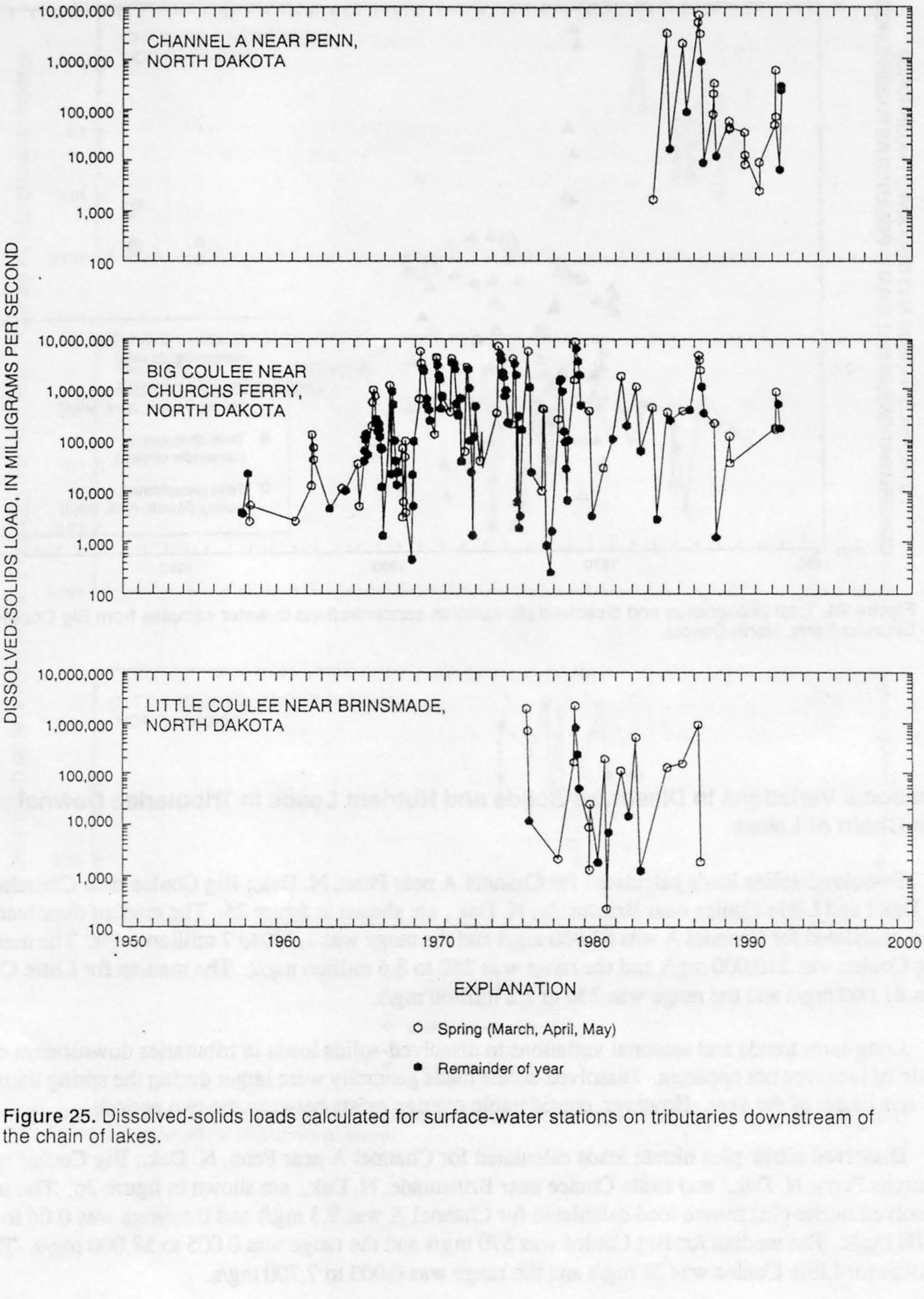


Figure 25. Dissolved-solids loads calculated for surface-water stations on tributaries downstream of the chain of lakes.

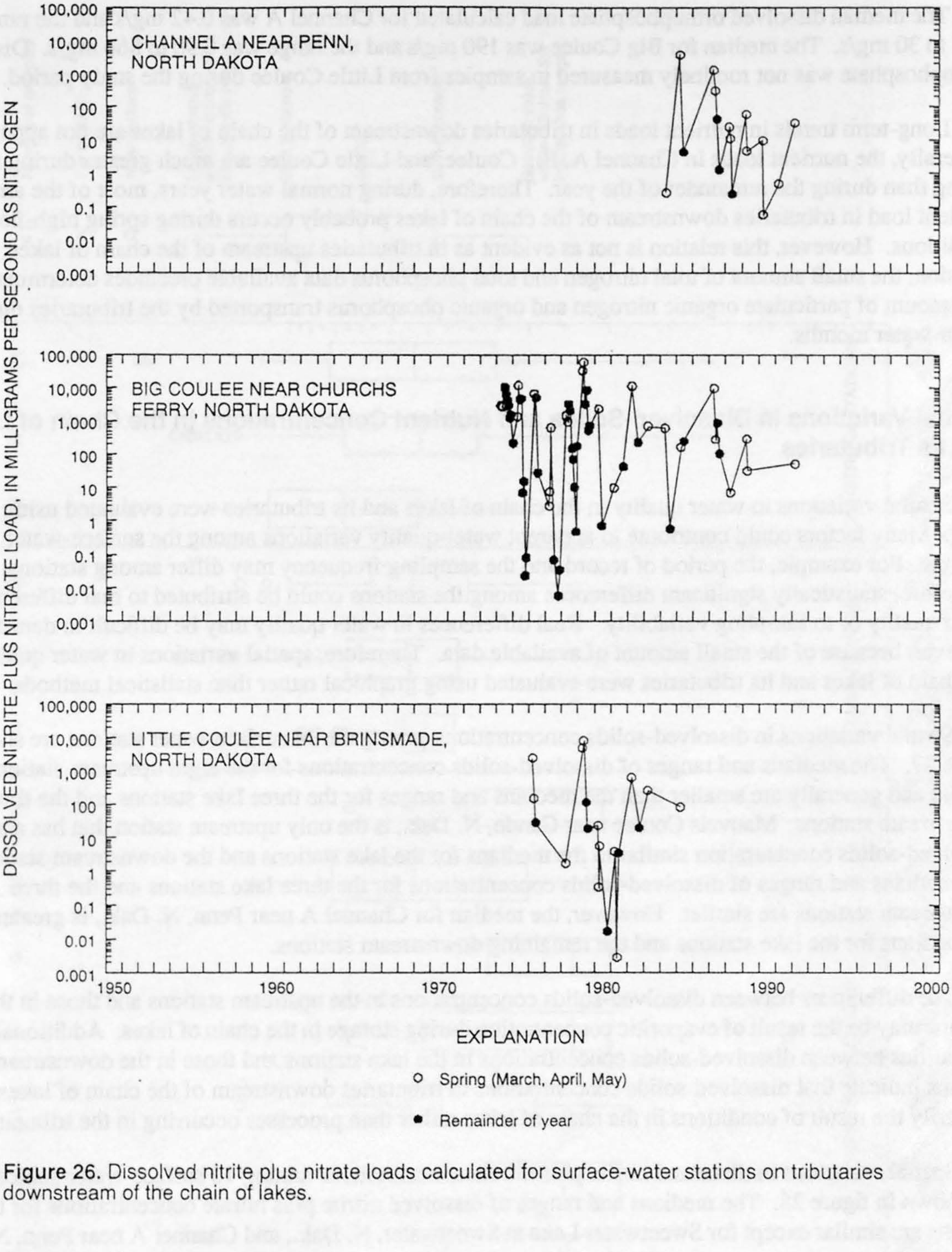


Figure 26. Dissolved nitrite plus nitrate loads calculated for surface-water stations on tributaries downstream of the chain of lakes.

The median dissolved orthophosphate load calculated for Channel A was 0.42 mg/s and the range was 0.07 to 30 mg/s. The median for Big Coulee was 190 mg/s and the range was 0.90 to 860 mg/s. Dissolved orthophosphate was not routinely measured in samples from Little Coulee during the study period.

Long-term trends in nutrient loads in tributaries downstream of the chain of lakes are not apparent. Generally, the nutrient loads in Channel A, Big Coulee, and Little Coulee are much greater during the spring than during the remainder of the year. Therefore, during normal water years, most of the annual nutrient load in tributaries downstream of the chain of lakes probably occurs during spring high-flow conditions. However, this relation is not as evident as in tributaries upstream of the chain of lakes. In addition, the small amount of total nitrogen and total phosphorus data available precludes determination of the amount of particulate organic nitrogen and organic phosphorus transported by the tributaries during warm-water months.

Spatial Variations in Dissolved-Solids and Nutrient Concentrations in the Chain of Lakes and Its Tributaries

Spatial variations in water quality in the chain of lakes and its tributaries were evaluated using box plots. Many factors could contribute to apparent water-quality variations among the surface-water stations. For example, the period of record and the sampling frequency may differ among stations. Therefore, statistically significant differences among the stations could be attributed to real differences in water quality or to sampling variability. Real differences in water quality may be difficult to detect, however, because of the small amount of available data. Therefore, spatial variations in water quality in the chain of lakes and its tributaries were evaluated using graphical rather than statistical methods.

Spatial variations in dissolved-solids concentrations among the 14 surface-water stations are shown in figure 27. The medians and ranges of dissolved-solids concentrations for the eight upstream stations are similar and generally are smaller than the medians and ranges for the three lake stations and the three downstream stations. Mauvais Coulee near Cando, N. Dak., is the only upstream station that has a median dissolved-solids concentration similar to the medians for the lake stations and the downstream stations. The medians and ranges of dissolved-solids concentrations for the three lake stations and the three downstream stations are similar. However, the median for Channel A near Penn, N. Dak., is greater than the medians for the lake stations and the remaining downstream stations.

The differences between dissolved-solids concentrations in the upstream stations and those in the lake stations may be the result of evaporitic concentration during storage in the chain of lakes. Additionally, the similarities between dissolved-solids concentrations in the lake stations and those in the downstream stations indicate that dissolved-solids concentrations in tributaries downstream of the chain of lakes are primarily the result of conditions in the chain of lakes rather than processes occurring in the tributaries.

Spatial variations in dissolved nitrite plus nitrate concentrations among 10 surface-water stations are shown in figure 28. The medians and ranges of dissolved nitrite plus nitrate concentrations for the 10 stations are similar except for Sweetwater Lake at Sweetwater, N. Dak., and Channel A near Penn, N. Dak.

Spatial variations in dissolved orthophosphate concentrations among nine surface-water stations are shown in figure 29. As with the dissolved nitrite plus nitrate concentrations, Channel A near Penn, N. Dak., had the smallest median dissolved orthophosphate concentration, and Big Coulee near Churchs Ferry, N. Dak., had the largest median dissolved orthophosphate concentration. Total phosphorus concentrations in the chain of lakes are smaller than in Big Coulee and Little Coulee. Dissolved phosphorus concentrations in Edmore Coulee and Starkweather Coulee are larger than in Channel A but smaller than in Big Coulee.

