METHODS FOR ESTIMATING MONTHLY MEAN CONCENTRATIONS OF SELECTED WATER-QUALITY CONSTITUENTS FOR STREAM SITES IN THE RED RIVER OF THE NORTH BASIN, NORTH DAKOTA AND MINNESOTA

By R. Scott Guenthner

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CONVERSION FACTORS

Multiply	By	To obtain
acre-foot	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
foot per mile	0.1894	meter per kilometer
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
ton per day (short)	0.9072	megagram per day

To convert degrees Fahrenheit (°F) to degrees Celsius (°C), use the following formula: °C = 5/9 x (°F-32).

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ABSTRACT

Future development of the Garrison Diversion Unit may divert water from the Missouri River into the Sheyenne River and the Red River of the North for municipal and industrial use. The U.S. Bureau of Reclamation's Canals, Rivers, and Reservoirs Salinity Accounting Procedures model can be used to predict the effect various operating plans could have on water quality in the Sheyenne River and the Red River of the North. The model uses, as input, monthly means of streamflow and selected water-quality constituents for a 54-year period at 28 nodes on the Sheyenne River and the Red River of the North. This report provides methods for estimating monthly mean concentrations of selected water-quality constituents that can be used for input to and calibration of the salinity model.

Water-quality data for 32 gaging stations can be used to define selected water-quality characteristics at the 28 model nodes. Water-quality data were retrieved from the U.S. Geological Survey's National Water Data Storage and Retrieval System data base and statistical summaries were prepared. The frequency of water-quality data collection at the gaging stations is inadequate to define monthly mean concentrations of the individual water-quality constituents for all months for the 54-year period; therefore, methods for estimating monthly mean concentrations were developed. Relations between selected water-quality constituents [dissolved solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride] and streamflow were developed as the primary method to estimate monthly mean concentrations. Relations between specific conductance and streamflow and relations between selected water-quality constituents [dissolved solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride] and specific conductance were developed so that a cascaded-regression relation could be developed as a second method of estimating monthly mean concentrations and, thus, utilize a large specific-conductance data base.

Information about the quantity and the quality of ground water discharging to the Sheyenne River is needed for model input for reaches of the river where ground water accounts for a substantial part of streamflow during periods of low flow. Ground-water discharge was identified for two reaches of the Sheyenne River. Ground-water discharge to the Sheyenne River in the vicinity of Warwick, N.Dak., was about 14.8 cubic feet per second and the estimated dissolved-solids concentration was about 441 milligrams per liter during October 15 and 16, 1986. Ground-water discharge to the Sheyenne River in a reach between Lisbon and Kindred, N.Dak., ranged from an average of 25.3 cubic feet per second during September 13 to November 19, 1963, to about 45.0 cubic feet per second during October 21 and 22, 1986. Dissolved-solids concentration was estimated at about 442 milligrams per liter during October 21 and 22, 1986.

INTRODUCTION

The Garrison Diversion Unit in North Dakota, as authorized by Congressional Act of August 5, 1965, Public Law 89-108, provides water for: (1) Irrigation of 250,000 acres; (2) municipal, rural, and industrial use; (3) fish and wildlife; (4) recreation; and (5) flood control. The Garrison Diversion Unit Reformulation Act of 1986, Public Law 99-294, specified several modifications and amendments to the 1965 Act. One of the amendments authorized and directed the Secretary of the Interior to construct, operate, and maintain a Sheyenne River water supply and release feature capable of delivering 100 cubic feet per second of water for the cities of Fargo and Grand Forks and the surrounding communities. Water from the Garrison Diversion Unit would be delivered to the upper reaches of the Sheyenne River, which would convey the water to the Red River of the North (pl. 1, in pocket).

Potential effects of releasing treated Missouri River water to the Sheyenne River on the quality in the Sheyenne River and the Red River of the North need to be evaluated. The U.S. Bureau of Reclamation's Canals, Rivers, and Reservoirs Salinity Accounting Procedures model (Hoovestol and Associates, 1988) can be used to predict water-quality changes in the Sheyenne River and the Red River of the North that could result from the proposed release of treated Missouri River water into the river system. The salinity model uses, as input, monthly means of streamflow and selected water-quality constituents for a 54-year period (1931-84) at 28 nodes on the Sheyenne River and the Red River of the North. The streamflow data base used by the model was developed by Guenthner and others (1990). Water-quality data available in the U.S. Geological Survey's computerized National Water Data Storage and Retrieval System (WATSTORE) were used to generate the water-quality data base used by the model.

Purpose

This report provides methods for estimating monthly mean concentrations of selected water-quality constituents that can be used for input to and calibration of the Canals, Rivers, and Reservoirs Salinity Accounting Procedures model. Specific objectives are to (1) provide statistical summaries of selected water-quality data available in WATSTORE; (2) provide relations for estimating monthly mean concentrations of dissolved solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride; and (3) estimate the quantity of and dissolved-solids concentrations in ground water discharging to the Sheyenne River for reaches of the river where ground water accounts for a substantial part of streamflow during periods of low flow.

Description of Study Area

The Red River of the North basin is part of the Hudson Bay drainage system (pl. 1). Parts of Montana, South Dakota, North Dakota, and Minnesota in the United States, and parts of Saskatchewan and Manitoba in Canada are drained by the Red River of the North. The North Dakota-Minnesota boundary is formed by the Red River of the North.

Drainage area of the Red River of the North at the Emerson, Man., gaging station, which is 0.8 mile downstream from the international boundary, is 40,200 square miles (U.S. Geological Survey, 1988, p. 143). The Red River of the North is formed where the Ottertail and the Bois de Sioux Rivers join at Wahpeton, N.Dak., and Breckenridge, Minn. The river flows northward 394 miles to the United States-Canadian boundary. From the international boundary, the Red River of the North flows north about 155 miles and discharges into Lake Winnipeg. The Red River of the North basin upstream from the international boundary is the only part of the basin included in the study area.

The Red River of the North flows over lacustrine deposits of glacial Lake Agassiz through its entire length in North Dakota. The slope of the river is extremely flat. The river falls only about 200 feet in its 394-mile course from Wahpeton to the international boundary (Miller and Frink, 1984).

Water quality in the river is affected by the lacustrine deposits, by inflow from major tributaries from both North Dakota and Minnesota, and by ground-water discharge. Mean dissolved-solids concentrations ranged from 327 milligrams per liter in 472 water samples collected from May 16, 1949, through September 16, 1986, at the Red River of the North at Fargo, N.Dak., gaging station to 430 milligrams per liter in 72 water samples collected from July 9, 1974, through September 23, 1986, near the international boundary at the Red River of the North at Emerson, Man., gaging station.

The Sheyenne River is one of the major tributaries to the Red River of the North. The Sheyenne River has a drainage area of about 6,910 square miles (not including the closed Devils Lake basin). From its headwaters near Harvey, N.Dak., the Sheyenne River, which is about 500 miles long, flows eastward about 150 miles, southward about 200 miles, and then northeastward to its confluence with the Red River of the North, north of Fargo, N.Dak. (Souris-Red-Rainy River Basins Commission, 1972, p. D-50).

The Sheyenne River basin lies in three distinct physiographic areas. The drift prairie area extends from the headwaters to the vicinity of Valley City, N.Dak.; a hilly delta area extends from Valley City, N.Dak., to the vicinity of Kindred, N.Dak.; and the glacial Lake Agassiz area extends from the vicinity of Kindred, N.Dak., to the confluence of the Sheyenne River and the Red River of the North. Most of the Sheyenne River valley from the headwaters to Kindred, N.Dak., is incised into glacial till. The valley from Sheyenne, N.Dak., to Kindred, N.Dak., ranges from 100 to 200 feet in depth and 0.2 to 2 miles in width. The Sheyenne River from Kindred, N.Dak., to the confluence of the Sheyenne River and the Red River of the North flows over lacustrine deposits of glacial Lake Agassiz. Average gradient of the river is 1.5 feet per mile in the drift prairie and hilly delta areas and about 1 foot per mile in the glacial Lake Agassiz area.

No flow has been recorded at times in the upper reaches of the Sheyenne River. Flow in the lower reaches of the river is regulated partly by releases from Baldhill Dam, which began regulating streamflow in 1949.

Lake Ashtabula, formed by Baldhill Dam, has a capacity of 69,100 acre-feet between the invert of the outlet conduit and the normal pool elevation. Lake Ashtabula is operated for flood control (capacity at maximum pool elevation of 1,273.2 feet is 116,500 acre-feet), municipal water supply, recreation, and low-flow augmentation.

Variation in dissolved-solids concentrations is less in water samples collected downstream of Lake Ashtabula than in water samples collected upstream of Lake Ashtabula. Mean dissolved-solids concentrations ranged from 867 milligrams per liter in 100 water samples collected from October 4, 1971, through August 18, 1986, at the Sheyenne River above Harvey, N.Dak., gaging station, upstream of Lake Ashtabula, to 432 milligrams per liter in 90 water samples collected from June 5, 1959, through September 15, 1986, at the Sheyenne River below Baldhill Dam, N.Dak., gaging station.

AVAILABLE WATER-QUALITY DATA

Water-quality data for 32 gaging stations in the Red River of the North basin can be used to define selected water-quality characteristics at the 28 model nodes. Reaches of the Sheyenne River and the Red River of the North that were selected for the salinity model and gaging stations used to define water-quality characteristics at the downstream end of each model reach are listed in table 1. Gaging stations used to define water-quality characteristics of tributary inflow also are listed in table 1.

Gaging stations where water-quality data are needed and periods of available water-quality record for each gaging station are listed in table 2. The location of each gaging station is shown on plate 1. Water-quality data for the gaging stations listed in table 2 were retrieved from WATSTORE. Statistical summaries of selected water-quality data for the gaging stations are given in supplement 1 at the end of this report.

Water-quality data collection at most gaging stations in the basin began after about 1960. Frequency of data collection varies widely among gaging stations in the study area and generally was determined by the original need for the data. The frequency distribution of dissolved-solids and specific-conductance data collection for the Sheyenne River near Cooperstown, N.Dak., gaging station (fig. 1) is typical of the frequency distribution for most of the gaging stations on the main stems of the Sheyenne River and the Red River of the North. The frequency distribution of dissolved-solids and specific-conductance data collection for Baldhill Creek near Dazey, N.Dak., gaging station (fig. 2) is typical of the frequency distribution for most of the gaging stations on tributaries of the Sheyenne River and the Red River of the North. Prior to October 1973, water-quality data were entered in WATSTORE along with concurrent daily mean streamflow data. Since October 1973, water-quality data were entered along with concurrent instantaneous streamflow data. When only two samples were obtained per year, dissolved-solids data generally were collected along with low- and high-flow streamflow measurements. The frequency distribution of hardness (as $CaCO_3$), sodium, sulfate, and chloride data collection generally is about the same as the frequency distribution of dissolved-solids data collection.

Table 1.--Reaches for the Sheyenne River and the Red River of the North salinity model

Model reaches on the Sheyenne River	Gaging station used to define water quality at the downstream end of each model reach
Harvey to Warwick	Sheyenne River near Warwick, N.Dak.
Warwick to Cooperstown	Sheyenne River near Cooperstown, N.Dak.
Cooperstown to Baldhill Dam	Lake Ashtabula at Baldhill Dam, N.Dak., and Sheyenne River below Baldhill Dam, N.Dak.
Baldhill Dam to Valley City	Sheyenne River at Valley City, N.Dak.
Valley City to Lisbon	Sheyenne River at Lisbon, N.Dak.
Lisbon to Kindred	Sheyenne River near Kindred, N.Dak.
Kindred to West Fargo	Sheyenne River at West Fargo, N.Dak.
Tributary inflow to the Sheyenne River	**Gaging station used to define water quality of tributary inflow**
Sheyenne River headwaters	Sheyenne River above Harvey, N.Dak.
Baldhill Creek	Baldhill Creek near Dazey, N.Dak.
Maple River	Maple River near Enderlin, N.Dak.
Rush River	Rush River at Amenia, N.Dak.
Model reaches on the Red River of the North	**Gaging station used to define water quality at the downstream end of each model reach**
Fargo to Halstad	Red River of the North at Halstad, Minn.
Halstad to Grand Forks	Red River of the North at Grand Forks, N.Dak.
Grand Forks to Drayton	Red River of the North at Drayton, N.Dak.
Drayton to Emerson	Red River of the North at Emerson, Man.
Tributary inflow to the Red River of the North	**Gaging station used to define water quality of tributary inflow**
Red River of the North headwaters	Red River of the North at Fargo, N.Dak., or Red River of the North below Fargo, N.Dak.
Buffalo River	Buffalo River near Dilworth, Minn.
Elm River	Elm River near Kelso, N.Dak.
Wild Rice River	Wild Rice River at Hendrum, Minn.
Goose River	Goose River at Hillsboro, N.Dak.
Marsh River	Marsh River near Shelly, Minn.
Sand Hill River	Sand Hill River at Climax, Minn.
Red Lake River	Red Lake River at Crookston, Minn.
Turtle River	Turtle River at Manvel, N.Dak.
Forest River	Forest River at Minto, N.Dak.
Snake River	Snake River at Warren, Minn., and Middle River at Argyle, Minn.
Park River	Park River at Grafton, N.Dak.
Pembina River	Pembina River at Neche, N.Dak., and Tongue River at Akra, N.Dak.

Table 2.--Selected U.S. Geological Survey gaging stations in the Red River of the North basin where water-quality data are needed for the model

Gaging station number	Gaging station name	Period of available water-quality record is for all water-quality data stored in the U.S. Geological Survey's National Water Data Storage and Retrieval System
05054000	Red River of the North at Fargo, N.Dak.	May 16, 1949, through September 16, 1986
05054020	Red River of the North below Fargo, N.Dak.	July 16, 1969, through September 16, 1986
05054500	Sheyenne River above Harvey, N.Dak.	October 4, 1971, through August 18, 1986
05056000	Sheyenne River near Warwick, N.Dak.	January 8, 1951, through July 8, 1986
05057000	Sheyenne River near Cooperstown, N.Dak.	October 10, 1959, through August 7, 1986
05057200	Baldhill Creek near Dazey, N.Dak.	October 5, 1971, through June 25, 1986
05057500	Lake Ashtabula at Baldhill Dam, N.Dak.	February 19, 1960, through April 8, 1971
05058000	Sheyenne River below Baldhill Dam, N.Dak.	June 5, 1959, through September 15, 1986
05058500	Sheyenne River at Valley City, N.Dak.	November 3, 1971, through March 22, 1985
05058700	Sheyenne River at Lisbon, N.Dak.	August 2, 1956, through September 10, 1986
05059000	Sheyenne River near Kindred, N.Dak.	September 15, 1969, through September 17, 1986
05059500	Sheyenne River at West Fargo, N.Dak.	September 16, 1969, through September 5, 1986
05059700	Maple River near Enderlin, N.Dak.	October 6, 1971, through September 16, 1986
05060500	Rush River at Amenia, N.Dak.	November 3, 1971, through September 16, 1986
05062000	Buffalo River near Dilworth, Minn.	April 10, 1962, through April 1, 1978
05062200	Elm River near Kelso, N.Dak.	February 19, 1981, through August 1, 1986
05064000	Wild Rice River at Hendrum, Minn.	October 1, 1962, through April 8, 1980
05064500	Red River of the North at Halstad, Minn.	July 8, 1961, through July 2, 1986
05066500	Goose River at Hillsboro, N.Dak.	September 15, 1969, through August 4, 1986
05067500	Marsh River near Shelly, Minn.	July 4, 1975, through April 21, 1979
05069000	Sand Hill River at Climax, Minn.	November 1, 1966, through April 22, 1979
05079000	Red Lake River at Crookston, Minn.	April 11, 1962, through August 12, 1986
05082500	Red River of the North at Grand Forks, N.Dak.	June 22, 1949, through September 26, 1986
05083000	Turtle River at Manvel, N.Dak.	October 15, 1971, through March 28, 1986
05085000	Forest River at Minto, N.Dak.	October 6, 1971, through September 2, 1986
05085500	Snake River at Warren, Minn.	September 16, 1953, through July 29, 1955
05087500	Middle River at Argyle, Minn.	April 10, 1954, through August 23, 1955
05090000	Park River at Grafton, N.Dak.	September 22, 1969, through September 2, 1986
05092000	Red River of the North at Drayton, N.Dak.	October 12, 1971, through August 28, 1986
05100000	Pembina River at Neche, N.Dak.	October 13, 1971, through August 21, 1986
05101000	Tongue River at Akra, N.Dak.	October 14, 1971, through September 30, 1986
05102500	Red River of the North at Emerson, Man.	September 15, 1969, through September 23, 1986

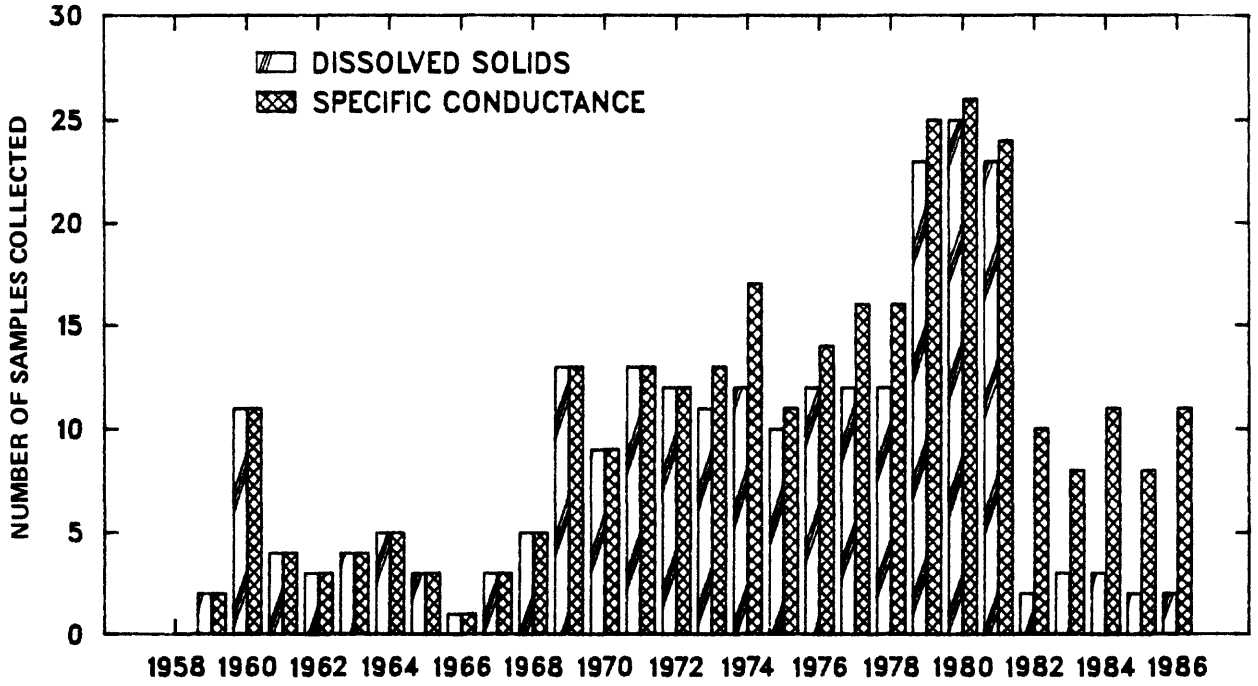


Figure 1.--Frequency distribution of dissolved-solids and specific-conductance data collection for the Sheyenne River near Cooperstown, North Dakota, gaging station, October 10, 1959, through August 7, 1986.

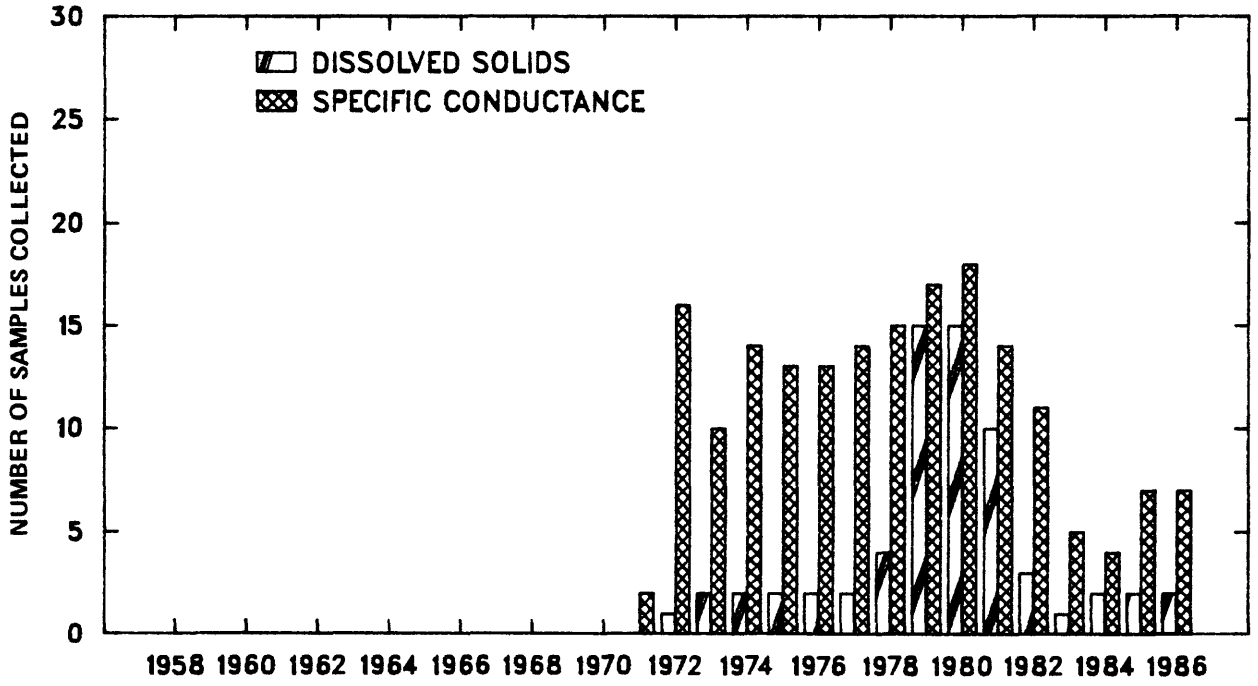


Figure 2.--Frequency distribution of dissolved-solids and specific-conductance data collection for the Baldhill Creek near Dazey, North Dakota, gaging station, October 5, 1971, through June 25, 1986.

A general knowledge of water quality in streams in the Red River of the North basin is necessary for calibration of the model and for predicting changes in water quality that could result from operation of the Garrison Diversion Unit. A statistical comparison of dissolved-solids concentrations (residue on evaporation at 180 °C) in streamflow for main-stem gaging stations on the Sheyenne River and the Red River of the North is shown in figure 3. Median and mean dissolved-solids concentrations in streamflow for all Sheyenne River and Red River of the North gaging stations are about equal.

METHODS FOR ESTIMATING MONTHLY MEAN CONCENTRATIONS OF SELECTED WATER-QUALITY CONSTITUENTS

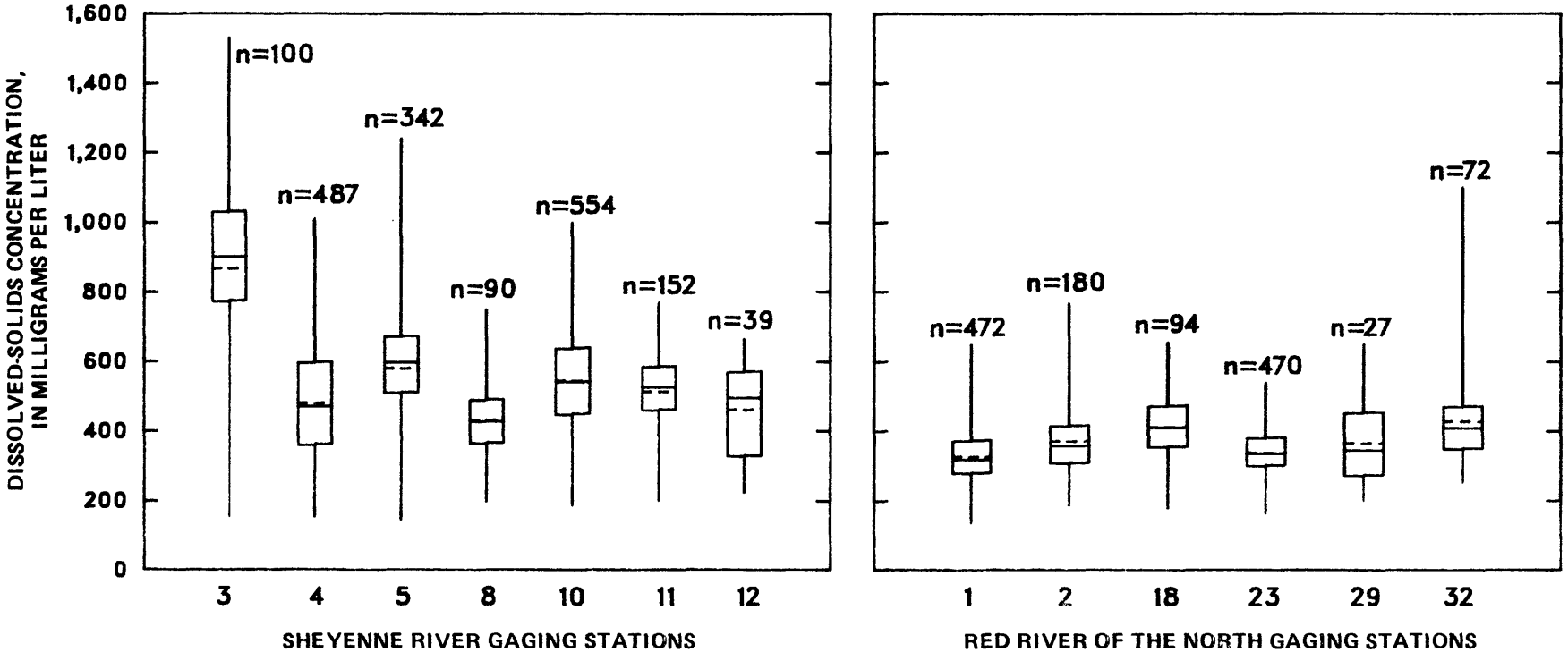
The frequency of water-quality data collection at the gaging stations listed in table 2 is inadequate to define monthly mean concentrations of the individual water-quality constituents for all months for 1931-84. Therefore, methods for estimating monthly mean dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride concentrations were developed. The primary, and preferable, method for obtaining an estimate of individual water-quality constituent concentrations is to use a direct relation between the individual water-quality constituent and streamflow. The second method for obtaining an estimate of individual water-quality constituent concentrations is to develop a relation between specific conductance and streamflow, then develop a relation between the individual water-quality constituent and specific conductance, and simultaneously solve the relations. Although the direct relation usually is the preferable method, the second method could be used instead of the direct relation when the direct relation is based on a small number of data pairs. In some cases, the direct relation based on a small number of data pairs may be biased because of errors introduced from random sampling. For those cases where neither of these methods can be used, alternative methods are proposed.

The Canals, Rivers, and Reservoirs Salinity Accounting Procedures model can accept input as a file of monthly mean concentrations or as parameter values that define the relation between the water-quality constituent and streamflow. The model can use the parameter values and streamflow to compute monthly mean concentrations. The only parameter values accepted by the model are from log-linear and log-log equations. Although other equations may provide a better estimate of the water-quality constituent at some gaging stations, because of the model limitations, only the log-linear and the log-log equations were examined.

For Lake Ashtabula at Baldhill Dam, N.Dak., the model only uses a set of initial conditions for the selected water-quality constituents. The mean values used for these initial conditions are listed in supplement 1.

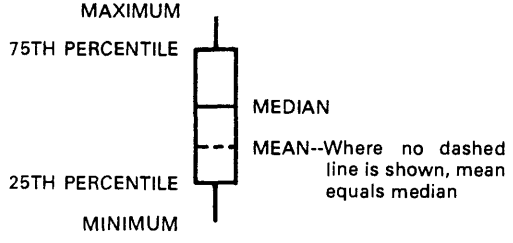
Estimating Monthly Mean Dissolved-Solids, Hardness (as $CaCO_3$), Sodium, Sulfate, and Chloride Concentrations from Streamflow

Monthly mean dissolved-solids concentrations can be estimated by using the relation between dissolved-solids concentration and instantaneous



EXPLANATION

n= IS NUMBER OF SAMPLES USED IN ANALYSIS



SITE NUMBER	GAGING STATION NAME	GAGING STATION NUMBER
3.	SHEYENNE RIVER ABOVE HARVEY, N.DAK.	05054500
4.	SHEYENNE RIVER NEAR WARWICK, N.DAK.	05056000
5.	SHEYENNE RIVER NEAR COOPERSTOWN, N.DAK.	05057000
8.	SHEYENNE RIVER BELOW BALDHILL DAM, N.DAK	05058000
10.	SHEYENNE RIVER AT LISBON, N.DAK.	05058700
11.	SHEYENNE RIVER NEAR KINDRED, N.DAK	05059000
12.	SHEYENNE RIVER AT WEST FARGO, N.DAK.	05059500
1.	RED RIVER OF THE NORTH AT FARGO, N.DAK.	05054000
2.	RED RIVER OF THE NORTH BELOW FARGO, N.DAK.	05054020
18.	RED RIVER OF THE NORTH AT HALSTAD, MINN.	05064500
23.	RED RIVER OF THE NORTH AT GRAND FORKS, N.DAK.	05082500
29.	RED RIVER OF THE NORTH AT DRAYTON, N.DAK.	05092000
32.	RED RIVER OF THE NORTH AT EMERSON, MAN.	05102500

Figure 3.--Dissolved-solids concentrations in streamflow for selected gaging stations on the Sheyenne River and the Red River of the North.

streamflow. The assumption was made that monthly mean dissolved-solids concentrations can be estimated by substituting monthly mean streamflow for instantaneous streamflow in the relation between dissolved-solids concentration and instantaneous streamflow. Two forms of regression equations were examined in developing the relation between dissolved-solids concentration and instantaneous streamflow. Both equations use the natural logarithm:

$$DS = a + b\ lnQ, \tag{1}$$

and

$$lnDS = a + b\ lnQ, \tag{2}$$

where

DS = dissolved-solids concentration, in milligrams per liter;
a and b = coefficients of the regression; and
Q = instantaneous streamflow, in cubic feet per second.

Equation (2) can be rewritten as follows:

$$DS = e^{a}Q^{b}, \tag{3}$$

where

e = the base of the natural logarithm.

Dissolved-solids concentration data and concurrent instantaneous streamflow data were retrieved from WATSTORE for the gaging stations listed in table 2, except for the Marsh River near Shelly, Minn., gaging station because no dissolved-solids data are available for this station. Dissolved-solids concentrations commonly are determined by two independent analytical procedures: (1) By summing the concentrations of major constituents from chemical analysis of samples, and (2) by residue on evaporation at 180 °C. Dissolved-solids data used in this report were determined by the residue on evaporation at 180 °C procedure unless otherwise specified.

Log-linear and log-log plots of the data pairs were made for each gaging station to identify outliers and to indicate if equation 1 or equation 2 would be appropriate for the data. Some of the data that appeared to represent outliers in both the log-linear plot and the log-log plot were not considered in the final analysis. The criteria for removing suspected outliers from the data were to develop a regression equation for the data that included the suspected outlier, then develop a second regression equation for the data that did not include the suspected outlier. If the regression equation for the data that included the suspected outlier was substantially different from the regression equation that did not include the suspected outlier, then the regression equation for the data that did not include the suspected outlier was used in the final relation. Outliers were not removed from the WATSTORE data base nor from the statistical summaries in supplement 1. Linear regression equations in the form of equations 1 and 2 were developed. An example of the data and the resulting regression lines for the Sheyenne River above Harvey, N.Dak., gaging station is shown in figures 4 and 5. Similar plots were made for each gaging station.

Relations between dissolved-solids concentration and instantaneous streamflow for both equations for the Sheyenne River above Harvey, N.Dak., gaging station are listed in table 3 along with the coefficient of

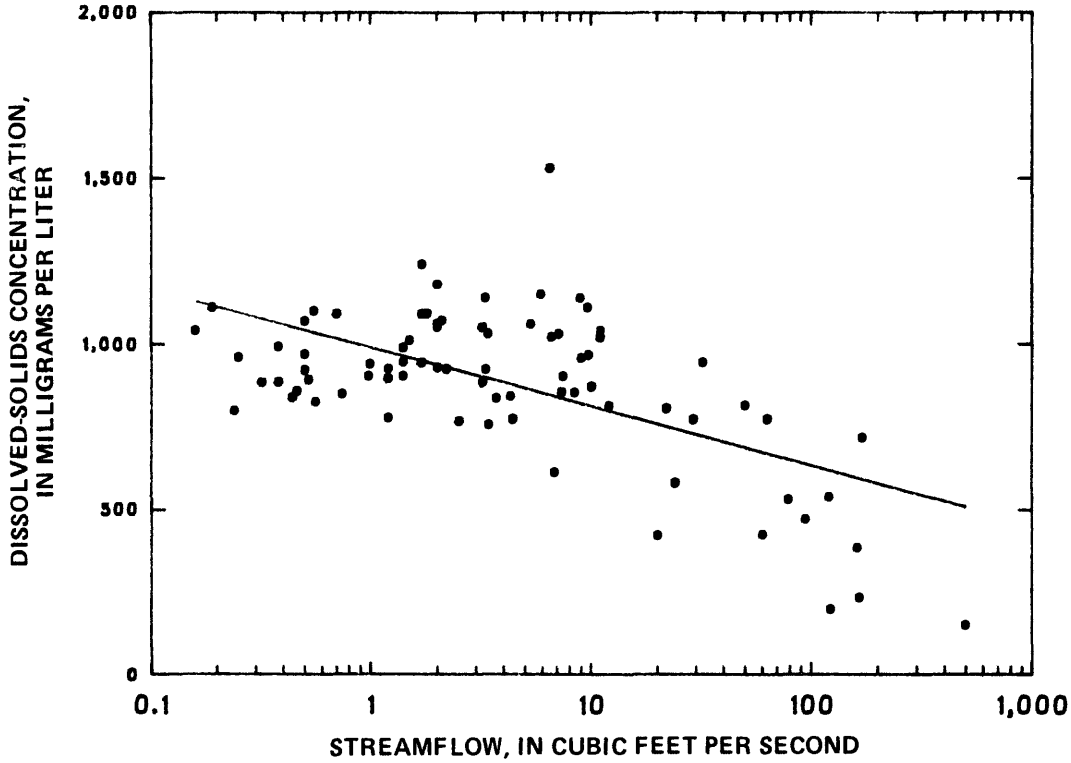


Figure 4.--Log-linear relation between dissolved-solids concentration and instantaneous streamflow for the Sheyenne River above Harvey, North Dakota, gaging station.