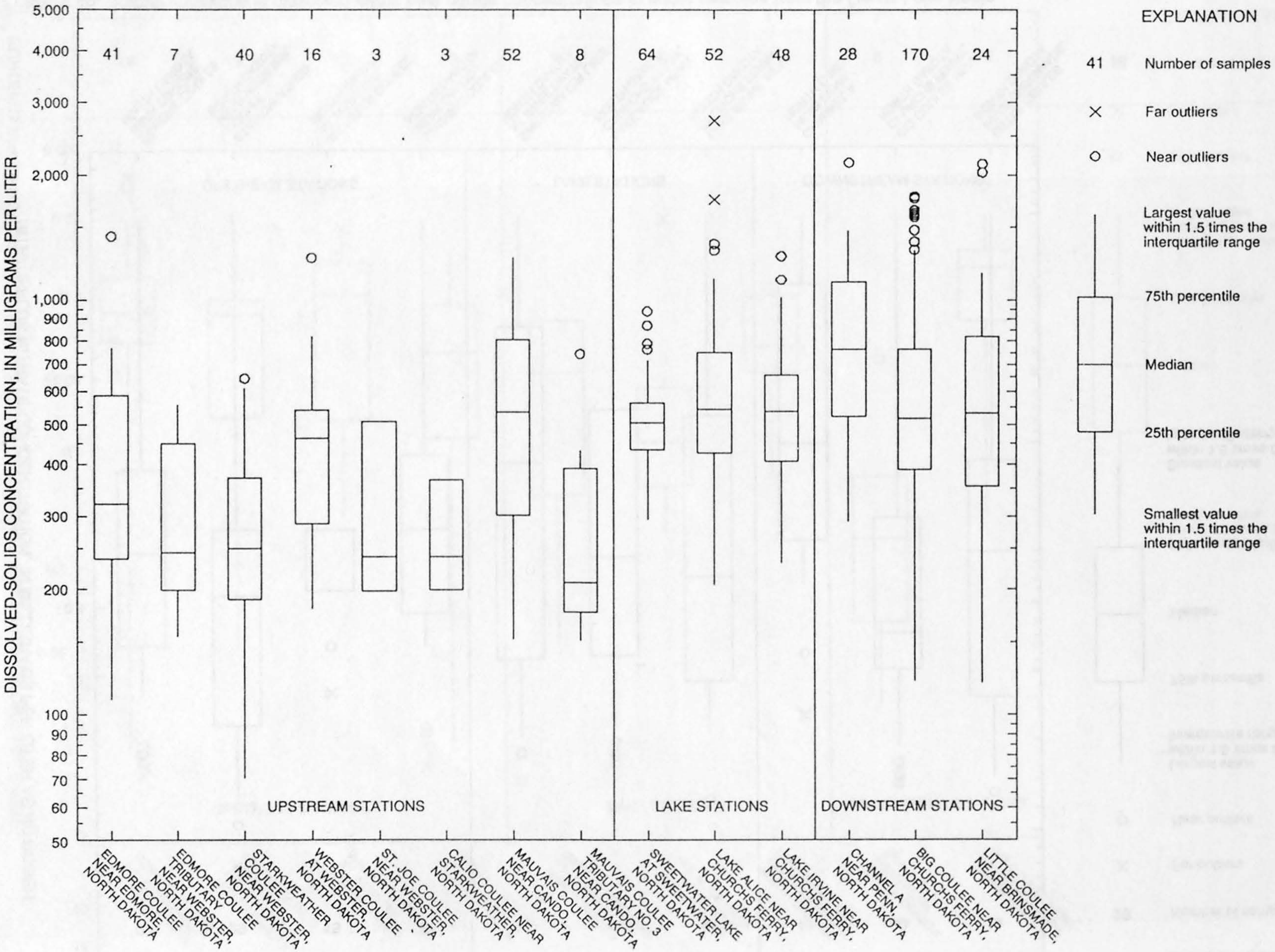


Figure 27. Spatial variations in dissolved-solids concentrations in water samples from the Devils Lake Basin.

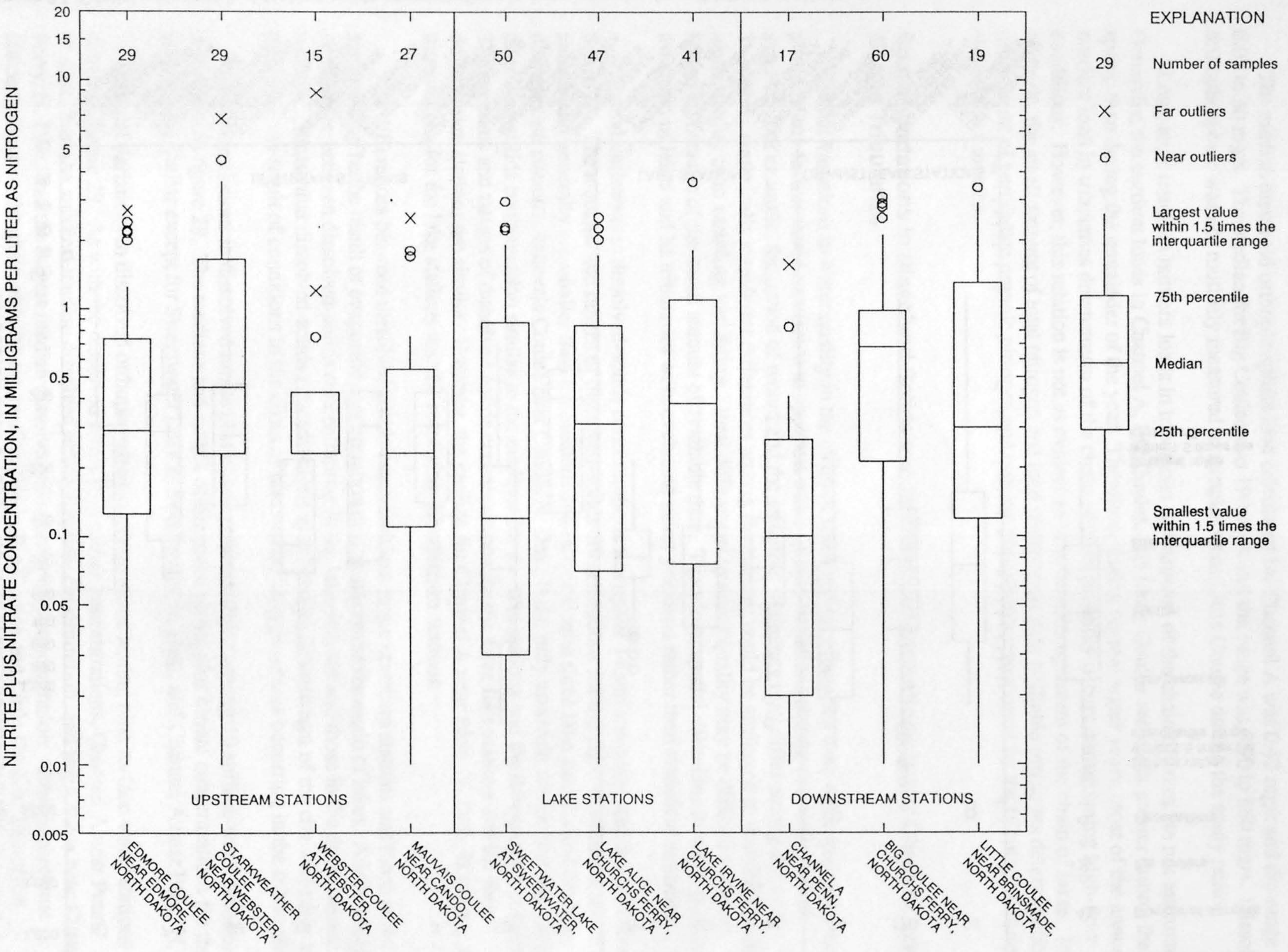


Figure 28. Spatial variations in dissolved nitrite plus nitrate concentrations in water samples from the Devils Lake Basin.

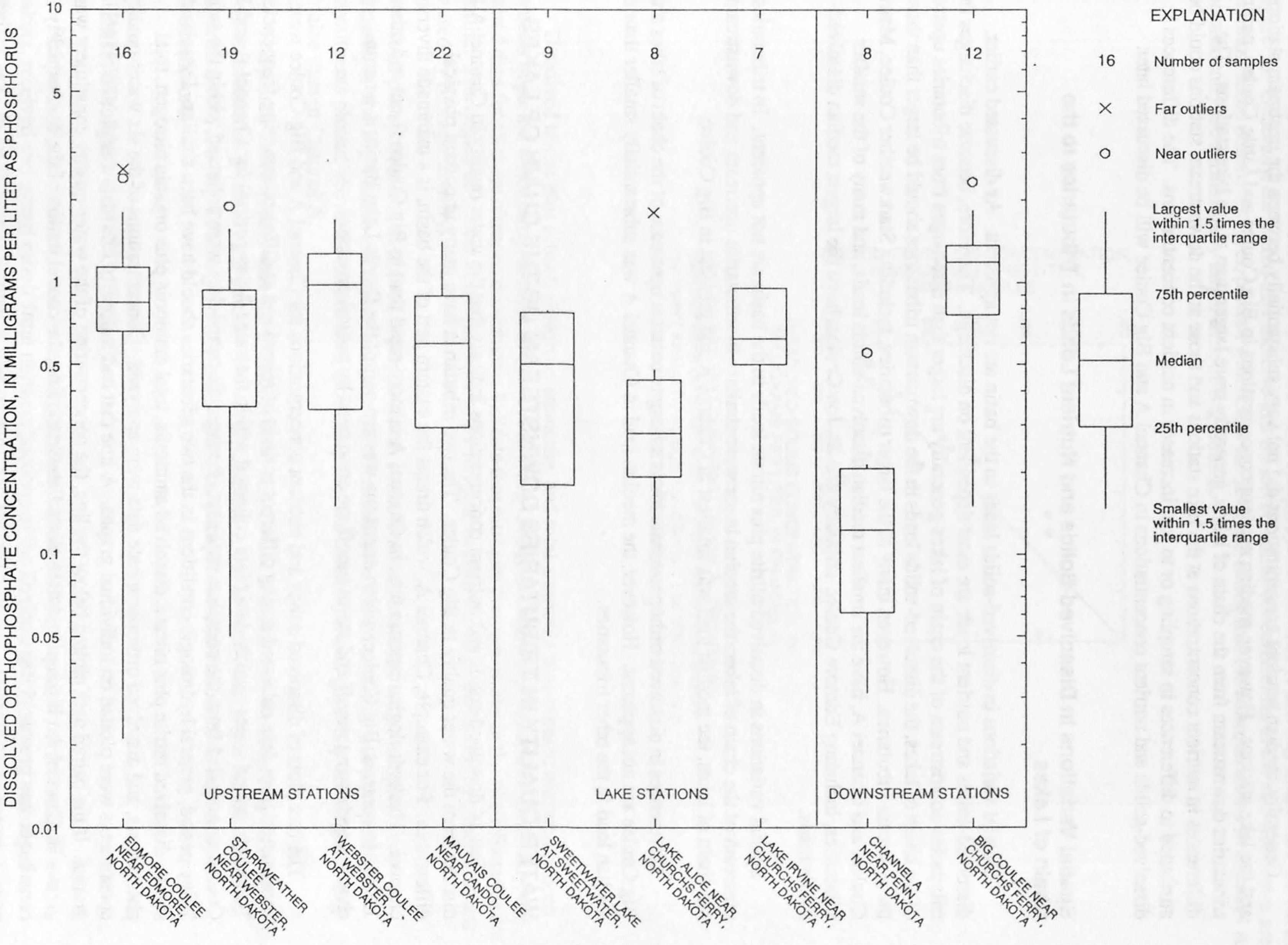


Figure 29. Spatial variations in dissolved orthophosphate concentrations in water samples from the Devils Lake Basin.

Generally, median nutrient concentrations did not vary substantially between the upstream stations and the lake stations. However, median nutrient concentrations in Big Coulee and Little Coulee, natural tributaries downstream from the chain of lakes, generally were larger than at the lake stations. The differences in nutrient concentrations at the lake stations and those at the downstream stations could be attributed to differences in sampling or to real increases in nutrient concentrations. The differences in dissolved-solids and nutrient concentrations in Channel A and Big Coulee will be discussed later.

Spatial Variations in Dissolved-Solids and Nutrient Loads in Tributaries to the Chain of Lakes

Spatial variations in dissolved-solids loads in the basin are not apparent. As discussed earlier, dissolved-solids and nutrient loads are most dependent on discharge. Therefore, because discharges from tributaries downstream of the chain of lakes generally are larger than discharges from tributaries upstream of the chain of lakes, the dissolved-solids loads in the downstream tributaries should be larger than those in the upstream tributaries. However, many of the larger tributaries, including Starkweather Coulee, Mauvais Coulee, and Channel A, have the smallest median dissolved-solids loads, and many of the smaller tributaries, including Edmore Coulee Tributary and St. Joe Coulee, have the largest median dissolved-solids loads.

Spatial variations in dissolved nitrite plus nitrate loads in the basin are not apparent. In tributaries upstream of the chain of lakes, the median loads were similar. In tributaries upstream and downstream of the chain of lakes, the median load was smallest in Channel A and greatest in Big Coulee.

Differences in dissolved orthophosphate loads among tributaries upstream of the chain of lakes and in Big Coulee are not apparent. However, the median load in Channel A was substantially smaller than the median load in the other tributaries.

WATER QUALITY IN TRIBUTARIES DOWNSTREAM OF THE CHAIN OF LAKES

Plots of dissolved-solids and nutrient concentrations indicate that the water quality in Channel A is distinct from the water quality in Big Coulee. The two tributaries have many important physical differences. For example, Channel A, which drains the eastern part of the basin, is a manmade diversion channel. The hydrologic response time in Channel A is more rapid than in Big Coulee (Lent and others, 1994). In contrast, Big Coulee, which drains the western part of the Devils Lake Basin, is a natural channel, and spring runoff and storm runoff are attenuated by natural processes.

The box plots of dissolved-solids and nutrient concentrations for Channel A and Big Coulee were constructed from data collected during different periods of record and at different sampling frequencies. Therefore, paired water-quality data (data collected within the same 7-day period) for Channel A and Big Coulee were culled from the complete data sets. Because all paired data were collected within the same 7-day period, general hydrologic conditions in the two tributaries should have been similar. Dissolved-solids, dissolved nitrite plus nitrate, dissolved ammonia, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphate data were analyzed. Concentrations of the six water-quality constituents were plotted on individual graphs. A line that had a slope of one also was plotted on the graphs. If the paired data plotted below the line, the concentration of the water-quality constituent was greater in Channel A. If the paired data plotted above the line, the concentration of the water-quality constituent was greater in Big Coulee.