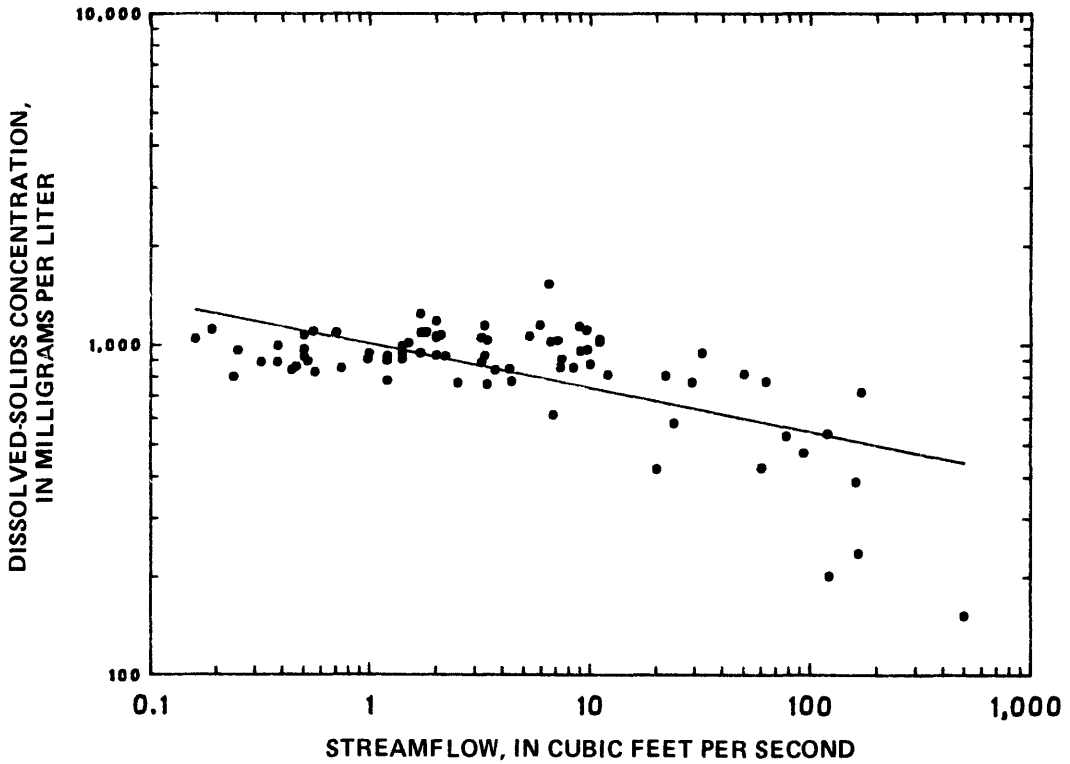


Figure 5.--Log-log relation between dissolved-solids concentration and instantaneous streamflow for the Sheyenne River above Harvey, North Dakota, gaging station.

Table 3.--Relations between dissolved-solids concentration and instantaneous steamflow for the Sheyenne River above Harvey, North Dakota, gaging station

[*DS*, dissolved-solids concentration, in milligrams per liter; *Q*, streamflow, in cubic feet per second; --, indicates no value]

	Equation	Coefficient of determination, R^2	Standard error of estimate (milligrams per liter)	Standard error of estimate (percent)
(1)	$DS = 987 - 77.2 \ln Q$	0.36	189	--
(2)	$\ln DS = 6.91 - 0.133 \ln Q$	.41	--	30

determination (R^2) and the standard error of estimate. The coefficient of determination is the percentage of the total variation in the dissolved-solids data that is explained by the regression equation. The standard error of estimate is a measure of the goodness of fit for a regression line. About two-thirds of the dissolved-solids data should fall between +1 and -1 standard error of estimate from the regression line.

The decision to use equation 1 or equation 2 was based partly on examination of residual plots, which show the difference between measured concentrations and predicted concentrations. Residual plots were examined to determine if the regression resulted in equal variance of the residuals for the full range of predicted values. When only one equation resulted in equal variance of the residuals, then that equation was selected as the better relation. Residual plots for the two equations for the Sheyenne River above Harvey, N.Dak., gaging station are shown in figures 6 and 7. The variance of residual data is very similar for the two equations. The log-linear equation (eq. 1) is not noticeably better or worse than the log-log equation (eq. 2).

When no clear choice between the two equations could be made on the basis of residual plots, the equation that had the smallest difference between the +1 and -1 standard error of estimate for predicted dissolved-solids concentration evaluated at the mean annual streamflow was selected as the final regression equation. Dissolved-solids concentrations and associated standard error of estimate predicted from equations 1 and 2 for mean annual streamflow of the Sheyenne River above Harvey, N.Dak., gaging station are shown in table 4. Because the difference between the +1 and -1 standard error of estimate for equation 1 was less than the difference for equation 2, equation 1 was selected as the better relation between dissolved-solids concentration and instantaneous streamflow for the Sheyenne River above Harvey, N.Dak., gaging station. A similiar evaluation

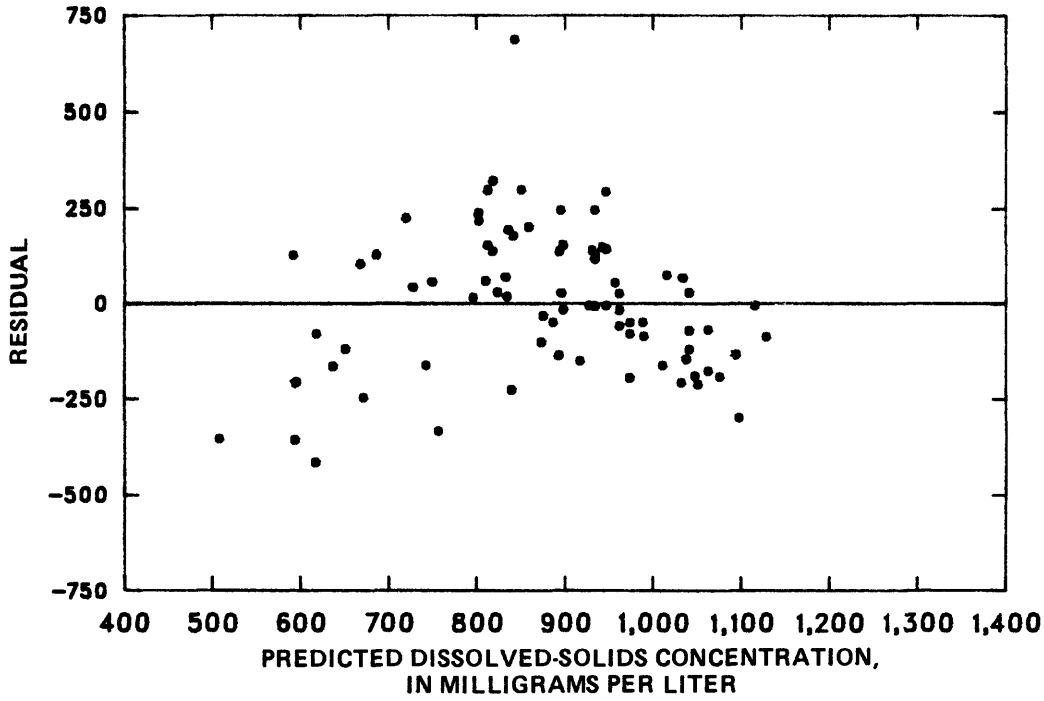


Figure 6.--Residuals and predicted dissolved-solids concentrations for the log-linear relation between dissolved-solids concentration and instantaneous streamflow for the Sheyenne River above Harvey, North Dakota, gaging station.

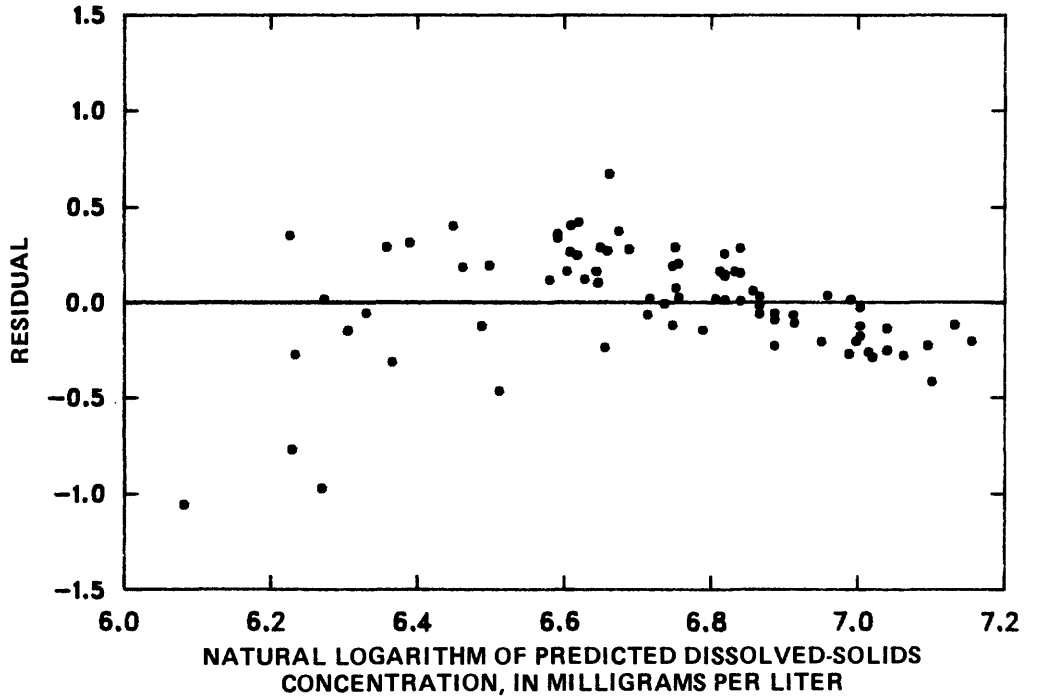


Figure 7.--Residuals and predicted dissolved-solids concentrations for the log-log relation between dissolved-solids concentration and instantaneous streamflow for the Sheyenne River above Harvey, North Dakota, gaging station.

Table 4.--Dissolved-solids concentrations from log-linear and log-log relations for the Sheyenne River above Harvey, North Dakota, gaging station for mean annual streamflow of 8.4 cubic feet per second

[mg/L, milligrams per liter; s_e, standard error of estimate; *DS*, dissolved-solids concentration, in milligrams per liter; *Q*, streamflow, in cubic feet per second]

	Equation	Dissolved-solids concentration (mg/L)			
		Predicted	+1 s_e	-1 s_e	Difference
(1)	$DS = 987 - 77.2 \ln Q$	823	1,012	634	378
(2)	$\ln DS = 6.91 - 0.133 \ln Q$	755	1,013	562	451

process was performed for each gaging station listed in table 2 except for the Marsh River near Shelly, Minn., gaging station where no dissolved-solids data were available and for the Sand Hill River at Climax, Minn., gaging station where only one dissolved-solids value was available. An alternative method for estimating monthly means for these gaging stations is discussed in the "Alternative Methods for Estimating Monthly Mean Dissolved-Solids, Hardness (as $CaCO_3$), Sodium, Sulfate, and Chloride Concentrations" section.

Relations between dissolved-solids concentration (as well as other water-quality constituents) and streamflow were developed for both the Red River of the North at Fargo, N.Dak., and the Red River of the North below Fargo, N.Dak., gaging stations. However, only the relation for the Red River of the North below Fargo, N.Dak., gaging station is given in this report.

Changes in dissolved-solids concentration could not be explained by changes in streamflow for the Sheyenne River below Baldhill Dam, N.Dak., and the Sheyenne River at Valley City, N.Dak., gaging stations. An alternative method for estimating monthly means for these gaging stations is discussed in the "Alternative Methods for Estimating Monthly Mean Dissolved-Solids, Hardness (as $CaCO_3$), Sodium, Sulfate, and Chloride Concentrations" section.

Data for the Sheyenne River near Warwick, N.Dak., gaging station could not be fitted well with a single equation in the form of equation 1 or equation 2. Therefore, 12 monthly equations were developed for the gaging station. Both equations 1 and 2 were developed for each set of monthly values and the better equation was selected.

The selected relations between dissolved-solids concentration and instantaneous streamflow for the gaging stations are listed in table 5. Equation 2 provided the better relation for a majority of the gaging stations. The monthly relations between dissolved-solids concentration and streamflow for the Sheyenne River near Warwick, N.Dak., gaging station are listed in table 6.

A small data set of paired dissolved-solids concentration and instantaneous streamflow values was available for some gaging stations, but a significantly larger data set of paired dissolved-solids concentration and daily mean streamflow values also was available. The larger dissolved-solids concentration and daily mean streamflow data set was used to develop the relations for some gaging stations. Equations developed by using daily mean streamflow are identified in tables 5 and 6.

The procedure discussed for dissolved solids also was used to select the relations for hardness (as $CaCO_3$), sodium, sulfate, and chloride. The relations between concentrations of these constituents and streamflow were developed using data sets that included instantaneous streamflow and daily mean streamflow when instantaneous streamflow was not available. Relations between hardness (as $CaCO_3$), sodium, sulfate, and chloride and streamflow are summarized in tables 7 through 10.

Estimating Monthly Mean Dissolved-Solids, Hardness (as $CaCO_3$), Sodium, Sulfate, and Chloride Concentrations from Specific Conductance and Streamflow

The second method uses the large specific-conductance data base to estimate concentrations of selected water-quality constituents. Specific-conductance data generally are collected more frequently than are dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride data.

Individual water-quality constituent concentrations could be estimated by first solving the equation that represents the relation between specific conductance and streamflow, for a known value of streamflow, and then solving the equation that represents the relation between the individual water-quality constituent and specific conductance for the previously estimated value of specific conductance. Karlinger and Troutman (1985) refer to simultaneous solution of two regression equations as "cascading regressions."

The first relation necessary to develop a cascaded-regression model is the relation between specific conductance and streamflow. Log-linear (similar to equation 1) and log-log (similar to equation 2) equations were examined for estimating specific conductance from streamflow. Specific conductance was related to instantaneous streamflow or daily mean streamflow when instantaneous streamflow was not available. The equation form selected was based partly on examination of residual plots. When no clear choice between the two equations could be made on the basis of residual plots, the equation that had the smallest difference between the +1 and -1 standard error of estimate in predicted specific conductance evaluated at mean annual streamflow was selected as the final relation. The selected relations between specific conductance and streamflow are listed in table 11.