Dissolved-solids concentrations in paired water samples from Channel A and Big Coulee are shown in figure 30. Generally, the paired data indicate that dissolved-solids concentrations in the two tributaries are similar. Some points, however, plotted well below the line, indicating that the concentrations in Channel A occasionally are substantially larger than in Big Coulee.

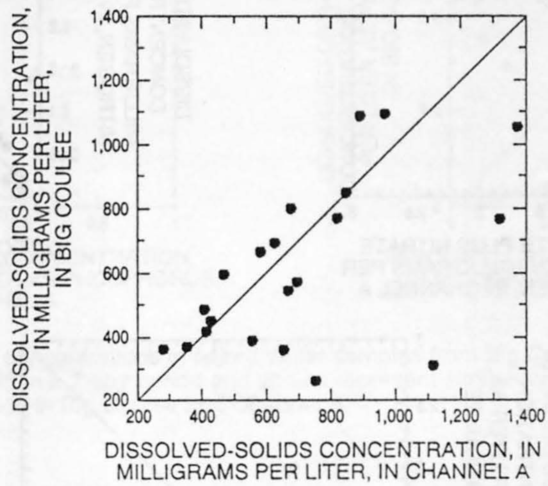


Figure 30. Dissolved-solids concentrations in paired water samples from Big Coulee and Channel A. Paired water samples were collected within a 7-day period and should represent similar hydrologic conditions. The solid line is a line of equal concentration in Big Coulee and Channel A.

Dissolved nitrite plus nitrate, dissolved ammonia, and total ammonia plus organic nitrogen concentrations in paired water samples from Channel A and Big Coulee are shown in figure 31. Generally, the paired data for all three nitrogen constituents indicate that nitrogen concentrations in the two tributaries are similar. The degree of scatter in the plots probably reflects, in part, the large variations in concentrations caused by biologic activity.

Total phosphorus and dissolved orthophosphate concentrations in paired water samples from Channel A and Big Coulee are shown in figure 32. Generally, the paired data for both phosphorus constituents plotted above the sloped line, indicating that the concentrations generally are larger in Big Coulee than in Channel A.

The paired water-quality data for Channel A and Big Coulee indicate that water-quality conditions in the two tributaries generally are similar. However, Channel A occasionally has larger dissolved-solids concentrations, and Big Coulee generally has larger total phosphorus and dissolved orthophosphate concentrations.

SUMMARY AND CONCLUSIONS

Before 1979, the chain of lakes, located in the Devils Lake drainage basin in northeastern North Dakota, received and stored runoff from northern sections of the Devils Lake Basin and recharged Devils Lake. In 1979, when Channel A was constructed, the chain of lakes became two separate chains.

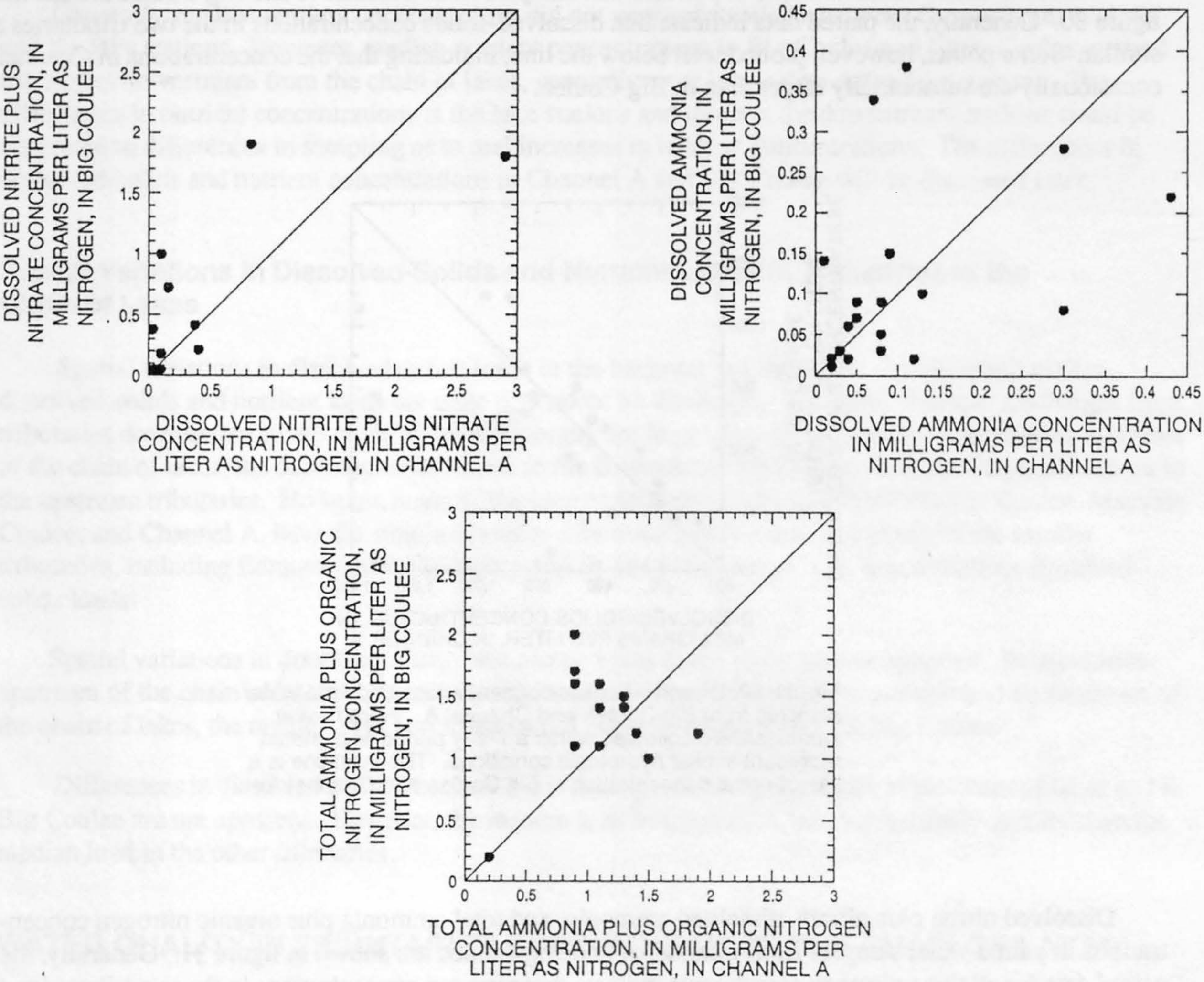


Figure 31. Nitrogen-species concentrations in paired water samples from Big Coulee and Channel A. Paired water samples were collected within a 7-day period and should represent similar hydrologic conditions. The solid line is a line of equal concentration in Big Coulee and Channel A.

Together, the two chains act as an evaporation and storage basin and can affect water-level fluctuations in Devils Lake. However, water-quality variations between the two chains are difficult to determine. The purpose of this report is to describe seasonal and spatial variations in water quality in the chain of lakes and its tributaries.

Long-term trends in dissolved-solids and nutrient concentrations in tributaries upstream of the chain of lakes are not apparent. However, dissolved-solids and nutrient concentrations do vary seasonally in tributaries upstream of the chain of lakes. Generally, samples collected during the spring high-flow months have smaller dissolved-solids concentrations and larger nutrient concentrations than samples collected during the remainder-of-the-year low-flow months. The seasonal variations in dissolved-solids concentrations probably are caused by exclusion of dissolved solids during initial spring runoff over frozen soils and by evaporitic concentration of dissolved solids during summer low-flow conditions. The seasonal variations in dissolved nitrite plus nitrate concentrations are consistent with partitioning of nitrogen by biologic activity. Phosphorus also is partitioned by biologic activity.

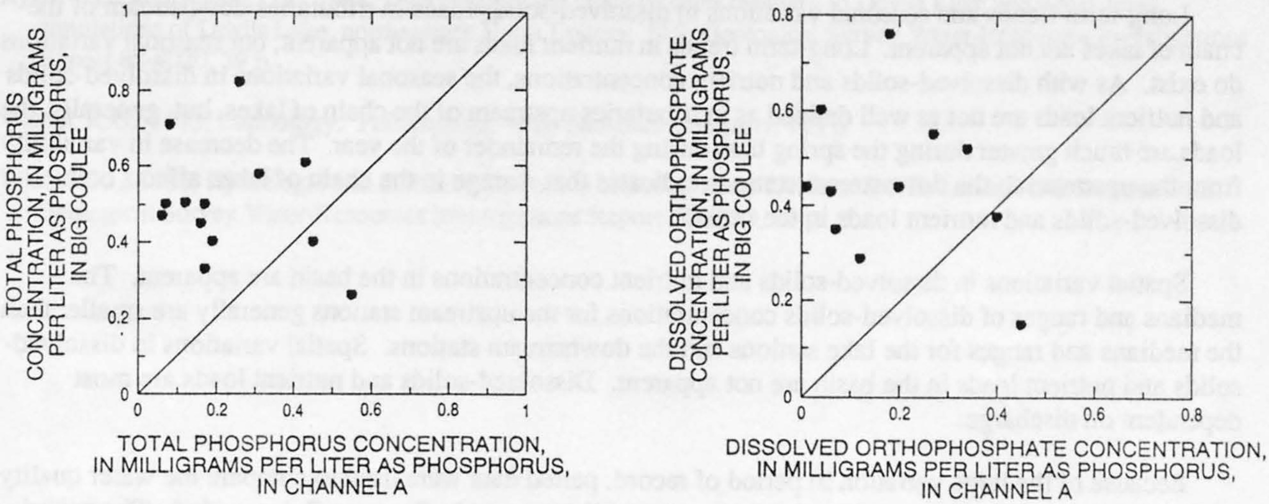


Figure 32. Phosphorus-species concentrations in paired water samples from Big Coulee and Channel A. Paired water samples were collected within a 7-day period and should represent similar hydrologic conditions. The solid line is a line of equal concentration in Big Coulee and Channel A.

Long-term trends in dissolved-solids and nutrient loads in tributaries upstream of the chain of lakes are not apparent. Generally, the dissolved-solids loads are much greater during the spring than during the remainder of the year. In addition, the relative variations between dissolved-solids loads during the spring and during the remainder of the year were much greater than the relative variations between dissolved-solids concentrations during the spring and during the remainder of the year. This indicates that discharge is the more influential component in calculating dissolved-solids loads. Seasonal variations in nutrient loads are similar to those in dissolved-solids loads, indicating that discharge also is the more influential component in calculating nutrient loads.

Long-term trends and seasonal variations in dissolved-solids and nutrient concentrations in the chain of lakes generally are not apparent. However, three notable exceptions exist. First, dissolved-solids concentrations in Sweetwater Lake generally increased during the period of record. Second, dissolved-solids concentrations in Lake Alice and Lake Irvine do vary seasonally--dissolved-solids concentrations in water samples collected during the spring routinely were smaller than those in water samples collected during the remainder of the year. Finally, dissolved phosphorus concentrations in water samples collected from Lake Alice during the spring generally increased during the period of record.

Seasonal variations in dissolved-solids masses in the chain of lakes are apparent, but seasonal variations in dissolved nitrite plus nitrate and dissolved phosphorus masses are not systematic. Dissolved-solids masses in Sweetwater Lake and Lake Irvine are larger during the spring than during the remainder of the year, indicating that seasonal variations in water volumes in the chain of lakes are important to the chemical budgets of the lakes.

Long-term trends in dissolved-solids and nutrient concentrations in tributaries downstream of the chain of lakes are not apparent. As in tributaries upstream of the chain of lakes, dissolved-solids concentrations generally were smallest in the first sample collected during spring snowmelt each year and increased in subsequent samples. The seasonal variations in dissolved-solids and nutrient concentrations in tributaries downstream of the chain of lakes are not as well defined as in tributaries upstream of the chain of lakes. The difference may be related to water storage in the chain of lakes.

Long-term trends and seasonal variations in dissolved-solids loads in tributaries downstream of the chain of lakes are not apparent. Long-term trends in nutrient loads are not apparent, but seasonal variations do exist. As with dissolved-solids and nutrient concentrations, the seasonal variations in dissolved-solids and nutrient loads are not as well defined as in tributaries upstream of the chain of lakes, but, generally, the loads are much greater during the spring than during the remainder of the year. The decrease in variability from the upstream to the downstream stations indicates that storage in the chain of lakes affects both dissolved-solids and nutrient loads in the basin.

Spatial variations in dissolved-solids and nutrient concentrations in the basin are apparent. The medians and ranges of dissolved-solids concentrations for the upstream stations generally are smaller than the medians and ranges for the lake stations and the downstream stations. Spatial variations in dissolved-solids and nutrient loads in the basin are not apparent. Dissolved-solids and nutrient loads are most dependent on discharge.

Because of the large variation in period of record, paired data were used to compare the water quality in Channel A and Big Coulee. All paired data were collected within the same 7-day period. The paired water-quality data for Channel A and Big Coulee indicate that water-quality conditions in the two tributaries generally are similar. However, dissolved-solids concentrations occasionally are larger in Channel A than in Big Coulee, and total phosphorus and dissolved orthophosphate concentrations generally are larger in Big Coulee than in Channel A.

Long-term, annual dissolved-solids and nutrient load data are essential to understanding water-quality variations in the Devils Lake Basin. Long-term load calculations could be used to relate land-use practices, such as agriculture and waterfowl management, to water-quality trends in the basin; to determine the effect of lake storage on water quality in the basin; and to evaluate the effectiveness of best-management practices within the subbasins. However, the small amount of water-quality data available precluded using concentration data to calculate long-term dissolved-solids and nutrient loads for tributaries in the Devils Lake Basin.

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Supplement 1. Summary of water-quality data for Edmore Coulee near Edmore, North Dakota (05056200), 1971 through 1992

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg./L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Discharge (cubic feet per second) 00060	11	132	0.04	35	132	61	5.7	0.17	0.04
Discharge, instantaneous (cubic feet per second) 00061	107	1,110	0.01	133	687	138	17	1.9	0.08
Specific conductance, field (µS/cm) 00094	21	1,890	205	696	1,810	964	585	448	210
Specific conductance, laboratory (µS/cm) 00095	117	1,880	0	686	1,290	918	620	418	267
pH, field (standard units) 00400	40	9.0	6.9	7.8	8.7	8.1	7.7	7.5	7.1
pH, laboratory (standard units) 00403	22	8.3	6.5	7.6	8.3	7.9	7.7	7.4	6.5
Temperature, water (degrees Celsius) 00010	119	28.0	0	10.6	24.0	17.0	9.0	3.0	0
Color, platinum-cobalt electrode 00080	1	15	--	--	--	--	--	--	--
Dissolved oxygen (mg/L) 00300	17	13.1	5.1	9.0	13.1	11.0	9.0	7.6	5.1
Dissolved oxygen, percent saturation 00301	16	137	45	84	137	105	78	66	45
Carbon dioxide, dissolved (mg/L as CO_2) 00405	14	20	2.8	6.7	20	7.8	5.2	3.3	2.8
Alkalinity, field (mg/L as $CaCO_3$) 00410	16	390	0	160	390	240	120	89	0
Alkalinity, laboratory (mg/L) 90410	27	360	63	170	320	220	150	120	63
Solids, suspended, residue on evaporation at 105 degrees Celsius (mg/L) 00530	3	5	0	--	--	--	--	--	--
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	41	1,460	135	432	788	639	352	252	157
Calcium, dissolved (mg/L as Ca) 00915	41	140	18	52	86	72	42	34	20
Magnesium, dissolved (mg/L as Mg) 00925	41	100	4.5	23	46	34	18	13	7.5

Supplement 1. Summary of water-quality data for Edmore Coulee near Edmore, North Dakota (05056200), 1971 through 1992—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Sodium, dissolved (mg/L as Na) 00930	41	150	5.0	46	110	71	35	22	6.1
Potassium, dissolved (mg/L as K) 00935	41	31	4.5	13	27	16	12	9.4	5.0
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	15	450	72	206	450	290	150	120	72
Carbonate, unfiltered (mg/L as CO_3) 00445	15	10	0	1	10	0	0	0	0
Sulfate, dissolved (mg/L as SO_4) 00945	41	830	17	140	350	200	110	64	18
Chloride, dissolved (mg/L as Cl) 00940	41	49	1.5	17	40	24	16	7.0	3.3
Fluoride, dissolved (mg/L as F) 00950	41	0.3	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	41	33	2.7	15	31	19	15	8.6	2.8
Nitrogen, nitrite, total (mg/L as N) 00615	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as N) 00613	15	0.09	--	*0.02	*0.09	*0.03	*0.01	*0	*0
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	9	0.30	0.03	0.09	0.30	0.13	0.07	0.03	0.03
Nitrogen, nitrate, dissolved (mg/L as N) 00618	21	2.7	0.02	0.76	2.7	1.4	0.29	0.13	0.03
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	24	12	0.10	3.3	12	5.0	1.4	0.70	0.16
Nitrogen, nitrite plus nitrate, total (mg/L as N) 00630	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	17	2.4	--	*0.46	*2.4	*0.60	*0.11	*0.01	*0
Nitrogen, ammonia, total (mg/L as N) 00610	5	0.12	0.02	--	--	--	--	--	--
Nitrogen, ammonia, dissolved (mg/L as N) 00608	16	0.22	0.02	0.09	0.22	0.15	0.08	0.03	0.02
Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) 00625	9	2.2	1.0	1.4	2.2	1.6	1.4	1.2	1.0

Supplement 1. Summary of water-quality data for Edmore Coulee near Edmore, North Dakota (05056200), 1971 through 1992—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg./L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Phosphorus, total (mg/L as P) 00665	9	0.61	0.25	0.38	0.61	0.41	0.39	0.30	0.25
Phosphate, total (mg/L as PO_4) 00650	5	1.0	0.83	--	--	--	--	--	--
Phosphorus, dissolved (mg/L as P) 00666	1	0.04	--	--	--	--	--	--	--
Orthophosphate, total (mg/L as P) 70507	5	0.34	0.27	--	--	--	--	--	--
Orthophosphate, dissolved (mg/L as P) 00671	10	0.39	0.01	0.23	0.39	0.30	0.25	0.17	0.01
Orthophosphate, dissolved (mg/L as PO_4) 00660	16	2.6	0.02	1.0	2.6	1.1	0.84	0.66	0.02
Phosphorus, hydrolyzable plus orthophosphate, dissolved (mg/L as P) 00677	11	0.42	0.09	0.25	0.42	0.31	0.28	0.17	0.09
Arsenic, dissolved (μg/L as As) 01000	25	8	1	3	7	4	3	2	1
Boron, dissolved (μg/L as B) 01020	41	980	--	90	*200	*90	*60	*30	*10
Lithium, dissolved (μg/L as Li) 01130	25	110	6	30	90	30	20	10	10
Manganese, dissolved (μg/L as Mn) 01056	40	1,100	--	*120	*870	*100	*50	*10	*2
Molybdenum, dissolved (μg/L as Mo) 01060	25	4	--	*2	*4	*2	*1	*1	*0
Selenium, dissolved (μg/L as Se) 01145	25	3	--	*1	*3	*1	*1	*0	*0
Strontium, dissolved (μg/L as Sr) 01080	25	750	100	240	650	280	230	140	100

Supplement 2. Summary of water-quality data for Edmore Coulee Tributary near Webster, North Dakota (05056215), 1986 through 1992

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
Water-quality property or constituent and parameter code	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	30	489	0.12	78	416	111	28	3.1	0.14
Specific conductance, laboratory (µS/cm) 00095	28	1,140	220	568	1,120	642	498	422	246
pH, field (standard units) 00400	8	7.8	6.8	7.2	7.8	7.6	7.1	6.9	6.8
pH, laboratory (standard units) 00403	5	7.7	6.7	--	--	--	--	--	--
Temperature, water (degrees Celsius) 00010	30	23.5	1.0	11.6	23.5	20.0	11.8	3.8	1.0
Alkalinity, field (mg/L as CaCO3) 00410	1	0	--	--	--	--	--	--	--
Alkalinity, laboratory (mg/L) 90410	7	230	81	140	230	180	120	90	81
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	7	625	187	340	625	481	280	219	187
Calcium, dissolved (mg/L as Ca) 00915	7	87	29	50	87	76	38	31	29
Magnesium, dissolved (mg/L as Mg) 00925	7	35	8.0	18	35	25	14	11	8.0
Sodium, dissolved (mg/L as Na) 00930	7	50	8.0	24	50	34	21	14	8.0
Potassium, dissolved (mg/L as K) 00935	7	16	8.0	12	16	15	13	8.3	8.0
Sulfate, dissolved (mg/L as SO_4) 00945	7	210	25	110	210	190	79	76	25
Chloride, dissolved (mg/L as Cl) 00940	7	22	4.3	11	22	19	9.6	4.7	4.3
Fluoride, dissolved (mg/L as F) 00950	7	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	7	33	15	20	33	25	17	15	15
Arsenic, dissolved (µg/L as As) 01000	7	6	3	4	6	6	4	3	3
Boron, dissolved (µg/L as B) 01020	7	170	10	80	170	170	50	20	10

Supplement 2. Summary of water-quality data for Edmore Coulee Tributary near Webster, North Dakota (05056215), 1986 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Lithium, dissolved (µg/L as Li) 01130	7	30	10	20	30	20	20	10	10
Manganese, dissolved (µg/L as Mn) 01056	7	80	10	44	80	70	40	20	10
Molybdenum, dissolved (µg/L as Mo) 01060	7	5	--	*2	*5	*5	*2	*1	*0
Selenium, dissolved (µg/L as Se) 01145	8	--	--	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	7	310	140	220	310	260	250	150	140

Supplement 3. Summary of water-quality data for Starkweather Coulee near Webster, North Dakota (05056239), 1980 through 1992

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	75	556	0.02	63	294	63	5.6	1.5	0.10
Specific conductance, laboratory (µS/cm) 00095	71	1,600	145	560	991	695	512	405	165
pH, field (standard units) 00400	41	9.4	6.8	7.9	8.8	8.2	7.9	7.5	7
pH, laboratory (standard units) 00403	26	10.3	6.3	7.6	9.6	7.9	7.5	7.1	6.4
Temperature, water (degrees Celsius) 00010	74	29.5	0	11.9	26.0	20.0	12.0	3.4	0
Dissolved oxygen (mg/L) 00300	22	13.7	3.2	9.5	13.5	11.3	10.0	7.4	3.5
Dissolved oxygen, percent saturation 00301	22	144	39	87	142	97	85	73	41
Carbon dioxide, dissolved (mg/L as CO_2) 00405	8	21	1.1	4.4	21	3.0	2.2	1.3	1.1
Alkalinity, field (mg/L as $CaCO_3$) 00410	8	300	64	190	300	240	220	120	64
Alkalinity, laboratory (mg/L) 90410	35	300	34	160	290	210	140	110	44
Solids, suspended, residue on evaporation at 105 degrees Celsius (mg/L) 00530	5	472	1	--	--	--	--	--	--
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	40	676	93	338	650	433	292	228	109
Calcium, dissolved (mg/L as Ca) 00915	40	97	13	52	95	70	46	36	17
Magnesium, dissolved (mg/L as Mg) 00925	40	49	4.5	21	45	27	17	13	4.7
Sodium, dissolved (mg/L as Na) 00930	39	82	3.5	18	49	19	14	8.5	4.0
Potassium, dissolved (mg/L as K) 00935	40	22	3.0	12	19	15	13	9.7	6.2
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	8	360	78	230	360	300	260	140	78

Supplement 3. Summary of water-quality data for Starkweather Coulee near Webster, North Dakota (05056239), 1980 through 1992—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Carbonate, unfiltered (mg/L as CO_3) 00445	8	0	--	--	--	--	--	--	--
Sulfate, dissolved (mg/L as SO_4) 00945	40	310	17	89	250	110	74	38	18
Chloride, dissolved (mg/L as Cl) 00940	40	91	2.1	14	33	15	10	4.9	3.2
Fluoride, dissolved (mg/L as F) 00950	40	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	40	44	1.4	20	36	24	19	15	5.9
Nitrogen, nitrite, total (mg/L as N) 00615	7	0.14	--	*0.06	*0.14	*0.10	*0.05	*0.02	*0.01
Nitrogen, nitrite, dissolved (mg/L as N) 00613	19	0.16	--	*0.05	*0.16	*0.06	*0.03	*0.01	*0
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	11	0.53	0.07	0.24	0.53	0.39	0.16	0.13	0.07
Nitrogen, nitrate, dissolved (mg/L as N) 00618	24	6.8	0.07	1.1	6.2	1.1	0.39	0.23	0.10
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	25	30	0.30	5.3	27	6.9	1.9	1.0	0.48
Nitrogen, nitrite plus nitrate, total (mg/L as N) 00630	7	0.62	--	*0.48	*0.62	*0.59	*0.47	*0.38	*0.34
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	19	3.3	--	*0.68	*3.3	*0.70	*0.45	*0.02	*0
Nitrogen, ammonia, total (mg/L as N) 00610	7	0.36	0.04	0.13	0.36	0.22	0.07	0.04	0.04
Nitrogen, ammonia, dissolved (mg/L as N) 00608	19	0.31	0.04	0.12	0.31	0.16	0.09	0.06	0.04
Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) 00625	13	1.7	0.60	1.3	1.7	1.6	1.3	1.0	0.60
Phosphorus, total (mg/L as P) 00665	12	0.64	0.02	0.29	0.64	0.37	0.33	0.12	0.02
Phosphate, total (mg/L as PO_4) 00650	6	1.2	0.49	0.88	1.2	1.1	0.90	0.70	0.49
Orthophosphate, total (mg/L as P) 70507	7	0.38	--	*0.27	*0.38	*0.35	*0.29	*0.16	*0.13