Table 5.--Relations between dissolved-solids concentration and streamflow for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; DS, dissolved-solids concentration, in milligrams per liter; Q, streamflow, in cubic feet per second; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	[1] $DS = 605\ Q^{-0.093}$	107	0.27	--	23
05054500	Sheyenne River above Harvey, N.Dak.	[1] $DS = 987 - 77.2\ \ln Q$	79	.36	189	--
05056000	Sheyenne River near Warwick, N.Dak.	(2)	--	--	--	--
05057000	Sheyenne River near Cooperstown, N.Dak.	[1] $DS = 730 - 43.8\ \ln Q$	141	.30	126	--
05057200	Baldhill Creek near Dazey, N.Dak.	[1] $DS = 597\ Q^{-0.175}$	58	.74	--	29
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(2)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(2)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	[1] $DS = 1{,}010\ Q^{-0.151}$	118	.58	--	17
05059000	Sheyenne River near Kindred, N.Dak.	[1] $DS = 841 - 69.2\ \ln Q$	128	.55	77	--
05059500	Sheyenne River at West Fargo, N.Dak.	[1] $DS = 753 - 62.6\ \ln Q$	21	.71	64	--
05059700	Maple River near Enderlin, N.Dak.	[1] $DS = 1{,}510\ Q^{-0.247}$	42	.86	--	21
05060500	Rush River at Amenia, N.Dak.	[1] $DS = 997\ Q^{-0.206}$	19	.73	--	40
05062000	Buffalo River near Dilworth, Minn.	[3] $DS = 915\ Q^{-0.165}$	7	.61	--	22
05062200	Elm River near Kelso, N.Dak.	[1] $DS = 425\ Q^{-0.081}$	6	.21	--	56
05064000	Wild Rice River at Hendrum, Minn.	[3] $DS = 737\ Q^{-0.163}$	5	.89	--	10
05064500	Red River of the North at Halstad, Minn.	[1] $DS = 904\ Q^{-0.116}$	73	.31	--	20
05066500	Goose River at Hillsboro, N.Dak.	[1] $DS = 1{,}280\ Q^{-0.152}$	36	.51	--	41
05067500	Marsh River near Shelly, Minn.	(4)	--	--	--	--

Table 5.--Relations between dissolved-solids concentration and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05069000	Sand Hill River at Climax, Minn.	(4)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	[1]$DS = 402\ Q^{-0.070}$	86	0.10	--	17
05082500	Red River of the North at Grand Forks, N.Dak.					
	January-December	[3]$DS = 506\ Q^{-0.052}$	437	.11	--	17
	April-June	[3]$DS = 914\ Q^{-0.112}$	156	.32	--	16
	January-March, July-December	[3]$DS = 612\ Q^{-0.084}$	281	.19	--	15
05083000	Turtle River at Manvel, N.Dak.	[1]$DS = 4{,}030\ Q^{-0.276}$	19	.59	--	38
05085000	Forest River at Minto, N.Dak.	[1]$DS = 673\ Q^{-0.121}$	49	.49	--	24
05085500	Snake River at Warren, Minn.	[3]$DS = 606\ Q^{-0.120}$	15	.42	--	25
05087500	Middle River at Argyle, Minn.	[3]$DS = 411 - 16.6\ \ln Q$	21	.10	84	--
05090000	Park River at Grafton, N.Dak.	[1]$DS = 732\ Q^{-0.109}$	32	.69	--	24
05092000	Red River of the North at Drayton, N.Dak.	[1]$DS = 1{,}150\ Q^{-0.141}$	22	.55	--	22
05100000	Pembina River at Neche, N.Dak.	[1]$DS = 743 - 57.3\ \ln Q$	23	.53	106	--
05101000	Tongue River at Akra, N.Dak.	[1]$DS = 376\ Q^{-0.040}$	45	.14	--	19
05102500	Red River of the North at Emerson, Man.	[1]$DS = 1{,}460\ Q^{-0.168}$	61	.48	--	20

[1]Q is instantaneous streamflow.
[2]Changes in water-quality characteristic could not be explained by changes in streamflow for the relations considered.
[3]Q is daily mean streamflow.
[4]Not enough data to develop a relation.

Table 6.--Monthly relations between dissolved-solids concentration and streamflow for the Sheyenne River near Warwick, North Dakota, gaging station

[mg/L, milligrams per liter; DS, dissolved-solids concentration, in milligrams per liter; Q, streamflow, in cubic feet per second; --, indicates no value]

Month	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
January	[1]$DS = 345 + 127 \ln Q$	24	0.40	106	--
February	[2]$DS = 608 - 61.4 \ln Q$	7	.57	95	--
March	[2]$DS = 591 - 49.0 \ln Q$	7	.64	64	--
April	[1]$DS = 739\ Q^{-0.170}$	54	.54	--	21
May	[2,3]$DS = 724 - 50.8 \ln Q$	5	.36	94	--
June	[2,3]$DS = 449 + 73.3 \ln Q$	6	.49	92	--
July	[1]$DS = 435 + 32.1 \ln Q$	35	.12	136	--
August	[1]$DS = 404 + 65.0 \ln Q$	28	.38	112	--
September	[1]$DS = 346 + 65.8 \ln Q$	23	.36	108	--
October	[2]$DS = 295 + 82.9 \ln Q$	8	.53	75	--
November	[2]$DS = 183 + 153 \ln Q$	6	.54	91	--
December	[1]$DS = 246 + 183 \ln Q$	24	.37	131	--

[1]Q is daily mean streamflow.
[2]Q is instantaneous streamflow.
[3]Relation is not significant at the 95 percent level.

Table 7.--Relations between hardness (as $CaCO_3$) concentration and streamflow for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; H, hardness as ($CaCO_3$) concentration, in milligrams per liter; Q, streamflow, in cubic feet per second; --, indicates no value; ft^3/s, cubic feet per second]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	$H = 340\ Q^{-0.048}$	171	0.12	--	17
05054500	Sheyenne River above Harvey, N.Dak.	$H = 183 - 9.56\ \ln Q$	93	.03	77	--
05056000	Sheyenne River near Warwick, N.Dak.					
	Q greater than or equal to 20 ft^3/s	$H = 609\ Q^{-0.243}$	217	.48	--	29
	Q less than 20 ft^3/s	$H = 233\ Q^{0.069}$	274	.08	--	21
05057000	Sheyenne River near Cooperstown, N.Dak.	$H = 446\ Q^{-0.130}$	326	.43	--	28
05057200	Baldhill Creek near Dazey, N.Dak.	$H = 348\ Q^{-0.164}$	62	.65	--	33
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(1)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(1)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	$H = 431\ Q^{-0.112}$	568	.41	--	19
05059000	Sheyenne River near Kindred, N.Dak.	$H = 602\ Q^{-0.157}$	149	.57	--	16
05059500	Sheyenne River at West Fargo, N.Dak.	$H = 720\ Q^{-0.202}$	39	.77	--	16
05059700	Maple River near Enderlin, N.Dak.	$H = 958\ Q^{-0.268}$	57	.76	--	29
05060500	Rush River at Amenia, N.Dak.	$H = 590\ Q^{-0.209}$	23	.74	--	37
05062000	Buffalo River near Dilworth, Minn.	$H = 962\ Q^{-0.228}$	10	.79	--	23
05062200	Elm River near Kelso, N.Dak.	$H = 436 - 48.4\ \ln Q$	7	.83	57	--
05064000	Wild Rice River at Hendrum, Minn.	$H = 578\ Q^{-0.155}$	5	.89	--	9
05064500	Red River of the North at Halstad, Minn.	$H = 642\ Q^{-0.124}$	92	.37	--	20
05066500	Goose River at Hillsboro, N.Dak.	$H = 767\ Q^{-0.144}$	63	.43	--	38
05067500	Marsh River near Shelly, Minn.	(2)	--	--	--	--

Table 7.--Relations between hardness (as $CaCO_3$) concentration and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05069000	Sand Hill River at Climax, Minn.	(2)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	$H = 348\ Q^{-0.081}$	106	0.13	--	17
05082500	Red River of the North at Grand Forks, N.Dak.	$H = 495\ Q^{-0.090}$	492	.26	--	18
05083000	Turtle River at Manvel, N.Dak.	$H = 1{,}030\ Q^{-0.182}$	35	.54	--	36
05085000	Forest River at Minto, N.Dak.	$H = 458\ Q^{-0.131}$	65	.58	--	22
05085500	Snake River at Warren, Minn.	$H = 437 - 37.8\ \ln Q$	15	.52	64	--
05087500	Middle River at Argyle, Minn.	$H = 355 - 20.9\ \ln Q$	21	.25	70	--
05090000	Park River at Grafton, N.Dak.	$H = 348\ Q^{-0.084}$	54	.52	--	28
05092000	Red River of the North at Drayton, N.Dak.	$H = 539\ Q^{-0.107}$	27	.45	--	19
05100000	Pembina River at Neche, N.Dak.	$H = 515 - 46.6\ \ln Q$	27	.63	68	--
05101000	Tongue River at Akra, N.Dak.	$H = 262\ Q^{-0.074}$	51	.31	--	23
05102500	Red River of the North at Emerson, Man.	$H = 551\ Q^{-0.097}$	56	.29	--	17

[1]Changes in water-quality characteristic could not be explained by changes in streamflow for the relations considered.
[2]Not enough data to develop a relation.

Table 8.--Relations between sodium concentration and streamflow for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; *Na*, sodium concentration, in milligrams per liter; *Q*, streamflow, in cubic feet per second; --, indicates no value; ft^3/s, cubic feet per second]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	$Na = 90\ Q^{-0.254}$	140	0.47	--	39
05054500	Sheyenne River above Harvey, N.Dak.	$Na = 288 - 35.4\ \ln Q$	96	.52	59.5	--
05056000	Sheyenne River near Warwick, N.Dak.					
	Q greater than or equal to 20 ft^3/s	$Na = 256\ Q^{-0.294}$	217	.30	--	54
	Q less than 20 ft^3/s	$Na = 35.0\ Q^{0.370}$	274	.29	--	57
05057000	Sheyenne River near Cooperstown, N.Dak.	$Na = 116.2\ Q^{-0.124}$	325	.25	--	40
05057200	Baldhill Creek near Dazey, N.Dak.	$Na = 69.0\ Q^{-0.310}$	62	.75	--	50
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(1)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(1)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	$Na = 164\ Q^{-0.195}$	567	.50	--	28
05059000	Sheyenne River near Kindred, N.Dak.	$Na = 141\ Q^{-0.183}$	149	.32	--	31
05059500	Sheyenne River at West Fargo, N.Dak.	$Na = 149\ Q^{-0.206}$	39	.64	--	22
05059700	Maple River near Enderlin, N.Dak.	$Na = 122\ Q^{-0.255}$	57	.60	--	41
05060500	Rush River at Amenia, N.Dak.	$Na = 89.9\ Q^{-0.323}$	23	.78	--	53
05062000	Buffalo River near Dilworth, Minn.	$Na = 45.4\ Q^{-0.249}$	10	.84	--	22
05062200	Elm River near Kelso, N.Dak.	$Na = 57.0 - 7.56\ \ln Q$	7	.91	6.1	--
05064000	Wild Rice River at Hendrum, Minn.	$Na = 52.6\ Q^{-0.336}$	5	.97	--	9
05064500	Red River of the North at Halstad, Minn.	$Na = 186\ Q^{-0.281}$	92	.54	--	33
05066500	Goose River at Hillsboro, N.Dak.	$Na = 193\ Q^{-0.291}$	63	.63	--	53
05067500	Marsh River near Shelly, Minn.	(2)	--	--	--	--

Table 8.--Relations between sodium concentration and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05069000	Sand Hill River at Climax, Minn.	(2)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	$Na = 22.1\ Q^{-0.216}$	107	0.30	--	27
05082500	Red River of the North at Grand Forks, N.Dak.	$Na = 60.1\ Q^{-0.170}$	491	.30	--	31
05083000	Turtle River at Manvel, N.Dak.	$Na = 733\ Q^{-0.259}$	34	.60	--	48
05085000	Forest River at Minto, N.Dak.	$Na = 54.8\ Q^{-0.161}$	65	.44	--	37
05085500	Snake River at Warren, Minn.	(2)	--	--	--	--
05087500	Middle River at Argyle, Minn.	(2)	--	--	--	--
05090000	Park River at Grafton, N.Dak.	$Na = 105.7\ Q^{-0.172}$	54	.68	--	42
05092000	Red River of the North at Drayton, N.Dak.	$Na = 558\ Q^{-0.356}$	27	.67	--	43
05100000	Pembina River at Neche, N.Dak.	$Na = 58.0 - 4.02\ \ln Q$	27	.47	8.1	--
05101000	Tongue River at Akra, N.Dak.	$Na = 29.9\ Q^{-0.074}$	46	.33	--	18
05102500	Red River of the North at Emerson, Man.	$Na = 382\ Q^{-0.323}$	56	.42	--	44

[1]Changes in water-quality characteristic could not be explained by changes in streamflow for the relations considered.
[2]Not enough data to develop a relation.

Table 9.--Relations between sulfate concentration and streamflow for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; SO_4, sulfate concentration, in milligrams per liter; Q, streamflow, in cubic feet per second; --, indicates no value; ft^3/s, cubic feet per second]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	$SO_4 = 112\ Q^{-0.080}$	171	0.03	--	65
05054500	Sheyenne River above Harvey, N.Dak.					
	Q greater than or equal to 12 ft^3/s	$SO_4 = 620\ Q^{-0.360}$	22	.26	--	58
	Q less than 12 ft^3/s	$SO_4 = 198\ Q^{0.119}$	74	.21	--	25
05056000	Sheyenne River near Warwick, N.Dak.					
	Q greater than or equal to 20 ft^3/s	$SO_4 = 280\ Q^{-0.232}$	104	.32	--	45
	Q less than 20 ft^3/s	$SO_4 = 60.8\ Q^{0.212}$	137	.21	--	40
05057000	Sheyenne River near Cooperstown, N.Dak.	$SO_4 = 181\ Q^{-0.086}$	275	.18	--	35
05057200	Baldhill Creek near Dazey, N.Dak.	$SO_4 = 192 - 22.1\ \ln Q$	62	.63	44.5	--
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(1)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(1)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	$SO_4 = 324\ Q^{-0.174}$	502	.43	--	28
05059000	Sheyenne River near Kindred, N.Dak.	$SO_4 = 257\ Q^{-0.125}$	149	.31	--	22
05059500	Sheyenne River at West Fargo, N.Dak.	$SO_4 = 311\ Q^{-0.186}$	38	.59	--	22
05059700	Maple River near Enderlin, N.Dak.	$SO_4 = 655\ Q^{-0.296}$	57	.68	--	40
05060500	Rush River at Amenia, N.Dak.	$SO_4 = 411\ Q^{-0.281}$	23	.69	--	59
05062000	Buffalo River near Dilworth, Minn.	$SO_4 = 265\ Q^{-0.187}$	10	.37	--	47
05062200	Elm River near Kelso, N.Dak.	$SO_4 = 192 - 21.9\ \ln Q$	7	.71	35.7	--
05064000	Wild Rice River at Hendrum, Minn.	$SO_4 = 82.3\ Q^{-0.124}$	6	.29	--	33

Table 9.--Relations between sulfate concentration and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05064500	Red River of the North at Halstad, Minn.	$SO_4 = 192\ Q^{-0.103}$	92	0.08	--	42
05066500	Goose River at Hillsboro, N.Dak.	$SO_4 = 595\ Q^{-0.191}$	63	.48	--	46
05067500	Marsh River near Shelly, Minn.	(2)	--	--	--	--
05069000	Sand Hill River at Climax, Minn.	(2)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	$SO_4 = 6.65\ Q^{0.199}$	107	.04	--	79
05082500	Red River of the North at Grand Forks, N.Dak.	$SO_4 = 38.8\ Q^{0.068}$	426	.04	--	42
05083000	Turtle River at Manvel, N.Dak.	$SO_4 = 597\ Q^{-0.172}$	34	.50	--	38
05085000	Forest River at Minto, N.Dak.	$SO_4 = 160\ Q^{-0.086}$	65	.21	--	33
05085500	Snake River at Warren, Minn.	$SO_4 = 158\ Q^{-0.089}$	15	.22	--	28
05087500	Middle River at Argyle, Minn.	$SO_4 = 52.5 + 3.56\ \ln Q$	21	.11	17.5	--
05090000	Park River at Grafton, N.Dak.	$SO_4 = 220\ Q^{-0.099}$	54	.56	--	31
05092000	Red River of the North at Drayton, N.Dak.	$SO_4 = 130 - 6.76\ \ln Q$	27	.15	23.8	--
05100000	Pembina River at Neche, N.Dak.	$SO_4 = 239 - 18.0\ \ln Q$	27	.45	38.0	--
05101000	Tongue River at Akra, N.Dak.	$SO_4 = 81.6\ Q^{-0.028}$	47	.04	--	24
05102500	Red River of the North at Emerson, Man.	(1)	--	--	--	--

[1]Changes in water-quality characteristic could not be explained by changes in streamflow for the relations considered.
[2]Not enough data to develop a relation.

Table 10.--Relations between chloride concentration and streamflow for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; Cl, chloride concentration, in milligrams per liter; Q, streamflow, in cubic feet per second; --, indicates no value; ft^3/s, cubic feet per second]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	$Cl = 68.4\ Q^{-0.297}$	159	0.51	--	41
05054500	Sheyenne River above Harvey, N.Dak.	$Cl = 20.1\ Q^{-0.142}$	96	.31	--	38
05056000	Sheyenne River near Warwick, N.Dak.					
	Q greater than or equal to 20 ft^3/s	$Cl = 50.5\ Q^{-0.313}$	88	.46	--	45
	Q less than 20 ft^3/s	$Cl = 7.20\ Q^{0.318}$	124	.31	--	48
05057000	Sheyenne River near Cooperstown, N.Dak.	$Cl = 24.8\ Q^{-0.141}$	260	.42	--	32
05057200	Baldhill Creek near Dazey, N.Dak.	$Cl = 20.8\ Q^{-0.244}$	62	.71	--	43
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(1)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(1)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	$Cl = 94.1\ Q^{-0.284}$	289	.59	--	33
05059000	Sheyenne River near Kindred, N.Dak.	$Cl = 133\ Q^{-0.336}$	149	.64	--	30
05059500	Sheyenne River at West Fargo, N.Dak.	$Cl = 152\ Q^{-0.362}$	39	.82	--	24
05059700	Maple River near Enderlin, N.Dak.	$Cl = 84.5\ Q^{-0.284}$	57	.56	--	50
05060500	Rush River at Amenia, N.Dak.	$Cl = 40.3\ Q^{-0.292}$	23	.60	--	77
05062000	Buffalo River near Dilworth, Minn.	$Cl = 8.51 - 0.674\ \ln Q$	9	.26	1.8	--
05062200	Elm River near Kelso, N.Dak.	$Cl = 36.9 - 4.60\ \ln Q$	7	.85	4.9	--
05064000	Wild Rice River at Hendrum, Minn.	$Cl = 7.63\ Q^{-0.125}$	114	.33	--	41
05064500	Red River of the North at Halstad, Minn.	$Cl = 99.5\ Q^{-0.279}$	92	.54	--	33
05066500	Goose River at Hillsboro, N.Dak.	$Cl = 141.6\ Q^{-0.313}$	63	.61	--	60
05067500	Marsh River near Shelly, Minn.	(2)	--	--	--	--

Table 10.--Relations between chloride concentration and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)	Standard error of estimate (percent)
05069000	Sand Hill River at Climax, Minn.	(2)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	$Cl = 5.89\ Q^{-0.082}$	104	0.02	--	37
05082500	Red River of the North at Grand Forks, N.Dak.	$Cl = 36.5\ Q^{-0.190}$	212	.22	--	44
05083000	Turtle River at Manvel, N.Dak.	$Cl = 1{,}190\ Q^{-0.265}$	35	.47	--	65
05085000	Forest River at Minto, N.Dak.	$Cl = 59.9\ Q^{-0.303}$	65	.62	--	49
05085500	Snake River at Warren, Minn.	$Cl = 2.72 - 0.534\ \ln Q$	15	.44	1.1	--
05087500	Middle River at Argyle, Minn.	$Cl = 4.92\ Q^{-0.268}$	19	.47	--	64
05090000	Park River at Grafton, N.Dak.	$Cl = 96.4\ Q^{-0.213}$	54	.62	--	61
05092000	Red River of the North at Drayton, N.Dak.	$Cl = 1{,}520\ Q^{-0.464}$	27	.72	--	51
05100000	Pembina River at Neche, N.Dak.	$Cl = 45.4\ Q^{-0.270}$	27	.81	--	26
05101000	Tongue River at Akra, N.Dak.	$Cl = 10.1 - 0.369\ \ln Q$	45	.05	2.3	--
05102500	Red River of the North at Emerson, Man.	$Cl = 764\ Q^{-0.408}$	56	.43	--	56

[1]Changes in water-quality characteristic could not be explained by changes in streamflow for the relations considered.
[2]Not enough data to develop a relation.

Table 11.--Relations between specific conductance and streamflow for selected gaging stations in the Red River of the North basin

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; Q, streamflow, in cubic feet per second; --, indicates no value; ft^3/s, cubic feet per second]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error or estimate (µS/cm)	Standard error of estimate (percent)
05054020	Red River of the North below Fargo, N.Dak.	$SC = 995\ Q^{-0.97}$	221	0.32	--	18
05054500	Sheyenne River above Harvey, N.Dak.	$SC = 1{,}420 - 154\ \ln Q$	170	.47	295	--
05056000	Sheyenne River near Warwick, N.Dak.					
	Q is greater than or equal to 20 ft^3/s	$SC = 1{,}840\ Q^{-0.219}$	255	.40	--	32
	Q is less than 20 ft^3/s	$SC = 586\ Q^{0.155}$	305	.27	--	25
05057000	Sheyenne River near Cooperstown, N.Dak.	$SC = 1{,}140 - 79.5\ \ln Q$	381	.33	206	
05057200	Baldhill Creek near Dazey, N.Dak.	$SC = 1{,}020\ Q^{-0.184}$	174	.67	--	28
05058000	Sheyenne River below Baldhill Dam, N.Dak.	(1)	--	--	--	--
05058500	Sheyenne River at Valley City, N.Dak.	(1)	--	--	--	--
05058700	Sheyenne River at Lisbon, N.Dak.	$SC = 1{,}490\ Q^{-0.142}$	603	.56	--	19
05059000	Sheyenne River near Kindred, N.Dak.	$SC = 1{,}330 - 112\ \ln Q$	255	.58	120	--
05059500	Sheyenne River at West Fargo, N.Dak.	$SC = 1{,}440 - 127\ \ln Q$	202	.60	148	--
05059700	Maple River near Enderlin, N.Dak.	$SC = 1{,}900\ Q^{-0.196}$	186	.60	--	32
05060500	Rush River at Amenia, N.Dak.	$SC = 1{,}260\ Q^{-0.181}$	102	.63	--	39
05062000	Buffalo River near Dilworth, Minn.	$SC = 1{,}650\ Q^{-0.200}$	10	.80	--	20
05062200	Elm River near Kelso, N.Dak.	$SC = 750\ Q^{-0.088}$	26	.23	--	51
05064000	Wild Rice River at Hendrum, Minn.	$SC = 900\ Q^{-0.113}$	115	.60	--	20
05064500	Red River of the North at Halstad, Minn.	$SC = 2{,}020\ Q^{-0.172}$	213	.65	--	20
05066500	Goose River at Hillsboro, N.Dak.	$SC = 2{,}040\ Q^{-0.179}$	194	.62	--	35
05067500	Marsh River near Shelly, Minn.	(2)	--	--	--	--

Table 11.--Relations between specific conductance and streamflow for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error or estimate (µS/cm)	Standard error of estimate (percent)
05069000	Sand Hill River at Climax, Minn.	(2)	--	--	--	--
05079000	Red Lake River at Crookston, Minn.	$SC = 665\ Q^{-0.080}$	106	0.14	--	16
05082500	Red River of the North at Grand Forks, N.Dak.	$SC = 1{,}100\ Q^{-0.099}$	723	.37	--	17
05083000	Turtle River at Manvel, N.Dak.	$SC = 4{,}270\ Q^{-0.180}$	35	.54	--	34
05085000	Forest River at Minto, N.Dak.	$SC = 1{,}130\ Q^{-0.152}$	165	.70	--	21
05085500	Snake River at Warren, Minn.	$SC = 888\ Q^{-0.118}$	15	.43	--	24
05087500	Middle River at Argyle, Minn.	$SC = 655 - 35.9\ \ln Q$	21	.28	113	--
05090000	Park River at Grafton, N.Dak.	$SC = 1{,}200\ Q^{-0.113}$	173	.58	--	31
05092000	Red River of the North at Drayton, N.Dak.	$SC = 2{,}200\ Q^{-0.161}$	226	.49	--	24
05100000	Pembina River at Neche, N.Dak.	$SC = 1{,}210 - 97.1\ \ln Q$	167	.78	123	--
05101000	Tongue River at Akra, N.Dak.	$SC = 614\ Q^{-0.057}$	156	.22	--	21
05102500	Red River of the North at Emerson, Man.	$SC = 1{,}960\ Q^{-0.146}$	68	.41	--	21

[1]Changes in specific conductance could not be explained by changes in streamflow for the relations considered.
[2]Not enough data to develop a relation.

The second relation necessary to develop a cascaded-regression model is the relation between a selected water-quality constituent and specific conductance. According to Hem (1985), this relation generally is linear. The linear relation between dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride concentrations and specific conductance for selected gaging stations is listed in tables 12 through 16, respectively.

The technique of cascading regressions, however, does have limitations that users should be aware of so they can properly evaluate the accuracy of a predicted value. A method of evaluating the accuracy of a cascaded-regression model was developed by Karlinger and Troutman (1985). The accuracy of a cascaded-regression model can be evaluated by determining error bounds of the population parameters and of the standard error of estimate. Determination of error bounds of the population parameters and of the standard error of estimate for a cascaded-regression model are beyond the scope of this study. However, the individual regression equations, the coefficient of determination, and the standard error of estimate for each equation are given in tables 11-16. The data in these tables can be used to develop and evaluate the cascaded-regression model.

Alternative Methods for Estimating Monthly Mean Dissolved-Solids, Hardness (as $CaCO_3$), Sodium, Sulfate, and Chloride Concentrations

Because changes in water-quality characteristics could not be explained by changes in streamflow or because of a lack of water-quality data, the previously discussed methods could not be used to develop relations for estimating monthly mean concentrations for some of the gaging stations where model input was needed. One alternative method would be to use mean monthly values of dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride concentrations if sufficient data are available to determine a mean value for each of the 12 months. The mean monthly value concept especially is applicable for stations where monthly values do not vary much from year to year. If insufficient data are available to compute mean values for these constituents for each of the 12 months, mean values of specific conductance could be computed in some cases. Then, the mean values of specific conductance could be used with the equations appearing in tables 12-16 to estimate dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride concentrations. Another alternative method for developing input to the model, especially for gaging stations with little or no water-quality data, would be to use the relations for a similar gaging station (or basin). The relation for a similar gaging station could be adjusted through trial and error until the salinity model output for downstream model nodes closely matches values calculated from well-defined equations, such as equation 1 or equation 2, that relate dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride concentrations to streamflow for these downstream nodes.

Monthly statistics for concentrations of dissolved solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride and for specific conductance for the Sheyenne River below Baldhill Dam, N.Dak., gaging station are listed in table 17.

Not enough data were available to compute monthly statistics for dissolved solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride for

Table 12.--Relations between dissolved-solids concentration and specific conductance for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; *DS*, dissolved-solids concentration, in milligrams per liter; *SC*, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05054020	Red River of the North below Fargo, N.Dak.	$DS = -6.58 + 0.641\ SC$	178	0.90	31.0
05054500	Sheyenne River above Harvey, N.Dak.	$DS = 12.0 + 0.666\ SC$	98	.93	61.0
05056000	Sheyenne River near Warwick, N.Dak.	$DS = -19.5 + 0.680\ SC$	485	.96	31.4
05057000	Sheyenne River near Cooperstown, N.Dak.	$DS = 4.66 + 0.661\ SC$	341	.95	35.5
05057200	Baldhill Creek near Dazey, N.Dak.	$DS = 4.91 + 0.653\ SC$	63	.98	25.8
05058000	Sheyenne River below Baldhill Dam, N.Dak.	$DS = -30.5 + 0.688\ SC$	90	.96	19.9
05058500	Sheyenne River at Valley City, N.Dak.	$DS = -48.8 + 0.711\ SC$	14	.91	27.6
05058700	Sheyenne River at Lisbon, N.Dak.	$DS = -23.8 + 0.683\ SC$	551	.97	22.9
05059000	Sheyenne River near Kindred, N.Dak.	$DS = 3.95 + 0.635\ SC$	152	.94	28.0
05059500	Sheyenne River at West Fargo, N.Dak.	$DS = -2.87 + 0.634\ SC$	39	.93	35.1
05059700	Maple River near Enderlin, N.Dak.	$DS = 33.4 + 0.712\ SC$	56	.89	114
05060500	Rush River at Amenia, N.Dak.	$DS = -47.9 + 0.796\ SC$	23	.98	67.1
05062000	Buffalo River near Dilworth, Minn.	$DS = -19.1 + 0.696\ SC$	10	.99	13.3
05062200	Elm River near Kelso, N.Dak.	$DS = -21.8 + 0.704\ SC$	8	.99	23.9
05064000	Wild Rice River at Hendrum, Minn.	$DS = -36.3 + 0.698\ SC$	5	.99	7.33
05064500	Red River of the North at Halstad, Minn.	$DS = 46.3 + 0.562\ SC$	94	.89	33.8
05066500	Goose River at Hillsboro, N.Dak.	$DS = 11.5 + 0.706\ SC$	64	.97	76.9
05067500	Marsh River near Shelly, Minn.	(1)	--	--	--

Table 12.--Relations between dissolved-solids concentration and specific conductance for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05069000	Sand Hill River at Climax, Minn.	(1)	--	--	--
05079000	Red Lake River at Crookston, Minn.	$DS = -2.20 + 0.664\ SC$	106	0.81	21.0
05082500	Red River of the North at Grand Forks, N.Dak.	$DS = -0.782 + 0.646\ SC$	470	.91	18.7
05083000	Turtle River at Manvel, N.Dak.	$DS = -5.90 + 0.628\ SC$	34	.99	109
05085000	Forest River at Minto, N.Dak.	$DS = 4.08 + 0.647\ SC$	65	.97	28.7
05085500	Snake River at Warren, Minn.	$DS = 17.9 + 0.656\ SC$	15	.98	19.6
05087500	Middle River at Argyle, Minn.	$DS = 3.16 + 0.655\ SC$	21	.95	19.6
05090000	Park River at Grafton, N.Dak.	$DS = 40.6 + 0.614\ SC$	53	.97	45.5
05092000	Red River of the North at Drayton, N.Dak.	$DS = 35.4 + 0.559\ SC$	27	.93	30.6
05100000	Pembina River at Neche, N.Dak.	$DS = 5.38 + 0.671\ SC$	27	.96	30.1
05101000	Tongue River at Akra, N.Dak.	$DS = 30.5 + 0.588\ SC$	50	.84	28.4
05102500	Red River of the North at Emerson, Man.	$DS = 23.8 + 0.589\ SC$	71	.97	25.6

[1]Not enough data to develop a relation.

Table 13.--Relations between hardness (as $CaCO_3$) concentration and specific conductance for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; *H*, hardness (as $CaCO_3$) concentration, in milligrams per liter; *SC*, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05054020	Red River of the North below Fargo, N.Dak.	$H = 111 + 0.257\ SC$	178	0.61	30.6
05054500	Sheyenne River above Harvey, N.Dak.	$H = 78.9 + 0.092\ SC$	97	.16	70.9
05056000	Sheyenne River near Warwick, N.Dak.	$H = 59.5 + 0.250\ SC$	489	.65	42.4
05057000	Sheyenne River near Cooperstown, N.Dak.	$H = -5.55 + 0.349\ SC$	343	.87	32.0
05057200	Baldhill Creek near Dazey, N.Dak.	$H = 8.93 + 0.373\ SC$	63	.88	45.6
05058000	Sheyenne River below Baldhill Dam, N.Dak.	$H = 10.7 + 0.310\ SC$	90	.92	13.8
05058500	Sheyenne River at Valley City, N.Dak.	$H = 21.1 + 0.298\ SC$	14	.90	12.3
05058700	Sheyenne River at Lisbon, N.Dak.	$H = 22.0 + 0.301\ SC$	566	.92	17.6
05059000	Sheyenne River near Kindred, N.Dak.	$H = 28.2 + 0.328\ SC$	148	.84	23.1
05059500	Sheyenne River at West Fargo, N.Dak.	$H = -10.2 + 0.380\ SC$	39	.93	20.5
05059700	Maple River near Enderlin, N.Dak.	$H = -5.61 + 0.452\ SC$	57	.89	70.9
05060500	Rush River at Amenia, N.Dak.	$H = 0.871 + 0.434\ SC$	23	.94	57.5
05062000	Buffalo River near Dilworth, Minn.	$H = -42.2 + 0.583\ SC$	10	.99	10.3
05062200	Elm River near Kelso, N.Dak.	$H = -8.84 + 0.426\ SC$	8	.98	16.8
05064000	Wild Rice River at Hendrum, Minn.	$H = -8.26 + 0.529\ SC$	5	.99	6.1
05064500	Red River of the North at Halstad, Minn.	$H = 58.2 + 0.340\ SC$	94	.79	29.2
05066500	Goose River at Hillsboro, N.Dak.	$H = 130 + 0.299\ SC$	64	.80	91.0
05067500	Marsh River near Shelly, Minn.	(1)	--	--	--

Table 13.--Relations between hardness (as $CaCO_3$) concentration and specific conductance for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05069000	Sand Hill River at Climax, Minn.	(1)	--	--	--
05079000	Red Lake River at Crookston, Minn.	$H = 13.5 + 0.483\ SC$	105	0.83	14.5
05082500	Red River of the North at Grand Forks, N.Dak.	$H = 5.44 + 0.460\ SC$	489	.93	12.4
05083000	Turtle River at Manvel, N.Dak.	$H = 144 + 0.162\ SC$	34	.87	97.1
05085000	Forest River at Minto, N.Dak.	$H = 15.7 + 0.413\ SC$	65	.95	25.5
05085500	Snake River at Warren, Minn.	$H = 45.8 + 0.429\ SC$	16	.80	39.5
05087500	Middle River at Argyle, Minn.	$H = -41.5 + 0.609\ SC$	21	.99	6.5
05090000	Park River at Grafton, N.Dak.	$H = 59.7 + 0.258\ SC$	54	.84	44.3
05092000	Red River of the North at Drayton, N.Dak.	$H = 99.1 + 0.213\ SC$	27	.64	32.7
05100000	Pembina River at Neche, N.Dak.	$H = -47.7 + 0.494\ SC$	27	.96	22.6
05101000	Tongue River at Akra, N.Dak.	$H = -19.6 + 0.466\ SC$	51	.81	24.6
05102500	Red River of the North at Emerson, Man.	$H = 131 + 0.197\ SC$	71	.70	31.2

[1]Not enough data to develop a relation.