Supplement 3. Summary of water-quality data for Starkweather Coulee near Webster, North Dakota (05056239), 1980 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics			Value at which indicated percent of all sample values is less than or equal to that shown				
		Maximum	Minimum	Mean	95	75	50	25	5
Orthophosphate, dissolved (mg/L as P) 00671	9	0.51	--	*0.26	*0.51	*0.32	*0.28	*0.12	*0.07
Orthophosphate, dissolved (mg/L as PO_4) 00660	19	1.9	0.05	0.73	1.9	0.94	0.83	0.35	0.05
Phosphorus, hydrolyzable plus orthophosphate, dissolved (mg/L as P) 00677	12	0.46	0.08	0.28	0.46	0.35	0.30	0.24	0.08
Arsenic, dissolved (µg/L as As) 01000	30	11	1	5	10	7	6	4	2
Boron, dissolved (µg/L as B) 01020	40	550	--	*80	*230	*100	*40	*30	*10
Lithium, dissolved (µg/L as Li) 01130	30	60	10	20	50	20	20	10	10
Manganese, dissolved (µg/L as Mn) 01056	40	180	--	*22	*60	*28	*10	*10	*4
Molybdenum, dissolved (µg/L as Mo) 01060	30	5	--	*2	*4	*2	*2	*1	*0
Selenium, dissolved (µg/L as Se) 01145	30	2	--	*1	*2	*1	*1	*0	*0
Strontium, dissolved (µg/L as Sr) 01080	30	350	50	210	340	260	210	160	70

Supplement 4. Summary of water-quality data for Webster Coulee at Webster, North Dakota (05056225), 1980 through 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	26	404	0.01	48	339	59	9.6	2.5	0.02
Specific conductance, field (µS/cm) 00094	4	807	479	--	--	--	--	--	--
Specific conductance, laboratory (µS/cm) 00095	26	1,720	330	782	1,550	851	760	690	376
pH, field (standard units) 00400	16	8.6	7.1	8.0	8.6	8.3	8.2	7.8	7.1
pH, laboratory (standard units) 00403	5	8.2	7.4	--	--	--	--	--	--
Temperature, water (degrees Celsius) 00010	25	28.0	0.5	11.6	27.8	16.8	11.0	4.2	0.6
Carbon dioxide, dissolved (mg/L as CO_2) 00405	9	17	0.9	5.0	17	6.0	3.1	2.6	0.9
Alkalinity, field (mg/L as $CaCO_3$) 00410	9	390	92	210	390	270	180	130	92
Alkalinity, laboratory (mg/L) 90410	10	290	110	180	290	220	180	140	110
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	16	1,300	229	558	1,300	623	513	369	229
Calcium, dissolved (mg/L as Ca) 00915	16	150	31	62	150	75	52	46	31
Magnesium, dissolved (mg/L as Mg) 00925	16	96	10	34	96	34	31	22	10
Sodium, dissolved (mg/L as Na) 00930	15	120	12	53	120	71	55	40	12
Potassium, dissolved (mg/L as K) 00935	16	45	9.2	19	45	21	19	13	9.2
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	9	480	110	250	480	330	220	160	110
Carbonate, unfiltered (mg/L as CO_3) 00445	9	0	--	--	--	--	--	--	--
Sulfate, dissolved (mg/L as SO_4) 00945	16	590	37	200	590	230	170	120	37
Chloride, dissolved (mg/L as Cl) 00940	16	47	8.8	22	47	26	22	17	8.8

Supplement 4. Summary of water-quality data for Webster Coulee at Webster, North Dakota (05056225), 1980 through 1986—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
Water-quality property or constituent and parameter code	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Fluoride, dissolved (mg/L as F) 00950	16	0.3	0	0.2	0.3	0.2	0.1	0.1	0
Silica, dissolved (mg/L as SiO_2) 00955	16	34	8.5	17	34	21	16	12	8.5
Nitrogen, nitrate, dissolved (mg/L as N) 00618	14	8.8	0.23	0.96	8.8	0.51	0.23	0.23	0.23
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	15	39	1.0	4.1	39	1.9	1.0	1.0	1.0
Orthophosphate, dissolved (mg/L as PO_4) 00660	12	1.7	0.15	0.87	1.7	1.3	0.98	0.34	0.15
Arsenic, dissolved (µg/L as As) 01000	5	7	3	--	--	--	--	--	--
Boron, dissolved (µg/L as B) 01020	16	260	30	90	260	100	90	40	30
Lithium, dissolved (µg/L as Li) 01130	5	60	20	--	--	--	--	--	--
Manganese, dissolved (µg/L as Mn) 01056	16	660	0	140	660	170	35	10	0
Molybdenum, dissolved (µg/L as Mo) 01060	5	5	1	--	--	--	--	--	--
Selenium, dissolved (µg/L as Se) 01145	5	0	--	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	5	190	120	--	--	--	--	--	--

Supplement 5. Summary of water-quality data for St. Joe Coulee near Webster, North Dakota (05056244), 1986 through 1988

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Descriptive statistics: Maximum	Descriptive statistics: Minimum	Descriptive statistics: Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	10	316	0.11	56	316	73	15	1.5	0.11
Specific conductance, field (µS/cm) 00094	3	760	371	--	--	--	--	--	--
Specific conductance, laboratory (µS/cm) 00095	8	1,110	360	598	1,110	746	552	382	360
pH, field (standard units) 00400	3	8.7	7.2	--	--	--	--	--	--
pH, laboratory (standard units) 00403	3	7.8	7.3	--	--	--	--	--	--
Temperature, water (degrees Celsius) 00010	10	26.0	1.5	13.2	26.0	21.1	14.2	3.1	1.5
Alkalinity, laboratory (mg/L) 90410	3	190	100	--	--	--	--	--	--
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	3	526	234	--	--	--	--	--	--
Magnesium, dissolved (mg/L as Mg) 00925	3	29	11	--	--	--	--	--	--
Sodium, dissolved (mg/L as Na) 00930	3	28	13	--	--	--	--	--	--
Potassium, dissolved (mg/L as K) 00935	3	19	9.5	--	--	--	--	--	--
Sulfate, dissolved (mg/L as SO_4) 00945	3	210	50	--	--	--	--	--	--
Chloride, dissolved (mg/L as Cl) 00940	3	15	5.9	--	--	--	--	--	--
Fluoride, dissolved (mg/L as F) 00950	3	0.1	0.1	--	--	--	--	--	--
Silica, dissolved (mg/L as SiO_2) 00955	3	34	20	--	--	--	--	--	--
Arsenic, dissolved (µg/L as As) 01000	3	8	5	--	--	--	--	--	--
Boron, dissolved (µg/L as B) 01020	3	190	40	--	--	--	--	--	--
Lithium, dissolved (µg/L as Li) 01130	3	30	20	--	--	--	--	--	--

Supplement 5. Summary of water-quality data for St. Joe Coulee near Webster, North Dakota (05056244), 1986 through 1988—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics			Value at which indicated percent of all sample values is less than or equal to that shown				
		Maximum	Minimum	Mean	95	75	50	25	5
Manganese, dissolved (µg/L as Mn) 01056	3	20	10	--	--	--	--	--	--
Molybdenum, dissolved (µg/L as Mo) 01060	3	--	--	--	--	--	--	--	--
Selenium, dissolved (µg/L as Se) 01145	3	--	--	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	3	290	110	--	--	--	--	--	--

Supplement 6. Summary of water-quality data for Calio Coulee near Starkweather, North Dakota (05056247), 1986 through 1988

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	7	279	1.0	96	279	234	64	5.2	1.0
Specific conductance, field (µS/cm) 00094	3	587	381	--	--	--	--	--	--
Specific conductance, laboratory (µS/cm) 00095	7	930	380	560	930	640	558	420	380
pH, field (standard units) 00400	3	8.0	7.4	--	--	--	--	--	--
pH, laboratory (standard units) 00403	3	7.8	7.5	--	--	--	--	--	--
Temperature, water (degrees Celsius) 00010	5	14.5	0	--	--	--	--	--	--
Alkalinity, laboratory (mg/L) 90410	3	190	110	--	--	--	--	--	--
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	3	410	246	--	--	--	--	--	--
Calcium, dissolved (mg/L as Ca) 00915	3	63	34	--	--	--	--	--	--
Magnesium, dissolved (mg/L as Mg) 00925	3	27	15	--	--	--	--	--	--
Sodium, dissolved (mg/L as Na) 00930	3	21	13	--	--	--	--	--	--
Potassium, dissolved (mg/L as K) 00935	3	11	8.4	--	--	--	--	--	--
Sulfate, dissolved (mg/L as SO_4) 00945	3	120	56	--	--	--	--	--	--
Chloride, dissolved (mg/L as Cl) 00940	3	11	2.8	--	--	--	--	--	--
Fluoride, dissolved (mg/L as F) 00950	3	0.1	0.1	--	--	--	--	--	--
Silica, dissolved (mg/L as SiO_2) 00955	3	32	20	--	--	--	--	--	--
Arsenic, dissolved (µg/L as As) 01000	3	5	5	--	--	--	--	--	--
Boron, dissolved (µg/L as B) 01020	3	150	100	--	--	--	--	--	--

Supplement 6. Summary of water-quality data for Calio Coulee near Starkweather, North Dakota (05056247), 1986 through 1988—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Lithium, dissolved (µg/L as Li) 01130	3	20	10	--	--	--	--	--	--
Manganese, dissolved (µg/L as Mn) 01056	3	20	0	--	--	--	--	--	--
Molybdenum, dissolved (µg/L as Mo) 01060	3	3	0	--	--	--	--	--	--
Selenium, dissolved (µg/L as Se) 01145	3	2	1	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	3	230	150	--	--	--	--	--	--

Supplement 7. Summary of water-quality data for Mauvais Coulee near Cando, North Dakota (05056100), 1971 through 1992

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge (cubic feet per second) 00060	20	102	0.03	11	99	8.1	1.4	0.13	0.03
Discharge, instantaneous (cubic feet per second) 00061	148	2,090	0.01	116	638	53	1.30	0.09	0.01
Specific conductance, field (μS/cm) 00094	23	1,660	346	838	1,620	1,160	774	502	349
Specific conductance, laboratory (μS/cm) 00095	161	2,900	240	993	2,150	1,280	920	545	375
pH, field (standard units) 00400	49	8.7	6.8	7.9	8.6	8.1	7.8	7.6	7.2
pH, laboratory (standard units) 00403	23	8.5	6.2	7.7	8.5	8.3	7.8	7.4	6.3
Temperature, water (degrees Celsius) 00010	165	27.5	0	10.5	24.7	18.0	10.0	1.8	0
Dissolved oxygen (mg/L) 00300	18	12.7	5.6	9.0	12.7	10.0	8.9	8.1	5.6
Dissolved oxygen, percent saturation 00301	17	118	40	85	118	100	83	70	40
Carbon dioxide, dissolved (mg/L as CO_2) 00405	23	16	0.8	5.8	15	8.0	5.1	2.3	0.8
Alkalinity, field (mg/L as $CaCO_3$) 00410	23	400	55	220	390	300	210	130	62
Alkalinity, laboratory (mg/L) 90410	30	390	74	210	370	270	200	130	78
Solids, suspended, residue on evaporation at 105 degrees Celsius (mg/L) 00530	6	13	2	5	13	7	4	2	2
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	52	1,350	196	618	1,240	854	576	328	227
Calcium, dissolved (mg/L as Ca) 00915	52	170	26	75	140	92	74	45	32
Magnesium, dissolved (mg/L as Mg) 00925	52	100	8.5	45	95	65	41	23	14
Sodium, dissolved (mg/L as Na) 00930	52	120	10	48	100	71	39	19	12