Table 14.--Relations between sodium concentration and specific conductance for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; *Na*, sodium concentration, in milligrams per liter; *SC*, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05054020	Red River of the North below Fargo, N.Dak.	$Na = -38.6 + 0.106\ SC$	148	0.73	9.8
05054500	Sheyenne River above Harvey, N.Dak.	$Na = -42.4 + 0.218\ SC$	98	.76	42.0
05056000	Sheyenne River near Warwick, N.Dak.	$Na = -42.3 + 0.157\ SC$	489	.81	17.3
05057000	Sheyenne River near Cooperstown, N.Dak.	$Na = -13.3 + 0.110\ SC$	342	.81	12.4
05057200	Baldhill Creek near Dazey, N.Dak.	$Na = -18.7 + 0.097\ SC$	63	.80	16.1
05058000	Sheyenne River below Baldhill Dam, N.Dak.	$Na = -19.0 + 0.121\ SC$	90	.94	4.7
05058500	Sheyenne River at Valley City, N.Dak.	$Na = -24.4 + 0.127\ SC$	14	.84	6.6
05058700	Sheyenne River at Lisbon, N.Dak.	$Na = -22.6 + 0.117\ SC$	566	.92	7.0
05059000	Sheyenne River near Kindred, N.Dak.	$Na = -15.2 + 0.096\ SC$	149	.71	9.9
05059500	Sheyenne River at West Fargo, N.Dak.	$Na = -4.74 + 0.081\ SC$	39	.85	6.7
05059700	Maple River near Enderlin, N.Dak.	$Na = -4.20 + 0.063\ SC$	57	.74	16.9
05060500	Rush River at Amenia, N.Dak.	$Na = -26.3 + 0.090\ SC$	23	.90	16.6
05062000	Buffalo River near Dilworth, Minn.	$Na = -1.82 + 0.025\ SC$	10	.94	1.6
05062200	Elm River near Kelso, N.Dak.	$Na = -13.9 + 0.065\ SC$	8	.88	6.9
05064000	Wild Rice River at Hendrum, Minn.	$Na = -16.1 + 0.051\ SC$	5	.93	2.6
05064500	Red River of the North at Halstad, Minn.	$Na = -15.9 + 0.070\ SC$	94	.72	7.3
05066500	Goose River at Hillsboro, N.Dak.	$Na = -53.5 + 0.114\ SC$	64	.89	24.6
05067500	Marsh River near Shelly, Minn.	(1)	--	--	--

Table 14.--Relations between sodium concentration and specific conductance for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05069000	Sand Hill River at Climax, Minn.	(1)	--	--	--
05079000	Red Lake River at Crookston, Minn.	$Na = -0.835 + 0.016\ SC$	106	0.26	1.7
05082500	Red River of the North at Grand Forks, N.Dak.	$Na = -10.5 + 0.052\ SC$	491	.68	3.4
05083000	Turtle River at Manvel, N.Dak.	$Na = -56.2 + 0.159\ SC$	34	.87	95.9
05085000	Forest River at Minto, N.Dak.	$Na = -17.7 + 0.073\ SC$	65	.79	9.8
05085500	Snake River at Warren, Minn.	(1)	--	--	--
05087500	Middle River at Argyle, Minn.	(1)	--	--	--
05090000	Park River at Grafton, N.Dak.	$Na = -31.2 + 0.125\ SC$	54	.88	18.6
05092000	Red River of the North at Drayton, N.Dak.	$Na = -39.5 + 0.127\ SC$	27	.86	10.3
05100000	Pembina River at Neche, N.Dak.	$Na = 8.09 + 0.045\ SC$	27	.79	5.1
05101000	Tongue River at Akra, N.Dak.	$Na = 7.06 + 0.033\ SC$	51	.44	4.0
05102500	Red River of the North at Emerson, Man.	$Na = -53.3 + 0.139\ SC$	71	.93	9.0

[1]Not enough data to develop a relation.

Table 15.--Relations between sulfate concentration and specific conductance for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; SO_4, sulfate concentration, in milligrams per liter; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05054020	Red River of the North below Fargo, N.Dak.	$SO_4 = -79.4 + 0.275\ SC$	178	0.62	31.8
05054500	Sheyenne River above Harvey, N.Dak.	$SO_4 = 2.04 + 0.162\ SC$	98	.56	49.4
05056000	Sheyenne River near Warwick, N.Dak.	$SO_4 = -24.8 + 0.164\ SC$	240	.79	20.2
05057000	Sheyenne River near Cooperstown, N.Dak.	$SO_4 = 6.30 + 0.158\ SC$	292	.72	23.7
05057200	Baldhill Creek near Dazey, N.Dak.	$SO_4 = -9.94 + 0.212\ SC$	63	.93	20.0
05058000	Sheyenne River below Baldhill Dam, N.Dak.	$SO_4 = -11.6 + 0.186\ SC$	90	.77	15.4
05058500	Sheyenne River at Valley City, N.Dak.	$SO_4 = -30.6 + 0.220\ SC$	14	.87	10.1
05058700	Sheyenne River at Lisbon, N.Dak.	$SO_4 = -45.6 + 0.251\ SC$	501	.82	23.6
05059000	Sheyenne River near Kindred, N.Dak.	$SO_4 = -0.021 + 0.180\ SC$	149	.76	16.3
05059500	Sheyenne River at West Fargo, N.Dak.	$SO_4 = -8.63 + 0.184\ SC$	38	.91	11.2
05059700	Maple River near Enderlin, N.Dak.	$SO_4 = -17.7 + 0.310\ SC$	57	.85	58.9
05060500	Rush River at Amenia, N.Dak.	$SO_4 = -84.6 + 0.385\ SC$	23	.95	46.1
05062000	Buffalo River near Dilworth, Minn.	$SO_4 = -6.88 + 0.189\ SC$	10	.52	44.0
05062200	Elm River near Kelso, N.Dak.	$SO_4 = -24.9 + 0.207\ SC$	8	.87	24.0
05064000	Wild Rice River at Hendrum, Minn.	$SO_4 = -0.015 + 0.086\ SC$	6	.64	11.7
05064500	Red River of the North at Halstad, Minn.	$SO_4 = -19.6 + 0.187\ SC$	94	.57	27.2
05066500	Goose River at Hillsboro, N.Dak.	$SO_4 = 23.4 + 0.261\ SC$	64	.92	48.2
05067500	Marsh River near Shelly, Minn.	(1)	--	--	--

Table 15.--Relations between sulfate concentration and specific conductance for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05069000	Sand Hill River at Climax, Minn.	(1)	--	--	--
05079000	Red Lake River at Crookston, Minn.	$SO_4 = -67.6 + 0.264\ SC$	106	0.47	18.5
05082500	Red River of the North at Grand Forks, N.Dak.	$SO_4 = -23.3 + 0.181\ SC$	426	.36	22.5
05083000	Turtle River at Manvel, N.Dak.	$SO_4 = 46.8 + 0.119\ SC$	34	.93	48.7
05085000	Forest River at Minto, N.Dak.	$SO_4 = 24.9 + 0.140\ SC$	65	.65	26.7
05085500	Snake River at Warren, Minn.	$SO_4 = 53.4 + 0.112\ SC$	16	.34	27.6
05087500	Middle River at Argyle, Minn.	$SO_4 = 35.5 + 0.051\ SC$	21	.09	17.7
05090000	Park River at Grafton, N.Dak.	$SO_4 = 17.2 + 0.182\ SC$	54	.84	31.6
05092000	Red River of the North at Drayton, N.Dak.	$SO_4 = 8.15 + 0.110\ SC$	27	.74	13.1
05100000	Pembina River at Neche, N.Dak.	$SO_4 = 5.07 + 0.216\ SC$	27	.89	16.5
05101000	Tongue River at Akra, N.Dak.	$SO_4 = 29.6 + 0.098\ SC$	50	.34	14.5
05102500	Red River of the North at Emerson, Man.	$SO_4 = -4.24 + 0.129\ SC$	71	.65	22.7

[1]Not enough data to develop a relation.

Table 16.--Relations between chloride concentration and specific conductance for selected gaging stations in the Red River of the North basin

[mg/L, milligrams per liter; *Cl*, chloride concentration, in milligrams per liter; *SC*, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; --, indicates no value]

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05054020	Red River of the North below Fargo, N.Dak.	$Cl = -26.1 + 0.070\ SC$	166	0.61	8.4
05054500	Sheyenne River above Harvey, N.Dak.	$Cl = 1.20 + 0.012\ SC$	97	.57	3.7
05056000	Sheyenne River near Warwick, N.Dak.	$Cl = -2.87 + 0.021\ SC$	210	.77	2.7
05057000	Sheyenne River near Cooperstown, N.Dak.	$Cl = -1.62 + 0.021\ SC$	278	.79	2.6
05057200	Baldhill Creek near Dazey, N.Dak.	$Cl = -4.72 + 0.029\ SC$	63	.70	6.4
05058000	Sheyenne River below Baldhill Dam, N.Dak.	$Cl = -2.65 + 0.024\ SC$	90	.70	2.4
05058500	Sheyenne River at Valley City, N.Dak.	$Cl = -4.52 + 0.027\ SC$	14	.67	2.2
05058700	Sheyenne River at Lisbon, N.Dak.	$Cl = -26.3 + 0.069\ SC$	288	.73	8.3
05059000	Sheyenne River near Kindred, N.Dak.	$Cl = -22.3 + 0.064\ SC$	149	.64	7.8
05059500	Sheyenne River at West Fargo, N.Dak.	$Cl = -15.2 + 0.058\ SC$	39	.75	6.6
05059700	Maple River near Enderlin, N.Dak.	$Cl = -11.6 + 0.050\ SC$	57	.61	18.3
05060500	Rush River at Amenia, N.Dak.	$Cl = -13.6 + 0.045\ SC$	23	.77	13.3
05062000	Buffalo River near Dilworth, Minn.	$Cl = 0.524 + 0.007\ SC$	9	.52	1.5
05062200	Elm River near Kelso, N.Dak.	$Cl = -4.77 + 0.037\ SC$	8	.75	6.3
05064000	Wild Rice River at Hendrum, Minn.	$Cl = -0.035 + 0.008\ SC$	113	.67	1.6
05064500	Red River of the North at Halstad, Minn.	$Cl = -7.52 + 0.037\ SC$	94	.53	5.8
05066500	Goose River at Hillsboro, N.Dak.	$Cl = -57.1 + 0.096\ SC$	64	.81	28.9
05067500	Marsh River near Shelly, Minn.	(1)	--	--	--

Table 16.--Relations between chloride concentration and specific conductance for selected gaging stations in the Red River of the North basin--Continued

Gaging station number	Gaging station name	Equation	Number of data pairs	Coefficient of determination, R^2	Standard error of estimate (mg/L)
05069000	Sand Hill River at Climax, Minn.	(1)	--	--	--
05079000	Red Lake River at Crookston, Minn.	$Cl = -0.228 + 0.010\ SC$	104	0.18	1.3
05082500	Red River of the North at Grand Forks, N.Dak.	$Cl = -2.59 + 0.022\ SC$	211	.30	3.3
05083000	Turtle River at Manvel, N.Dak.	$Cl = -160 + 0.269\ SC$	33	.96	68.9
05085000	Forest River at Minto, N.Dak.	$Cl = -56.0 + 0.116\ SC$	65	.74	17.8
05085500	Snake River at Warren, Minn.	$Cl = -46.8 + 0.083\ SC$	16	.41	17.9
05087500	Middle River at Argyle, Minn.	$Cl = -2.02 + 0.010\ SC$	19	.16	2.7
05090000	Park River at Grafton, N.Dak.	$Cl = -47.1 + 0.137\ SC$	54	.77	30.0
05092000	Red River of the North at Drayton, N.Dak.	$Cl = -63.5 + 0.181\ SC$	27	.82	17.2
05100000	Pembina River at Neche, N.Dak.	$Cl = -4.50 + 0.027\ SC$	27	.63	4.6
05101000	Tongue River at Akra, N.Dak.	$Cl = 4.33 + 0.009\ SC$	50	.14	2.2
05102500	Red River of the North at Emerson, Man.	$Cl = -79.1 + 0.187\ SC$	71	.88	16.5

[1]Not enough data to develop a relation.

Table 17.--Statistical summary, by month, of selected water-quality constituents for the Sheyenne River below Baldhill Dam, North Dakota, gaging station, June 5, 1959, through September 15, 1986

[--, not enough data to compute statistic]

Month	Number of samples	Maximum	Minimum	Mean	Standard deviation
	Dissolved-solids concentration (milligrams per liter)				
January	5	527	373	450	71
February	3	593	558	580	19
March	13	750	300	547	121
April	11	638	196	496	124
May	7	455	252	362	75
June	10	488	232	370	90
July	10	476	308	387	69
August	7	458	328	402	53
September	11	450	310	383	43
October	9	523	313	392	70
November	1	400	400	400	--
December	3	476	382	431	47
	Hardness (as $CaCO_3$) concentration (milligrams per liter)				
January	5	260	210	234	23
February	3	310	260	290	26
March	13	360	150	274	57
April	11	310	96	247	58
May	7	240	140	193	36
June	10	230	140	194	36
July	10	240	170	200	25
August	7	240	180	206	22
September	11	210	160	190	14
October	9	260	120	198	41
November	1	200	200	200	--
December	3	220	200	210	10
	Sodium concentration (milligrams per liter)				
January	5	78	48	65	14
February	3	96	79	89	9
March	13	120	40	80	21
April	11	100	20	73	23
May	7	67	32	49	14
June	10	77	27	51	18
July	10	71	39	56	11
August	7	73	41	59	12
September	11	78	36	55	12
October	9	80	43	58	14
November	1	54	54	54	--
December	3	65	56	60	5

Table 17.--Statistical summary, by month, of selected water-quality constituents for the Sheyenne River below Baldhill Dam, North Dakota, gaging station, June 5, 1959, through September 15, 1986--Continued

Month	Number of samples	Maximum	Minimum	Mean	Standard deviation
	Sulfate concentration (milligrams per liter)				
January	5	150	83	108	27
February	3	170	150	160	10
March	13	230	70	142	45
April	11	160	48	127	36
May	7	130	64	92	22
June	10	140	62	98	27
July	10	140	69	111	23
August	7	130	90	113	16
September	11	120	73	95	14
October	9	140	72	102	23
November	1	110	110	110	--
December	3	120	100	113	12
	Chloride concentration (milligrams per liter)				
January	5	17	12	15	2
February	3	26	18	21	5
March	13	26	12	17	4
April	11	20	5	15	4
May	7	15	7	12	3
June	10	18	6	11	4
July	10	14	7	11	3
August	7	14	9	11	2
September	11	26	8	13	5
October	9	19	9	12	3
November	1	11	11	11	--
December	3	15	11	13	2
	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)				
January	17	1,100	600	798	112
February	12	1,260	740	925	133
March	24	1,090	484	867	149
April	22	960	290	708	176
May	14	740	285	577	129
June	22	766	400	594	116
July	17	738	489	597	77
August	15	800	491	625	98
September	17	725	485	611	66
October	19	792	495	633	85
November	8	850	580	690	101
December	12	995	600	736	128

the Sheyenne River at Valley City, N.Dak., gaging station. Therefore, the relation between specific conductance and each constituent was used to estimate the value for the constituent, and the estimated values were used to compute the monthly statistics. Monthly statistics for specific conductance and estimated water-quality constituents for the Sheyenne River at Valley City, N.Dak., gaging station are listed in table 18.

Because of a lack of data, mean monthly statistics could not be summarized for any of the selected water-quality constituents for the Marsh River near Shelly, Minn., and the Sand Hill River near Climax, Minn., gaging stations, and monthly water-quality statistics could not be summarized for sodium for the Snake River at Warren, Minn., and the Middle River at Argyle, Minn., gaging stations. For these gaging stations, a relation for a similar gaging station (or basin) could be used to estimate model input.