Supplement 7. Summary of water-quality data for Mauvais Coulee near Cando, North Dakota (05056100), 1971 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
Water-quality property or constituent and parameter code	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Potassium, dissolved (mg/L as K) 00935	52	22	4.9	11	17	14	10	8.6	6.3
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	23	480	67	260	470	360	260	160	76
Carbonate, unfiltered (mg/L as CO_3) 00445	23	7	0	0	6	0	0	0	0
Sulfate, dissolved (mg/L as SO_4) 00945	52	650	35	240	600	380	210	100	47
Chloride, dissolved (mg/L as Cl) 00940	52	60	3.6	24	54	36	20	12	4.2
Fluoride, dissolved (mg/L as F) 00950	52	0.5	--	*0.2	*0.3	*0.2	*0.1	*0.1	*0.1
Silica, dissolved (mg/L as SiO_2) 00955	52	36	1.7	13	22	18	14	8.2	2.7
Nitrogen, nitrite, total (mg/L as N) 00615	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as N) 00613	17	--	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	2	0.20	0.13	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N) 00618	20	2.5	0.02	0.51	2.5	0.62	0.23	0.23	0.02
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	23	11	0.10	2.2	10	2.3	1.0	1.0	0.18
Nitrogen, nitrite plus nitrate, total (mg/L as N) 00630	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	17	1.7	--	*0.18	*1.7	*0.05	*0.01	*0	*0
Nitrogen, ammonia, total (mg/L as N) 00610	5	0.25	0.02	--	--	--	--	--	--
Nitrogen, ammonia, dissolved (mg/L as N) 00608	17	0.21	--	*0.06	*0.21	*0.08	*0.04	*0.02	*0.01
Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) 00625	9	1.5	0.90	1.2	1.5	1.4	1.2	1.0	0.90
Phosphorus, total (mg/L as P) 00665	9	0.44	0.06	0.26	0.44	0.42	0.24	0.15	0.06

Supplement 7. Summary of water-quality data for Mauvais Coulee near Cando, North Dakota (05056100), 1971 through 1992—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Phosphate, total (mg/L as PO_4) 00650	5	1.1	0.21	--	--	--	--	--	--
Orthophosphate, total (mg/L as P) 70507	5	0.37	0.07	--	--	--	--	--	--
Orthophosphate, dissolved (mg/L as P) 00671	11	0.39	0.01	0.18	0.39	0.29	0.15	0.06	0.01
Orthophosphate, dissolved (mg/L as PO_4) 00660	22	1.4	0.02	0.60	1.4	0.89	0.60	0.29	0.04
Phosphorus, hydrolyzable plus orthophosphate, dissolved (mg/L as P) 00677	12	0.36	0.04	0.16	0.36	0.27	0.10	0.08	0.04
Arsenic, dissolved (μg/L as As) 01000	28	8	1	3	8	4	2	2	1
Boron, dissolved (μg/L as B) 01020	52	480	--	100	*350	*140	*70	*30	*10
Lithium, dissolved (μg/L as Li) 01130	28	120	10	50	120	70	30	20	10
Manganese, dissolved (μg/L as Mn) 01056	52	1,400	--	*180	*1,200	*170	*80	*30	*5
Molybdenum, dissolved (μg/L as Mo) 01060	28	5	--	*1	*4	*2	*1	*1	*0
Selenium, dissolved (μg/L as Se) 01145	28	4	--	*1	*4	*1	*1	*0	*0
Strontium, dissolved (μg/L as Sr) 01080	27	790	90	330	730	430	270	220	100

Supplement 8. Summary of water-quality data for Mauvais Coulee Tributary No. 3 near Cando, North Dakota (05056060), 1986 through 1992

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	19	640	0.02	93	640	90	5.5	1.3	0.02
Specific conductance, laboratory (µS/cm) 00095	18	1,200	268	500	1,200	581	398	318	268
pH, field (standard units) 00400	8	7.9	6.9	7.5	7.9	7.8	7.5	7.2	6.9
pH, laboratory (standard units) 00403	7	7.9	6.6	7.3	7.9	7.6	7.4	7.1	6.6
Temperature, water (degrees Celsius) 00010	20	26.5	0	10.8	26.4	18.0	10.8	3.0	0
Dissolved oxygen (mg/L) 00300	1	12.8	--	--	--	--	--	--	--
Dissolved oxygen, percent saturation 00301	1	89	--	--	--	--	--	--	--
Alkalinity, laboratory (mg/L) 90410	8	250	66	150	250	200	140	100	66
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	8	780	170	330	780	400	260	190	170
Calcium, dissolved (mg/L as Ca) 00915	8	110	26	51	110	68	40	31	26
Magnesium, dissolved (mg/L as Mg) 00925	8	52	11	20	52	25	14	13	11
Sodium, dissolved (mg/L as Na) 00930	8	55	7.0	16	55	22	8.2	7.0	7.0
Potassium, dissolved (mg/L as K) 00935	8	17	7.9	12	17	14	12	8.1	7.9
Sulfate, dissolved (mg/L as SO_4) 00945	8	330	33	98	330	140	50	40	33
Chloride, dissolved (mg/L as Cl) 00940	8	29	2.0	10	29	21	5.1	3.5	2.0
Fluoride, dissolved (mg/L as F) 00950	8	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	8	56	6.1	23	56	39	16	12	6.1
Arsenic, dissolved (µg/L as As) 01000	8	7	1	4	7	7	3	2	1

Supplement 8. Summary of water-quality data for Mauvais Coulee Tributary No. 3 near Cando, North Dakota (05056060), 1986 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Boron, dissolved (µg/L as B) 01020	8	150	20	60	150	90	40	30	20
Lithium, dissolved (µg/L as Li) 01130	8	60	10	20	60	30	10	10	10
Manganese, dissolved (µg/L as Mn) 01056	8	610	10	110	610	98	15	10	10
Molybdenum, dissolved (µg/L as Mo) 01060	8	3	--	*1	*3	*2	*1	*0	*0
Selenium, dissolved (µg/L as Se) 01145	8	--	--	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	8	580	130	250	580	280	220	150	130

Supplement 9. Summary of water-quality data for Sweetwater Lake at Sweetwater, North Dakota (05056220), 1960 through 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Specific conductance, laboratory (µS/cm) 00095	69	1,400	530	860	1,200	950	820	740	640
pH, field (standard units) 00400	65	9.5	6.8	8.3	9.3	8.8	8.1	7.8	7.3
pH, laboratory (standard units) 00403	12	8.9	7.9	8.4	8.9	8.7	8.2	8.1	7.9
Temperature, water (degrees Celsius) 00010	59	23.5	0	10.2	23.5	16.0	9.5	4.0	0
Color, platinum-cobalt electrode 00080	51	85	11	32	60	40	30	20	13
Dissolved oxygen (mg/L) 00300	9	15.8	7.6	12.0	15.8	13.2	12.2	11.2	7.6
Dissolved oxygen, percent saturation 00301	9	161	83	109	161	114	104	100	83
Carbon dioxide, dissolved (mg/L as CO_2) 00405	29	21	0.1	3.9	18	5.4	1.5	0.4	0.2
Alkalinity, field (mg/L as $CaCO_3$) 00410	52	400	18	230	340	250	220	190	160
Alkalinity, laboratory (mg/L) 90410	12	290	18	210	290	240	230	200	18
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	64	1,080	365	581	856	630	556	484	415
Calcium, dissolved (mg/L as Ca) 00915	64	80	19	40	59	48	38	32	22
Magnesium, dissolved (mg/L as Mg) 00925	64	71	21	39	58	43	37	33	28
Sodium, dissolved (mg/L as Na) 00930	64	130	35	75	120	86	72	61	42
Potassium, dissolved (mg/L as K) 00935	64	43	11	25	34	27	24	21	18
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	49	490	22	260	410	280	250	230	160
Carbonate, unfiltered (mg/L as CO_3) 00445	48	54	0	5	41	0	0	0	0
Sulfate, dissolved (mg/L as SO_4) 00945	64	360	80	180	290	210	180	140	98

Supplement 9. Summary of water-quality data for Sweetwater Lake at Sweetwater, North Dakota (05056220), 1960 through 1986—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Chloride, dissolved (mg/L as Cl) 00940	64	46	11	26	45	29	25	21	16
Fluoride, dissolved (mg/L as F) 00950	64	0.4	0.1	0.2	0.4	0.2	0.2	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	64	41	3.8	23	40	30	24	16	5.4
Nitrogen, nitrite, dissolved (mg/L as N) 00613	5	0.01	0	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	5	0.03	0	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N) 00618	15	2.2	0.02	0.62	2.2	1.2	0.20	0.05	0.02
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	26	13	0.09	3.9	12	6.5	3.0	0.38	0.10
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	43	1.6	--	*0.09	*0.15	*0.07	*0.04	*0.02	*0.01
Phosphate, total (mg/L as PO_4) 00650	2	0.52	0.24	--	--	--	--	--	--
Phosphorus, dissolved (mg/L as P) 00666	47	0.28	0.01	0.08	0.24	0.10	0.04	0.03	0.01
Orthophosphate, dissolved (mg/L as P) 00671	1	0.02	--	--	--	--	--	--	--
Orthophosphate, dissolved (mg/L as PO_4) 00660	9	0.79	0.05	0.47	0.79	0.77	0.50	0.18	0.05
Aluminum, dissolved (μg/L as Al) 01106	42	300	--	*50	*200	*30	*20	*10	*0
Arsenic, dissolved (μg/L as As) 01000	43	20	0	5	13	7	5	4	0
Barium, dissolved (μg/L as Ba) 01005	43	300	--	100	*200	*100	*100	*100	*0
Boron, dissolved (μg/L as B) 01020	59	240	20	120	200	150	120	90	80
Cadmium, dissolved (μg/L as Cd) 01025	43	3	--	*1	*3	*1	*1	*0	*0
Chromium, dissolved (μg/L as Cr) 01030	43	--	--	--	--	--	--	--	--

Supplement 9. Summary of water-quality data for Sweetwater Lake at Sweetwater, North Dakota (05056220), 1960 through 1986—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Cobalt, dissolved (µg/L as Co) 01035	43	10	--	*0	*0	*0	*0	*0	*0
Copper, dissolved (µg/L as Cu) 01040	44	50	--	*5	*23	*4	*2	*1	*0
Iron, dissolved (µg/L as Fe) 71885	13	240	10	50	240	50	30	20	10
Lithium, dissolved (µg/L as Li) 01130	44	100	30	60	100	60	50	40	40
Manganese, dissolved (µg/L as Mn) 01056	42	1,200	--	*110	*1,100	*30	*11	*5	*0
Molybdenum, dissolved (µg/L as Mo) 01060	43	14	--	*3	*9	*4	*2	*1	*1
Selenium, dissolved (µg/L as Se) 01145	42	20	--	*5	*17	*8	*2	*1	*0
Strontium, dissolved (µg/L as Sr) 01080	44	450	160	250	360	280	230	210	170
Vanadium, dissolved (µg/L as V) 01085	43	7.0	--	*1.0	*4.0	*1.0	*0	*0	*0
Zinc, dissolved (µg/L as Z) 01090	44	330	--	*30	*240	*20	*10	*0	*0
Cyanide, total (mg/L as CN) 00720	15	--	--	--	--	--	--	--	--

Supplement 10. Summary of water-quality data for Lake Alice near Churchs Ferry, North Dakota (05056250), 1960 through 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per lite; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Specific conductance, field (µS/cm) 00094	1	1,190	--	--	--	--	--	--	--
Specific conductance, laboratory (µS/cm) 00095	55	3,600	357	1,040	2,120	1,180	904	721	496
pH, field (standard units) 00400	53	8.8	7.1	7.9	8.6	8.2	7.9	7.7	7.3
pH, laboratory (standard units) 00403	12	7.9	7.5	7.7	7.9	7.8	7.8	7.6	7.5
Temperature, water (degrees Celsius) 00010	47	24.0	0	11.1	23.5	16.5	10.0	5.0	0
Color, platinum-cobalt electrode 00080	45	140	3	55	130	65	47	40	24
Dissolved oxygen (mg/L) 00300	9	14.4	7.0	9.7	14.4	11.8	8.8	7.7	7.0
Dissolved oxygen, percent saturation 00301	9	119	67	88	119	108	83	73	67
Carbon dioxide, dissolved (mg/L as CO_2) 00405	19	42	1.1	6.9	42	8.4	5.1	2.3	1.1
Alkalinity, field (mg/L as $CaCO_3$) 00410	42	1,370	95	280	390	320	270	210	120
Alkalinity, laboratory (mg/L) 90410	12	290	150	220	290	250	220	200	150
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	51	2,800	242	727	1,640	808	608	465	305
Calcium, dissolved (mg/L as Ca) 00915	52	370	41	82	190	88	66	56	46
Magnesium, dissolved (mg/L as Mg) 00925	52	190	13	47	110	54	39	30	17
Sodium, dissolved (mg/L as Na) 00930	52	290	8.8	69	140	84	66	39	19
Potassium, dissolved (mg/L as K) 00935	52	81	8.6	25	46	28	24	18	11
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	37	1,670	32	340	600	380	320	240	140
Carbonate, unfiltered (mg/L as CO_3) 00445	35	9	0	0	3	0	0	0	0

Supplement 10. Summary of water-quality data for Lake Alice near Churchs Ferry, North Dakota (05056250), 1960 through 1986—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per lite; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Sulfate, dissolved (mg/L as SO_4) 00945	52	1,000	55	250	820	280	170	130	81
Chloride, dissolved (mg/L as Cl) 00940	52	110	3.0	32	85	38	26	18	10
Fluoride, dissolved (mg/L as F) 00950	52	0.5	0.1	0.2	0.4	0.3	0.2	0.2	0.1
Silica, dissolved (mg/L as SiO_2) 00955	52	33	0.8	13	27	18	9.2	6.7	1.6
Nitrogen, nitrite, dissolved (mg/L as N) 00613	4	0	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	4	0	--	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N) 00618	13	2.0	0.01	0.53	2.0	0.88	0.30	0.12	0.01
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	22	9.9	0.04	2.3	9.8	3.4	1.2	0.55	0.05
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	34	2.5	--	*0.43	*1.9	*0.70	*0.22	*0.03	*0.01
Phosphate, total (mg/L as PO_4) 00650	2	0.19	0.17	--	--	--	--	--	--
Phosphorus, dissolved (mg/L as P) 00666	38	0.71	--	*0.21	*0.61	*0.26	*0.16	*0.08	*0.01
Orthophosphate, dissolved (mg/L as PO_4) 00660	8	1.8	0.13	0.46	1.8	0.44	0.28	0.19	0.13
Aluminum, dissolved (µg/L as Al) 01106	33	700	--	*100	*600	*80	*30	*10	*0
Arsenic, dissolved (µg/L as As) 01000	33	23	1	7	21	9	6	4	1
Barium, dissolved (µg/L as Ba) 01005	33	100	--	*100	*100	*100	*100	*100	*100
Boron, dissolved (µg/L as B) 01020	48	350	30	130	300	160	110	80	50
Cadmium, dissolved (µg/L as Cd) 01025	33	3	--	*1	*2	*1	*1	*0	*0
Chromium, dissolved (µg/L as Cr) 01030	32	--	--	--	--	--	--	--	--

Supplement 10. Summary of water-quality data for Lake Alice near Churchs Ferry, North Dakota (05056250), 1960 through 1986—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per lite; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Descriptive statistics: Minimum	Descriptive statistics: Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Cobalt, dissolved (µg/L as Co) 01035	33	0	--	*0	*0	*0	*0	*0	*0
Copper, dissolved (µg/L as Cu) 01040	33	60	--	*7	*31	*7	*3	*2	*1
Iron, dissolved (µg/L as Fe) 71885	10	110	20	60	110	100	60	40	20
Lithium, dissolved (µg/L as Li) 01130	33	250	20	70	180	90	70	40	20
Manganese, dissolved (µg/L as Mn) 01056	33	1,700	--	*200	*1,400	*220	*60	*20	*3
Molybdenum, dissolved (µg/L as Mo) 01060	33	24	--	*5	*15	*6	*3	*1	*1
Selenium, dissolved (µg/L as Se) 01145	33	30	--	*3	*20	*1	*0	*0	*0
Strontium, dissolved (µg/L as Sr) 01080	33	1,400	90	350	980	360	310	230	150
Vanadium, dissolved (µg/L as V) 01085	33	9.0	--	*2.0	*8.0	*4.0	*1.0	*1.0	*0
Zinc, dissolved (µg/L as Z) 01090	33	370	--	*30	*170	*20	*10	*10	*0
Cyanide, total (mg/L as CN) 00720	14	--	--	--	--	--	--	--	--

Supplement 11. Summary of water-quality data for Lake Irvine near Churchs Ferry, North Dakota (05056260), 1965 through 1986

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics			Value at which indicated percent of all sample values is less than or equal to that shown				
		Maximum	Minimum	Mean	95	75	50	25	5
Specific conductance, field (μS/cm) 00094	1	1,040	--	--	--	--	--	--	--
Specific conductance, laboratory (μS/cm) 00095	51	1,790	370	917	1,630	1,050	864	715	508
pH, field (standard units) 00400	49	9.0	7.1	8.2	8.9	8.5	8.2	7.8	7.4
pH, laboratory (standard units) 00403	12	8.4	7.5	8.0	8.4	8.2	7.9	7.8	7.5
Temperature, water (degrees Celsius) 00010	49	27.0	0.5	11.0	23.0	17.0	10.0	5.0	0.8
Color, platinum-cobalt electrode 00080	43	700	15	90	300	100	60	40	18
Dissolved oxygen (mg/L) 00300	9	13.7	9.3	11.3	13.7	12.6	11.4	9.8	9.3
Dissolved oxygen, percent saturation 00301	9	112	87	102	112	108	104	97	87
Carbon dioxide, dissolved (mg/L as CO_2) 00405	20	14	0.8	3.9	14	5.6	2.0	1.4	0.8
Alkalinity, field (mg/L as $CaCO_3$) 00410	38	450	94	250	390	290	250	170	130
Alkalinity, laboratory (mg/L) 90410	12	320	150	220	320	250	230	190	150
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	48	1,390	260	616	1,140	722	578	449	344
Calcium, dissolved (mg/L as Ca) 00915	48	110	24	64	110	76	61	48	36
Magnesium, dissolved (mg/L as Mg) 00925	48	98	15	42	79	47	40	31	19
Sodium, dissolved (mg/L as Na) 00930	48	150	18	63	140	79	61	37	25
Potassium, dissolved (mg/L as K) 00935	48	210	9.0	26	41	28	22	16	10
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	33	560	29	290	500	340	290	200	120
Carbonate, unfiltered (mg/L as CO_3) 00445	30	25	0	3	22	4	0	0	0

Supplement 11. Summary of water-quality data for Lake Irvine near Churchs Ferry, North Dakota (05056260), 1965 through 1986—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Sulfate, dissolved (mg/L as SO_4) 00945	48	660	79	210	490	240	190	120	94
Chloride, dissolved (mg/L as Cl) 00940	48	74	8.1	27	63	33	25	17	11
Fluoride, dissolved (mg/L as F) 00950	48	0.4	0.1	0.2	0.4	0.3	0.2	0.2	0.1
Silica, dissolved (mg/L as SiO_2) 00955	48	39	0	16	35	22	15	9.8	1.7
Nitrogen, nitrite, dissolved (mg/L as N) 00613	4	0.01	0	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	4	0.03	0	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N) 00618	13	1.8	0.01	0.54	1.8	1.0	0.20	0.07	0.01
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	17	8.0	0.04	3.1	8.0	5.4	3.1	0.40	0.04
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	34	3.6	--	*0.47	*2.2	*0.67	*0.11	*0.04	*0.01
Phosphate, total (mg/L as PO_4) 00650	2	0.46	0.41	--	--	--	--	--	--
Phosphorus, dissolved (mg/L as P) 00666	39	0.67	0.01	0.20	0.56	0.24	0.17	0.07	0.03
Orthophosphate, dissolved (mg/L as PO_4) 00660	7	1.1	0.21	0.68	1.1	0.95	0.62	0.50	0.21
Aluminum, dissolved (µg/L as Al) 01106	34	500	--	*90	*400	*90	*40	*20	*10
Arsenic, dissolved (µg/L as As) 01000	34	39	0	9	28	13	7	3	0
Barium, dissolved (µg/L as Ba) 01005	34	270	--	*100	*220	*100	*100	*100	*0
Boron, dissolved (µg/L as B) 01020	44	340	40	120	240	150	120	80	40
Cadmium, dissolved (µg/L as Cd) 01025	32	2	--	*1	*2	*1	*1	*0	*0
Chromium, dissolved (µg/L as Cr) 01030	34	--	--	--	--	--	--	--	--

Supplement 11. Summary of water-quality data for Lake Irvine near Churchs Ferry, North Dakota (05056260), 1965 through 1986—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics: Number of samples	Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Cobalt, dissolved (μg/L as Co) 01035	34	0	--	*0	*0	*0	*0	*0	*0
Copper, dissolved (μg/L as Cu) 01040	34	40	--	*7	*31	*8	*6	*3	*1
Iron, dissolved (μg/L as Fe) 71885	6	70	20	40	70	70	40	20	20
Lithium, dissolved (μg/L as Li) 01130	34	130	20	60	120	70	60	40	20
Manganese, dissolved (μg/L as Mn) 01056	34	330	--	*22	*100	*20	*10	*5	*2
Molybdenum, dissolved (μg/L as Mo) 01060	34	30	--	*4	*18	*5	*2	*1	*0
Selenium, dissolved (μg/L as Se) 01145	34	16	--	*3	*14	*2	*1	*0	*0
Strontium, dissolved (μg/L as Sr) 01080	34	480	20	290	480	350	280	230	80
Vanadium, dissolved (μg/L as V) 01085	34	18	0	3.6	14	5.2	2.0	1.0	0
Zinc, dissolved (μg/L as Z) 01090	34	400	--	*30	*200	*20	*10	*10	*0
Cyanide, total (mg/L as CN) 00720	14	--	--	--	--	--	--	--	--

Supplement 12. Summary of water-quality data for Channel A near Penn, North Dakota (05056410), 1984 through 1992

[,µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	84	980	0.01	54	496	24	1.4	0.20	0.01
Specific conductance, field (µS/cm) 00094	19	2,850	573	1,260	2,850	1,500	1,180	905	573
Specific conductance, laboratory (µS/cm) 00095	82	3,590	450	1,400	2,980	1,830	1,190	929	563
pH, field (standard units) 00400	45	10.0	6.6	8.1	9.5	8.4	8.0	7.7	6.7
pH, laboratory (standard units) 00403	24	8.4	6.8	7.7	8.4	8.3	7.8	7.2	6.8
Temperature, water (degrees Celsius) 00010	84	29.5	0	9.6	25.0	16.9	7.2	1.1	0
Dissolved oxygen (mg/L) 00300	33	14.0	3.4	9.5	13.6	10.9	9.3	8.1	5.4
Dissolved oxygen, percent saturation 00301	26	115	40	83	113	94	84	71	44
Alkalinity, laboratory (mg/L) 90410	28	530	110	240	440	310	220	160	110
Solids, suspended, residue on evaporation at 105 degrees Celsius (mg/L) 00530	7	191	--	*37	*191	*28	*14	*1	*0
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	26	2,300	348	923	2,030	1,170	830	644	382
Calcium, dissolved (mg/L as Ca) 00915	26	170	30	82	160	110	72	55	31
Magnesium, dissolved (mg/L as Mg) 00925	26	110	23	50	110	60	47	33	24
Sodium, dissolved (mg/L as Na) 00930	26	360	42	130	310	170	110	76	45
Potassium, dissolved (mg/L as K) 00935	26	50	8.4	20	42	24	20	15	8.5
Sulfate, dissolved (mg/L as SO_4) 00945	28	1,200	92	410	1,100	580	350	180	96
Chloride, dissolved (mg/L as Cl) 00940	28	96	12	31	87	37	27	20	12

Supplement 12. Summary of water-quality data for Channel A near Penn, North Dakota (05056410), 1984 through 1992—Continued

[,µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Fluoride, dissolved (mg/L as F) 00950	26	0.3	0.1	0.2	0.3	0.2	0.1	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	26	30	1.3	14	28	19	14	8.1	1.9
Nitrogen, nitrite, total (mg/L as N) 00615	6	--	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as N) 00613	18	0.06	--	*0.01	*0.06	*0.01	*0	*0	*0
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	5	0.20	0.03	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N) 00618	4	0.79	0.06	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	7	6.9	0.27	2.1	6.9	3.5	1.0	0.62	0.27
Nitrogen, nitrite plus nitrate, total (mg/L as N) 00630	8	--	--	--	--	--	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	21	0.83	--	*0.11	*0.79	*0.12	*0.02	*0.01	*0
Nitrogen, ammonia, total (mg/L as N) 00610	6	0.08	0.02	0.05	0.08	0.06	0.04	0.04	0.02
Nitrogen, ammonia, dissolved (mg/L as N) 00608	21	0.43	0.01	0.11	0.43	0.11	0.07	0.02	0.01
Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) 00625	14	2.5	0.70	1.3	2.5	1.4	1.1	0.98	0.70
Phosphorus, total (mg/L as P) 00665	11	0.26	0.07	0.13	0.26	0.16	0.11	0.08	0.07
Phosphate, total (mg/L as PO_4) 00650	8	2.0	0.09	0.65	2.0	1.5	0.20	0.13	0.09
Phosphorus, dissolved (mg/L as P) 00666	2	0.75	0.62	--	--	--	--	--	--
Orthophosphate, total (mg/L as P) 70507	8	0.66	0.03	0.21	0.66	0.49	0.06	0.04	0.03
Orthophosphate, dissolved (mg/L as P) 00671	8	0.18	--	*0.06	*0.18	*0.07	*0.04	*0.02	*0.01
Orthophosphate, dissolved (mg/L as PO_4) 00660	7	0.55	0.06	0.19	0.55	0.21	0.12	0.06	0.06

Supplement 12. Summary of water-quality data for Channel A near Penn, North Dakota (05056410), 1984 through 1992—Continued