QUANTITY OF AND DISSOLVED-SOLIDS CONCENTRATION IN GROUND WATER DISCHARGING TO THE SHEYENNE RIVER

The quantity and the quality of ground water discharging to the Sheyenne River are needed for model input for reaches of the river where ground water accounts for a substantial part of streamflow during periods of low flow. Considerable ground-water discharge has been identified for two reaches of the Sheyenne River. Paulson and Akin (1964) and Randich (1971) suggested that the Warwick aquifer discharges to the Sheyenne River in the vicinity of Warwick, N.Dak. Paulson (1964) reported ground-water discharge to a reach of the river between the Sheyenne River at Lisbon, N.Dak., and the Sheyenne River near Kindred, N.Dak., gaging stations.

In order to determine the quantity of ground-water and the associated dissolved-solids concentrations discharging to the river in the vicinity of Warwick and in the reach between the Sheyenne River at Lisbon, N.Dak., gaging station and the Sheyenne River near Kindred, N.Dak., gaging station, streamflow and specific-conductance measurements were made at 16 sites during this study.

Streamflow and specific-conductance measurements were made on October 15 and 16, 1986, at six sites in the vicinity of Warwick (U.S. Geological Survey, 1988, p. 359). October was chosen because no overland runoff occurred during the month and water use and evapotranspiration were minimal. The most upstream site was located at discontinued gaging station 05055500, Sheyenne River at Sheyenne, N.Dak., about 26 river miles upstream from gaging station 05056000, Sheyenne River near Warwick, N.Dak. (fig. 8). The most downstream site, site 9, was located about 6 river miles downstream from the Sheyenne River near Warwick, N.Dak., gaging station. Streamflow, specific conductance, and estimated dissolved-solids concentrations and loads for the most upstream and the most downstream sites are listed in table 19. Ground-water discharge into the Sheyenne River in the vicinity of Warwick was 14.8 cubic feet per second on October 15 and 16, 1986 (table 19).

The relation between dissolved-solids concentration and specific conductance for the Sheyenne River near Warwick, N.Dak., gaging station

Table 18.--Statistical summary, by month, of specific conductance and estimated water-quality constituents for the Sheyenne River at Valley City, North Dakota, gaging station, November 3, 1971, through March 22, 1985

Month	Number of samples	Maximum	Minimum	Mean	Standard deviation
Specific conductance (microsiemens per centimeter at 25 degrees Celsius)					
January	3	830	760	790	36
February	3	880	700	767	99
March	10	1,000	235	726	252
April	9	810	410	666	128
May	6	807	460	636	139
June	4	790	470	590	140
July	5	770	540	655	107
August	6	740	600	672	55
September	5	730	610	667	58
October	5	790	615	721	66
November	3	700	600	640	53
December	4	800	630	683	79
Dissolved-solids concentration (milligrams per liter), estimated from specific conductance					
January	3	541	492	513	26
February	3	577	449	496	70
March	10	662	118	467	179
April	9	527	243	425	91
May	6	525	278	404	99
June	4	513	285	371	99
July	5	499	335	417	76
August	6	477	378	429	39
September	5	470	385	425	42
October	5	513	388	464	47
November	3	449	378	406	38
December	4	520	399	436	56
Hardness (as $CaCO_3$) concentration (milligrams per liter), estimated from specific conductance					
January	3	268	248	257	11
February	3	283	230	250	29
March	10	319	91	237	75
April	9	262	143	220	38
May	6	262	158	211	41
June	4	257	161	197	42
July	5	251	182	216	32
August	6	242	200	221	16
September	5	239	203	220	17
October	5	257	204	236	20
November	3	230	200	212	16
December	4	259	209	224	24

Table 18.--Statistical summary, by month, of specific conductance and estimated water-quality constituents for the Sheyenne River at Valley City, North Dakota, gaging station, November 3, 1971, through March 22, 1985--Continued

Month	Number of samples	Maximum	Minimum	Mean	Standard deviation
	Sodium concentrations (milligrams per liter), estimated from specific conductance				
January	3	81	72	76	5
February	3	87	64	73	13
March	10	103	5	68	32
April	9	78	28	60	16
May	6	78	34	56	18
June	4	76	35	51	18
July	5	73	44	59	14
August	6	70	52	61	7
September	5	68	53	60	7
October	5	76	54	67	8
November	3	64	52	57	7
December	4	77	56	62	10
	Sulfate concentration (milligrams per liter), estimated from specific conductance				
January	3	152	137	143	8
February	3	163	123	138	22
March	10	189	21	129	55
April	9	148	60	116	28
May	6	147	71	109	31
June	4	143	73	99	31
July	5	139	88	113	23
August	6	132	101	117	12
September	5	130	104	116	13
October	5	143	105	128	15
November	3	123	101	110	12
December	4	145	108	120	17
	Chloride concentration (milligrams per liter), estimated from specific conductance				
January	3	18	16	17	1
February	3	19	14	16	3
March	10	22	2	15	7
April	9	17	7	13	3
May	6	17	8	13	4
June	4	17	8	11	4
July	5	16	10	13	3
August	6	15	12	14	1
September	5	15	12	13	2
October	5	17	12	15	2
November	3	14	12	13	1
December	4	17	12	14	2

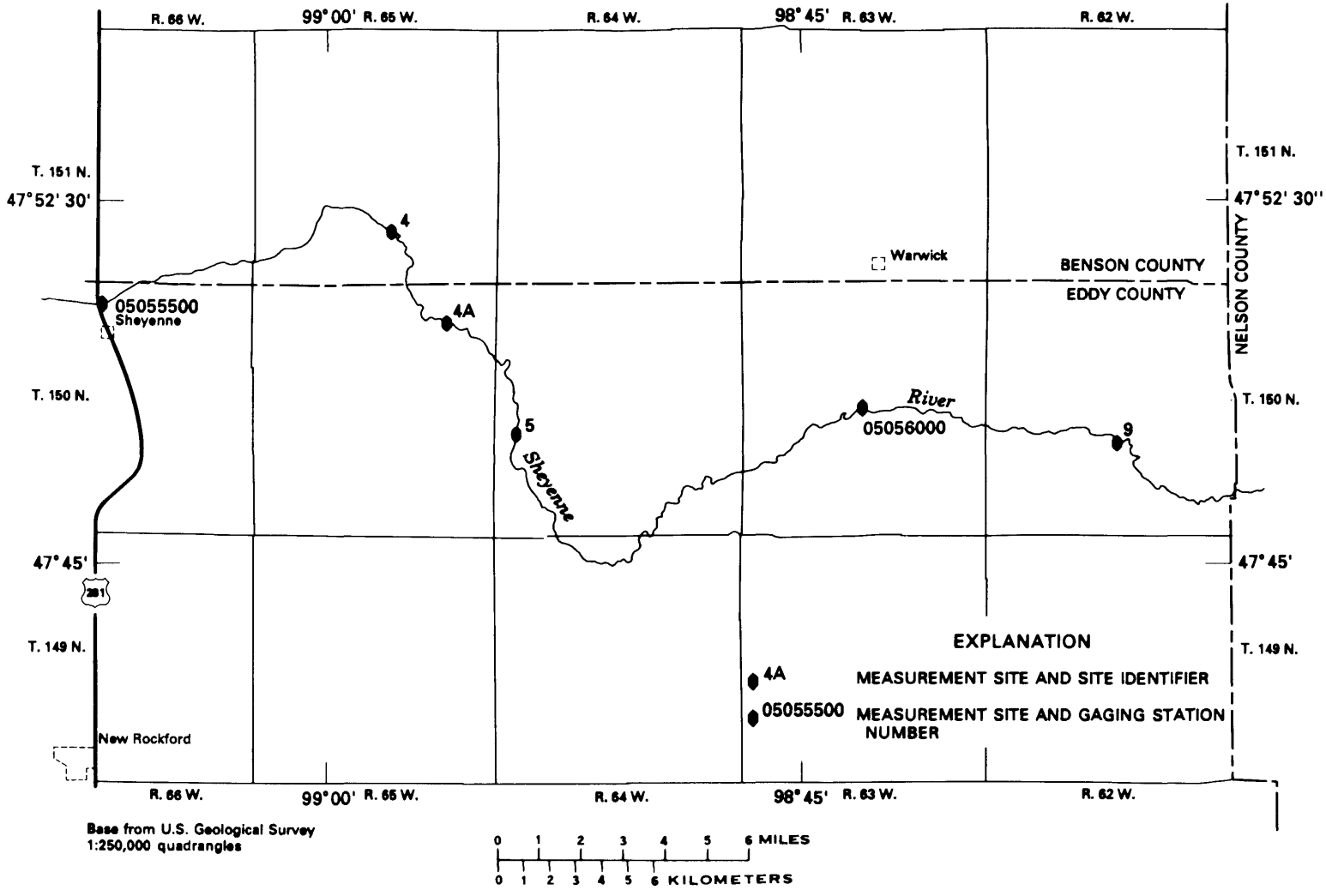


Figure 8.--Location of measurement sites used to determine quantity and quality of ground-water discharge to the Sheyenne River in the vicinity of Warwick, North Dakota, October 15 and 16, 1986.

Table 19.--Measurements of streamflow and specific conductance and estimates of dissolved-solids concentrations and loads for the Sheyenne River in the vicinity of Warwick, North Dakota, October 15 and 16, 1986

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; -- indicates no value]

Location	Streamflow (ft^3/s)	Specific conductance (µS/cm)	Estimated dissolved-solids concentration (mg/L)	Estimated dissolved-solids load (tons/day)
Gaging station 05055500 Lat 47°50'20" Long 99°07'35"	3.50	740	484	4.57
Site 9 Lat 47°46'24" Long 98°33'18"	18.3	691	450	22.2
Reach gain	14.8	--	--	17.6

(table 12) was used to estimate the dissolved-solids concentrations for both the most upstream and the most downstream sites. Estimates of dissolved-solids concentrations for the ground water discharging to the river were based on the difference in dissolved-solids load, as computed from measured specific conductance and streamflow, between the most upstream site and the most downstream site. The dissolved-solids concentration of ground-water discharge was estimated at about 441 milligrams per liter during October 15 and 16, 1986. Trapp (1966) reported that the dissolved-solids concentration of water from a spring immediately downstream from the Sheyenne River near Warwick, N.Dak., gaging station was 307 milligrams per liter.

Streamflow and specific-conductance measurements were made on October 21 and 22, 1986, at 10 measurement sites in the reach between the Sheyenne River at Lisbon, N.Dak., gaging station and the Sheyenne River near Kindred, N.Dak., gaging station. The most upstream site, site A, was about 14 river miles downstream from gaging station 05058700, the Sheyenne River at Lisbon, N.Dak., and the most downstream site, site L, was about 9 river miles upstream from gaging station 05059000, the Sheyenne River near Kindred, N.Dak. (fig. 9). Streamflow, specific conductance, and estimated dissolved-solids concentrations and loads for the most upstream and most downstream sites are listed in table 20.

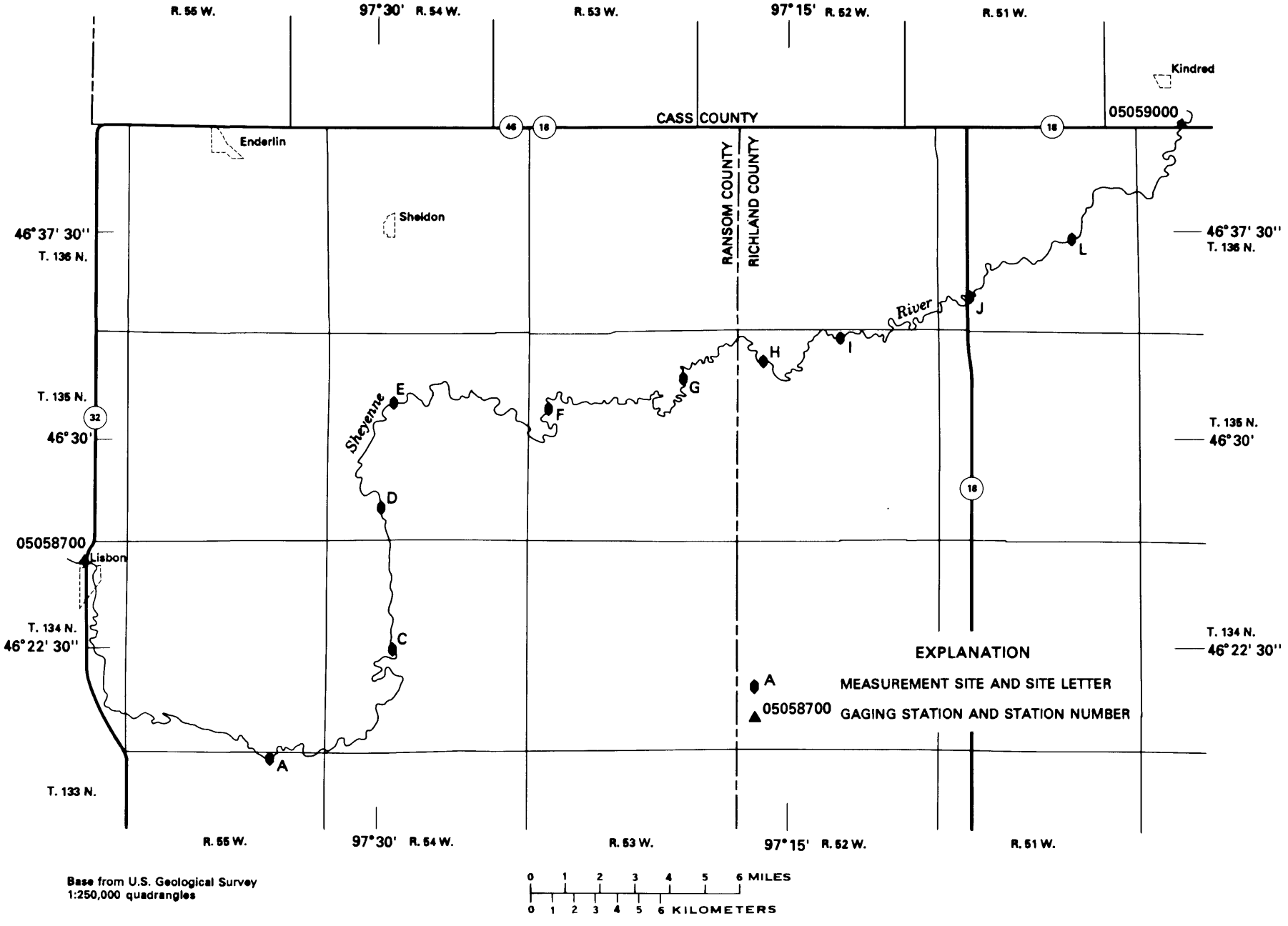


Figure 9.--Location of measurement sites used to determine quantity and quality of ground-water discharge to the Sheyenne River between the Sheyenne River at Lisbon, North Dakota, gaging station (05058700) and the Sheyenne River near Kindred, North Dakota, gaging station (05059000), October 21 and 22, 1986.

Table 20.--Measurements of streamflow and specific conductance and estimates of dissolved-solids concentrations and loads for the Sheyenne River between Lisbon and Kindred, North Dakota, October 21 and 22, 1986

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; -- indicates no value]

Location	Streamflow (ft^3/s)	Specific conductance (µS cm)	Estimated dissolved-solids concentration (mg/L)	Estimated dissolved-solids load (tons/day)
Site A Lat 46°22'02" Long 97°33'47"	31.0	1,160	768	64.3
Site L Lat 46°34'53" Long 97°04'28"	76.0	902	577	118
Reach gain	45.0	--	--	53.7

Ground-water discharge into the Sheyenne River in the reach between site A near the Sheyenne River at Lisbon, N.Dak., gaging station and site L near the Sheyenne River near Kindred, N.Dak., gaging station was about 45.0 cubic feet per second during October 21 and 22, 1986. Paulson (1964, p. D179-D181) reported the average increase in discharge of 25.3 cubic feet per second for the five daily mesurements made from September 13 to November 19, 1963, for the reach between site A and site L "***is due almost wholly to ground-water discharges***."

The relation between dissolved-solids concentration and specific conductance for the Sheyenne River at Lisbon, N.Dak., gaging station (table 12) was used to estimate the dissolved-solids concentration for the most upstream site, and the relation for the Sheyenne River near Kindred, N.Dak., gaging station (table 12) was used to estimate the dissolved-solids concentration for the most downstream site. Dissolved-solids concentration of ground-water discharge in the reach between the Sheyenne River at Lisbon, N.Dak., gaging station and the Sheyenne River near Kindred, N.Dak., gaging station was estimated at about 442 milligrams per liter during October 21 and 22, 1986.

SUMMARY

Future development of the Garrison Diversion Unit may divert water from the Missouri River into the Sheyenne River and the Red River of the North for municipal and industrial use. The U.S. Bureau of Reclamation's Canals, Rivers, and Reservoirs Salinity Accounting Procedures model can be used to predict the effect various operating plans could have on water quality in the Sheyenne River and the Red River of the North. The salinity model uses, as input, monthly means of streamflow and selected water-quality constituents for a 54-year period at 28 nodes on the Sheyenne River and the Red River of the North. The streamflow data base used by the model has been developed. Water-quality data available in the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) can be used to generate the water-quality data base used by the model. This report provides methods for estimating monthly mean concentrations of selected water-quality constituents that can be used for input to and calibration of the Canals, Rivers, and Reservoirs Salinity Accounting Procedures model.