[,µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Phosphorus, hydrolyzable plus orthophosphate, dissolved (mg/L as P) 00677	15	0.49	0.03	0.16	0.49	0.22	0.12	0.05	0.03
Arsenic, dissolved (µg/L as As) 01000	26	16	1	7	15	10	6	4	1
Boron, dissolved (µg/L as B) 01020	26	480	60	180	440	230	170	110	60
Lithium, dissolved (µg/L as Li) 01130	26	210	30	90	190	130	80	50	30
Manganese, dissolved (µg/L as Mn) 01056	26	1,100	10	320	1,000	640	190	20	10
Molybdenum, dissolved (µg/L as Mo) 01060	26	8	--	*3	*8	*5	*3	*2	*1
Selenium, dissolved (µg/L as Se) 01145	26	3	--	*1	*3	*1	*1	*0	*0
Strontium, dissolved (µg/L as Sr) 01080	26	1,100	220	500	1,000	670	440	320	230

Supplement 13. Summary of water-quality data for Big Coulee near Churchs Ferry, North Dakota (05056400), 1957 through 1992

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
Discharge (cubic feet per second) 00060	100	784	0.01	67	361	54	16	2.5	0.10
Discharge, instantaneous (cubic feet per second) 00061	162	1,400	0.01	90	460	77	15	1.7	0.06
Specific conductance, laboratory (µS/cm) 00095	257	2,800	229	996	2,120	1,200	880	660	364
pH, field (standard units) 00400	190	9.5	6.8	7.9	8.8	8.2	7.9	7.6	7.1
pH, laboratory (standard units) 00403	21	10.0	6.8	7.8	9.8	8.0	7.8	7.6	6.8
Temperature, water (degrees Celsius) 00010	241	29.0	0	9.7	24.0	16.2	8.5	1.0	0
Color, platinum-cobalt electrode 00080	112	100	2	43	90	50	40	25	16
Dissolved oxygen (mg/L) 00300	29	12.3	1.8	8.2	12.3	10.2	8.5	6.8	1.9
Dissolved oxygen, percent saturation 00301	21	119	14	67	116	84	76	46	14
Carbon dioxide, dissolved (mg/L as CO_2) 00405	47	100	0.1	8.8	38	9.6	4.1	1.8	0.2
Alkalinity, field (mg/L as $CaCO_3$) 00410	138	810	43	260	480	300	250	180	75
Alkalinity, laboratory (mg/L) 90410	26	360	60	210	360	260	220	160	78
Solids, suspended, residue on evaporation at 105 degrees Celsius (mg/L) 00530	5	99	17	--	--	--	--	--	--
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	169	1,920	154	677	1,570	786	588	440	260
Calcium, dissolved (mg/L as Ca) 00915	169	230	19	72	160	82	63	50	34
Magnesium, dissolved (mg/L as Mg) 00925	169	130	6.1	41	88	48	37	27	12
Sodium, dissolved (mg/L as Na) 00930	169	300	9.4	75	210	96	58	38	16

Supplement 13. Summary of water-quality data for Big Coulee near Churchs Ferry, North Dakota (05056400), 1957 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Potassium, dissolved (mg/L as K) 00935	166	65	5.3	21	37	25	20	15	9.6
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	135	990	52	310	570	370	300	220	92
Carbonate, unfiltered (mg/L as CO_3) 00445	126	44	0	2	18	0	0	0	0
Sulfate, dissolved (mg/L as SO_4) 00945	169	850	36	230	630	270	170	120	60
Chloride, dissolved (mg/L as Cl) 00940	169	120	5.0	31	82	40	24	16	8.3
Fluoride, dissolved (mg/L as F) 00950	166	1.2	0.1	0.2	0.5	0.3	0.2	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	165	66	0	18	38	24	15	10	2.8
Nitrogen, nitrite, total (mg/L as N) 00615	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite, dissolved (mg/L as N) 00613	28	0.12	--	*0.02	*0.10	*0.03	*0.01	*0	*0
Nitrogen, nitrite, dissolved (mg/L as NO_2) 71856	18	0.39	--	*0.09	*0.39	*0.11	*0.05	*0.02	*0
Nitrogen, nitrate, dissolved (mg/L as N) 00618	56	3.6	0.01	0.76	2.1	1.2	0.54	0.16	0.01
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	98	16	0	3.0	11	3.9	1.5	0.60	0.20
Nitrogen, nitrite plus nitrate, total (mg/L as N) 00630	5	--	--	--	--	--	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	76	3.1	--	*0.70	*2.2	*0.98	*0.59	*0.06	*0.01
Nitrogen, ammonia, total (mg/L as N) 00610	5	0.36	0.03	--	--	--	--	--	--
Nitrogen, ammonia, dissolved (mg/L as N) 00608	15	0.34	0.02	0.10	0.34	0.15	0.07	0.03	0.02
Nitrogen, ammonia plus organic nitrogen, total (mg/L as N) 00625	7	1.7	1.0	1.4	1.7	1.6	1.5	1.2	1.0
Phosphorus, total (mg/L as P) 00665	7	0.82	0.40	0.55	0.82	0.71	0.50	0.45	0.40

Supplement 13. Summary of water-quality data for Big Coulee near Churchs Ferry, North Dakota (05056400), 1957 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Phosphate, total (mg/L as PO_4) 00650	10	2.2	0.38	1.2	2.2	1.6	1.2	0.64	0.38
Phosphorus, dissolved (mg/L as P) 00666	78	7.3	0.01	0.46	1.5	0.39	0.24	0.10	0.02
Orthophosphate, total (mg/L as P) 70507	5	0.72	0.37	--	--	--	--	--	--
Orthophosphate, dissolved (mg/L as P) 00671	5	0.76	0.35	--	--	--	--	--	--
Orthophosphate, dissolved (mg/L as PO_4) 00660	12	2.3	0.15	1.1	2.3	1.4	1.2	0.76	0.15
Phosphorus, hydrolyzable plus orthophosphate, dissolved (mg/L as P) 00677	10	0.51	0.04	0.26	0.51	0.43	0.23	0.10	0.04
Aluminum, dissolved (µg/L as Al) 01106	20	400	--	*100	*400	*200	*30	*20	*10
Arsenic, dissolved (µg/L as As) 01000	45	18	--	*7	*16	*10	*6	*4	*1
Barium, dissolved (µg/L as Ba) 01005	20	--	--	--	--	--	--	--	--
Boron, dissolved (µg/L as B) 01020	164	830	0	140	370	170	110	80	30
Cadmium, dissolved (µg/L as Cd) 01025	20	--	--	--	--	--	--	--	--
Chromium, dissolved (µg/L as Cr) 01030	20	--	--	--	--	--	--	--	--
Cobalt, dissolved (µg/L as Co) 01035	20	--	--	--	--	--	--	--	--
Copper, dissolved (µg/L as Cu) 01040	20	40	--	*10	*40	*10	*6	*3	*2
Iron, dissolved (µg/L as Fe) 71885	12	110	10	60	110	80	60	40	10
Lithium, dissolved (µg/L as Li) 01130	45	670	0	60	130	70	50	30	10
Manganese, dissolved (µg/L as Mn) 01056	58	1,600	--	*180	*860	*180	*50	*29	*3
Molybdenum, dissolved (µg/L as Mo) 01060	45	9	--	*3	*7	*4	*2	*1	*1

Supplement 13. Summary of water-quality data for Big Coulee near Churchs Ferry, North Dakota (05056400), 1957 through 1992—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and parameter code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Selenium, dissolved (µg/L as Se) 01145	45	23	--	*2	*17	*1	*1	*0	*0
Strontium, dissolved (µg/L as Sr) 01080	45	560	80	280	450	360	260	210	100
Vanadium, dissolved (µg/L as V) 01085	20	9.0	--	*2.0	*9.0	*3.0	*2.0	*1.0	*0
Zinc, dissolved (µg/L as Z) 01090	20	30	--	*10	*30	*20	*10	*10	*0
Cyanide, total (mg/L as CN) 00720	4	--	--	--	--	--	--	--	--

Supplement 14. Summary of water-quality data for Little Coulee near Brinsmade, North Dakota (05056390), 1976 through 1989

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and computer code	Number of samples	Descriptive statistics: Maximum	Minimum	Mean	Value at which indicated percent of all sample values is less than or equal to that shown: 95	75	50	25	5
Discharge, instantaneous (cubic feet per second) 00061	57	377	0.01	40	331	41	1.7	0.12	0.02
Specific conductance, laboratory (µS/cm) 00095	56	2,920	225	910	1,710	1,120	892	530	270
pH, field (standard units) 00400	24	8.9	7.2	7.9	8.9	8.2	7.9	7.6	7.2
pH, laboratory (standard units) 00403	12	8.4	7.3	7.8	8.4	8.0	7.9	7.6	7.3
Temperature, water (degrees Celsius) 00010	56	25.5	0	8.9	24.0	12.8	6.8	3.0	0
Color, platinum-cobalt electrode 00080	15	70	20	41	70	50	40	30	20
Carbon dioxide, dissolved (mg/L as CO_2) 00405	6	16	1.1	9.1	16	15	7.6	5.6	1.1
Alkalinity, field (mg/L as $CaCO_3$) 00410	13	360	39	190	360	270	170	110	39
Alkalinity, laboratory (mg/L) 90410	12	380	94	250	380	340	240	160	94
Solids, dissolved, residue on evaporation at 180 degrees Celsius (mg/L) 70300	24	2,200	170	730	2,200	880	570	380	180
Calcium, dissolved (mg/L as Ca) 00915	24	310	20	87	310	92	66	41	23
Magnesium, dissolved (mg/L as Mg) 00925	24	110	8.3	39	100	50	33	23	9.5
Sodium, dissolved (mg/L as Na) 00930	24	230	8.7	79	220	88	66	44	9.3
Potassium, dissolved (mg/L as K) 00935	24	43	9.1	21	42	24	20	14	9.6
Bicarbonate, unfiltered (mg/L as HCO_3) 00440	5	440	47	--	--	--	--	--	--
Carbonate, unfiltered (mg/L as CO_3) 00445	4	14	0	--	--	--	--	--	--
Sulfate, dissolved (mg/L as SO_4) 00945	24	1,100	44	280	1,100	300	160	120	45
Chloride, dissolved (mg/L as Cl) 00940	24	150	3.6	38	140	45	32	20	4.3

Supplement 14. Summary of water-quality data for Little Coulee near Brinsmade, North Dakota (05056390), 1976 through 1989—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
Water-quality property or constituent and computer code	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Fluoride, dissolved (mg/L as F) 00950	24	0.3	0.1	0.2	0.3	0.2	0.2	0.1	0.1
Silica, dissolved (mg/L as SiO_2) 00955	24	37	3.0	17	36	22	18	11	3.2
Nitrogen, nitrate, dissolved (mg/L as N) 00618	3	2.9	0.23	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as NO_3) 71851	3	13	1.0	--	--	--	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) 00631	16	3.4	--	*0.68	*3.4	*1.2	*0.23	*0.05	*0.01
Phosphorus, dissolved (mg/L as P) 00666	16	1.0	0.10	0.45	1.0	0.75	0.36	0.24	0.10
Orthophosphate, dissolved (mg/L as PO_4) 00660	1	0.89	--	--	--	--	--	--	--
Aluminum, dissolved (µg/L as Al) 01106	6	--	--	--	--	--	--	--	--
Arsenic, dissolved (µg/L as As) 01000	14	10	--	*5	*10	*6	*4	*2	*1
Barium, dissolved (µg/L as Ba) 01005	6	--	--	--	--	--	--	--	--
Boron, dissolved (µg/L as B) 01020	24	360	40	140	350	160	140	90	40
Cadmium, dissolved (µg/L as Cd) 01025	6	--	--	--	--	--	--	--	--
Chromium, dissolved (µg/L as Cr) 01030	6	--	--	--	--	--	--	--	--
Cobalt, dissolved (µg/L as Co) 01035	6	--	--	--	--	--	--	--	--
Copper, dissolved (µg/L as Cu) 01040	6	--	--	--	--	--	--	--	--
Lithium, dissolved (µg/L as Li) 01130	14	120	10	60	120	80	50	30	10
Manganese, dissolved (µg/L as Mn) 01056	14	2,600	--	*340	*2,600	*280	*90	*18	*2
Molybdenum, dissolved (µg/L as Mo) 01060	13	16	--	*4	*16	*6	*2	*1	*0

Supplement 14. Summary of water-quality data for Little Coulee near Brinsmade, North Dakota (05056390), 1976 through 1989—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not calculated; *, calculated using log-probability regression procedure]

Water-quality property or constituent and computer code	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Number of samples	Maximum	Minimum	Mean	95	75	50	25	5
Selenium, dissolved (µg/L as Se) 01145	14	--	--	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr) 01080	14	3,800	60	510	3,800	380	260	120	60
Vanadium, dissolved (µg/L as V) 01085	5	--	--	--	--	--	--	--	--
Zinc, dissolved (µg/L as Z) 01090	6	--	--	--	--	--	--	--	--
Cyanide, total (mg/L as CN) 00720	6	--	--	--	--	--	--	--	--