Water-quality data for 32 gaging stations in the Red River of the North basin can be used to define selected water-quality characteristics at the 28 model nodes. Water-quality data for these gaging stations were retrieved from the WATSTORE data base and statistical summaries were prepared. Water-quality data collection at most of the gaging stations began after about 1960. Frequency of data collection varies widely among the gaging stations and generally was determined by the original need for the data. Prior to October 1973, water-quality data were entered in WATSTORE along with concurrent daily mean streamflow data. Since October 1973, water-quality data were entered along with concurrent instantaneous streamflow data.

The frequency of water-quality data collection at the gaging stations is inadequate to define monthly mean concentrations of the individual water-quality constituents for all months for 1931-84. Therefore, methods for estimating monthly mean dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride data were developed. The primary, and preferable, method is to use a direct relation between the individual water-quality constituent and streamflow. The second method is to develop a relation between specific conductance and streamflow, then develop a relation between the individual water-quality constituent and specific conductance, and simultaneously solve the relations. Although use of the direct relation often is preferable, the second method could be used instead of the direct relation if the direct relation is based on a small number of data pairs. For those cases where neither method can be used, alternative methods are proposed.

The Canals, Rivers, and Reservoirs Salinity Accounting Procedures model can accept input as a file of monthly mean concentrations or as parameter values that define the relation between the water-quality constituent and streamflow to compute monthly mean concentrations. The only parameter values accepted by the model are from log-linear and log-log equations. Although other equations may provide a better estimate of the water-quality constituent at some gaging stations, because of the model limitations, only the log-linear and the log-log equations were examined.

Monthly mean concentrations of water-quality constituents can be estimated by using the relation between the individual water-quality constituent and instantaneous streamflow. The assumption was made that monthly mean concentrations can be estimated by substituting monthly mean streamflow for instantaneous streamflow. Two forms of regression equations were examined in developing the relation between individual water-quality constituents and instantaneous streamflow. Both equations use the natural logarithm.

Log-linear and log-log plots of data pairs were made for each gaging station to identify outliers and to indicate if equation 1 or equation 2 would be appropriate for the data. Some of the data that appeared to represent outliers in both plots were not considered in the final analysis. A regression equation was developed for the data that included the suspected outlier and a second equation was developed for the data that did not include the suspected outlier. If the regression equation for the data that included the suspected outlier was substantially different from the equation that did not include the outlier, the equation that did not include the outlier was used in the final relation. Linear regression equations in the form of equations 1 and 2 were developed for each gaging station.

The decision to use equation 1 or equation 2 was based partly on examination of residual plots. Residual plots were examined to determine if the regression resulted in equal variance of the residuals for the full range of predicted values. When only one equation resulted in equal variance of the residuals, then that equation was selected as the better relation. When no clear choice could be made, the equation that had the smallest difference between +1 and -1 standard error of estimate for predicted constituent concentrations evaluated at the mean annual streamflow was selected as the final regression equation. Equation 2 provided the better relation for a majority of the gaging stations.

The second method of estimating monthly mean concentrations of dissolved-solids, hardness (as $CaCO_3$), sodium, sulfate, and chloride uses the large specific-conductance data base. Specific-conductance data generally are collected more frequently than other water-quality data. Individual water-quality constituent concentrations can be estimated by first solving the equation that represents the relation between specific conductance and streamflow, for a known value of streamflow, and then solving the equation that represents the relation between the individual water-quality constituent and specific conductance for the previously estimated value of specific conductance. Simultaneous solution of the two equations representing the relations is referred to as cascading regressions. The accuracy of a value estimated by this method needs to be examined closely before this method is selected for estimating monthly means. Individual regression equations, the coefficient of determination, and the standard error of estimate for each equation are given. These data can be used to develop and evaluate the cascaded-regression model.

The previously discussed methods could not be used to develop relations for estimating monthly mean concentrations for some of the gaging stations where model input was needed. One alternative method would be to use mean monthly concentrations to represent values for each month for 1931-84.

Another alternative for developing input to the model for these gaging stations would be to use the relations for a similar gaging station (or basin). The model input could be adjusted through trial and error until there was favorable agreement between model output and monthly water-quality statistics (if monthly water-quality statistics were available) for the gaging station.

The quantity and the quality of ground water discharging to the Sheyenne River are needed for model input for reaches of the river where ground water accounts for a substantial part of streamflow during periods of low flow. Considerable ground-water discharge has been identified for two reaches of the Sheyenne River. Ground-water discharge to the Sheyenne River in the vicinity of Warwick, N.Dak., was about 14.8 cubic feet per second and estimated dissolved-solids concentration was about 441 milligrams per liter during October 15 and 16, 1986. Ground-water discharge to the Sheyenne River in a reach between Lisbon and Kindred, N.Dak., ranged from an average of 25.3 cubic feet per second during September 13 to November 19, 1963, to about 45.0 cubic feet per second during October 21 and 22, 1986. Dissolved-solids concentration was estimated at about 442 milligrams per liter during October 21 and 22, 1986.

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SUPPLEMENT 1. STATISTICAL SUMMARIES OF SELECTED WATER-QUALITY DATA

Statistical summaries of selected properties and chemical constituents for the gaging stations are given in tables 21-51. The statistical summaries were developed from water-quality data stored in the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) data base through September 1986. The suite of constituents reported in the tables varies among the gaging stations. Water-quality sampling activities vary considerably from one station to another depending on the needs of cooperators and the objectives of Federal programs. If a constituent is not listed for a gaging station, no data are available for the constituent at that station.

The statistical summaries include the four descriptive statistics of maximum, minimum, mean, and standard deviation about the mean and the values for five percentiles. The percentiles are the percentage of samples in which the values or concentrations were less than or equal to the value given. Although maximum and minimum values define the overall range of occurrence of the properties and chemical constituents sampled, the 90th and 10th percentiles generally define a more effective range for general examination of stream quality. Values greater than the 90th percentile or less than the 10th percentile are outliers that may represent extraordinary events. When outlying values are significantly greater than the 90th percentile or significantly less than the 10th percentile, the median (50th percentile) may provide better information about water quality than does the mean. The mean is affected more by outliers than the median. The 75th percentile values may be used as indicators of concentrations during low-flow conditions, and the 25th percentile values may be used as indicators of concentrations during high-flow conditions.

As a basis for future analysis, the WATSTORE data base was reviewed for selected nutrient, trace-element, and pesticide data. Summaries of selected nutrient and trace-element data are given in tables 21-51. Pesticide data were available for only four of the gaging stations. Pesticide data are available only for the Red River of the North below Fargo, N.Dak., the Sheyenne River near Kindred, N.Dak., the Red River of the North at Grand Forks, N.Dak., and the Red River of the North at Emerson, Man., gaging stations, and these data are listed in tables 22, 31, 42, and 51, respectively.

Nutrient, trace-element, and pesticide data in the WATSTORE data base often contain less-than (<) values. Less-than values indicate that a sample was analyzed for the selected nutrient, trace element, or pesticide, but the concentration was less than the detection limit of the laboratory method used to analyze the sample. The data also may reflect samples that were analyzed at different detection limits. In such cases, different less-than values are reported. One method of computing summary statistics for data containing less-than values is to define a lower bound and an upper bound of the mean value. The lower bound and upper bound within which the mean lies were estimated for the nutrient and trace-element data. The two estimates of the mean were calculated by first substituting zero,

and then substituting the detection limit for less-than values. Data in WATSTORE also often contain remarks that indicate a sample was analyzed but no concentration was detected. The detection limit is not known in such cases. Samples that had unknown detection limits were not used when estimating the lower bound and upper bound of the mean. However, the number of samples that had unkown detection limits is reported separately for trace-element data in tables 21-51.

Table 21.--Statistical summary of selected water-quality data for the Red River of the North at Fargo, North Dakota, gaging station, May 16, 1949, through September 16, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	619	1,150.00	200.00	522.74	119.97	645.00	584.00	514.00	458.00	399.00
Hardness (mg/L as $CaCO_3$)	487	420.00	95.00	248.82	49.00	310.00	280.00	250.00	220.00	190.00
Alkalinity, total (mg/L as $CaCO_3$)	471	364.00	62.00	203.31	43.17	254.80	227.00	207.00	183.00	146.00
Dissolved solids, sum (mg/L)	213	610.00	130.00	314.32	75.26	410.00	360.00	300.00	270.00	240.00
Dissolved solids, residue (mg/L)	472	650.00	134.00	327.00	71.25	422.00	372.00	316.50	278.25	246.30
Calcium, dissolved (mg/L as Ca)	247	82.00	23.00	46.92	9.33	59.00	52.00	45.00	41.00	38.00
Magnesium, dissolved (mg/L as Mg)	247	52.00	8.90	31.82	7.64	41.00	36.00	32.00	29.00	22.00
Sodium, dissolved (mg/L as Na)	484	43.00	5.20	15.14	5.47	22.00	18.00	14.00	11.00	9.20
Potassium, dissolved (mg/L as K)	214	15.00	1.70	5.42	1.62	7.40	6.12	5.20	4.47	3.90
Bicarbonate, total (mg/L as HCO_3)	478	380.00	76.00	246.81	52.50	310.00	280.00	250.00	220.00	179.00
Sulfate, dissolved (mg/L as SO_4)	419	270.00	13.00	72.49	43.26	140.00	99.00	59.00	38.00	29.00
Chloride, dissolved (mg/L as Cl)	215	39.00	0	6.27	3.68	9.60	7.50	6.00	4.50	2.88

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	144	12.00	0.70	0.70
Nitrogen, nitrite, dissolved (mg/L as N)	16	.04	0	0
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	28	2.10	.21	.21
Phosphorus, dissolved (mg/L as P)	46	2.40	.15	.15

Table 21.--Statistical summary of selected water-quality data for the Red River of the North at Fargo, North Dakota, gaging station, May 16, 1949, through September 16, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	18	0	13.00	3.33	3.33
Barium, dissolved (µg/L as Ba)	9	0	600.00	66.67	77.78
Cadmium, dissolved (µg/L as Cd)	8	1	1.00	.37	.62
Chromium, dissolved (µg/L as Cr)	7	2	0	0	0
Lead, dissolved (µg/L as Pb)	17	1	6.00	.94	1.18
Mercury, dissolved (µg/L as Hg)	13	0	.60	.18	.26
Selenium, dissolved (µg/L as Se)	18	0	14.00	2.61	2.72
Silver, dissolved (µg/L as Ag)	6	2	4.00	.67	.67

Table 22.--Statistical summary of selected water-quality data for the Red River of the North below Fargo, North Dakota, gaging station, July 16, 1969, through September 16, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, indicates no value; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	230	1,200.00	290.00	584.86	143.00	738.00	636.00	559.50	500.75	440.40
Hardness (mg/L as $CaCO_3$)	180	510.00	120.00	262.67	48.53	320.00	290.00	260.00	230.00	210.00
Alkalinity, total (mg/L as $CaCO_3$)	111	390.00	62.00	220.04	41.57	180.00	200.00	211.00	240.00	273.20
Dissolved solids, sum (mg/L)	144	741.00	153.00	349.02	106.80	465.00	394.75	327.00	284.00	251.50
Dissolved solids, residue (mg/L)	180	769.00	183.00	371.78	99.17	477.30	414.50	356.00	307.25	272.10
Calcium, dissolved (mg/L as Ca)	169	98.00	30.00	49.57	9.96	63.00	54.00	48.00	43.00	38.00
Magnesium, dissolved (mg/L as Mg)	169	70.00	11.00	33.40	6.67	40.00	36.00	33.00	30.00	27.00
Sodium, dissolved (mg/L as Na)	149	110.00	6.80	24.28	18.73	44.00	24.50	20.00	15.00	12.00
Potassium, dissolved (mg/L as K)	139	20.00	3.70	6.92	2.62	11.00	7.80	6.20	5.30	4.40
Bicarbonate, total (mg/L as HCO_3)	88	470.00	150.00	267.61	46.49	330.00	290.00	260.00	250.00	219.00
Sulfate, dissolved (mg/L as SO_4)	180	330.00	19.00	83.15	51.29	160.00	100.00	69.00	49.00	31.10
Chloride, dissolved (mg/L as Cl)	168	96.00	4.40	14.86	13.37	26.20	14.75	11.00	8.62	7.09

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	34	3.50	0.62	0.62
Nitrogen, nitrite, dissolved (mg/L as N)	22	.04	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	101	2.70	.40	.40
Phosphorus, dissolved (mg/L as P)	93	2.20	.26	.26
Phosphorus, orthophosphate, dissolved (mg/L as P)	9	.78	.41	.41

Table 22.--Statistical summary of selected water-quality data for the Red River of the North below Fargo, North Dakota, gaging station, July 16, 1969, through September 16, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	47	0	10.00	3.91	3.91
Barium, dissolved (µg/L as Ba)	20	0	230.00	78.20	93.20
Cadmium, dissolved (µg/L as Cd)	44	4	26.00	.93	1.86
Chromium, dissolved (µg/L as Cr)	30	19	10.00	1.00	6.33
Lead, dissolved (µg/L as Pb)	43	4	15.00	2.63	3.02
Mercury, dissolved (µg/L as Hg)	42	0	8.00	.27	.50
Selenium, dissolved (µg/L as Se)	44	0	130.00	3.93	4.48
Silver, dissolved (µg/L as Ag)	12	1	2.00	.67	.67

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Aldrin, total (µg/L)	12	.01	0	<0.01
Chlordane, total (µg/L)	10	.1	0	<.01
DDD, total (µg/L)	12	.01	4	.04
DDE, total (µg/L)	12	0.01	2	0.02
DDT, total (µg/L)	12	.01	6	.07
Diazinon, total (µg/L)	3	.01	1	.26
Dieldrin, total (µg/L)	12	.01	7	.03
Endrin, total (µg/L)	12	.01	0	<.01
Heptachlor, total (µg/L)	12	.01	0	<.01
Heptachlor epoxide, total (µg/L)	12	.01	--	--
Lindane, total (µg/L)	12	.01	1	.01
Malathion, total (µg/L)	2	.01	0	<.01
Methyl parathion, total (µg/L)	3	.01	0	<.01

Table 23.--Statistical summary of selected water-quality data for the Sheyenne River above Harvey, North Dakota, gaging station, October 4, 1971, through August 18, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, indicates no value]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	173	2,100.00	50.00	1,162.69	401.02	1,560.00	1,485.00	1,250.00	917.50	492.00
Hardness (mg/L as $CaCO_3$)	100	550.00	58.00	201.54	84.70	320.00	247.50	180.00	140.00	121.00
Alkalinity, total (mg/L as $CaCO_3$)	59	746.00	58.00	515.19	142.59	298.00	240.00	210.00	162.50	121.00
Dissolved solids, sum (mg/L)	99	1,600.00	130.00	854.04	236.79	1,100.00	1,000.00	890.00	790.00	490.00
Dissolved solids, residue (mg/L)	100	1,530.00	152.00	867.44	235.38	1,109.00	1,030.00	901.50	773.25	486.90
Calcium, dissolved (mg/L as Ca)	100	140.00	13.00	35.78	14.87	48.00	41.00	33.00	29.00	23.00
Magnesium, dissolved (mg/L as Mg)	100	69.00	3.20	27.16	14.49	50.80	39.25	22.00	17.00	13.00
Sodium, dissolved (mg/L as Na)	100	370.00	20.00	236.85	85.37	320.00	300.00	260.00	172.50	110.00
Potassium, dissolved (mg/L as K)	99	20.00	4.20	9.12	3.28	14.00	11.00	8.60	6.40	5.10
Bicarbonate, total (mg/L as HCO_3)	35	910.00	270.00	604.29	159.47	770.00	730.00	640.00	520.00	316.00
Sulfate, dissolved (mg/L as SO_4)	100	560.00	37.00	209.57	73.45	298.00	240.00	210.00	162.50	121.00
Chloride, dissolved (mg/L as Cl)	100	54.00	2.20	17.57	6.72	23.90	21.00	17.50	14.00	9.70

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	19	1.10	0.45	0.45
Nitrogen, nitrite, dissolved (mg/L as N)	2	.02	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	85	2.00	.10	.13
Phosphorus, dissolved (mg/L as P)	85	.54	.23	.23
Phosphorus, orthophosphate, dissolved (mg/L as P)	17	.55	.24	.24

Table 23.--Statistical summary of selected water-quality data for the Sheyenne River above Harvey, North Dakota, gaging station, October 4, 1971, through August 18, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	20	0	6.00	2.85	2.85
Barium, dissolved (µg/L as Ba)	20	0	400.00	85.00	95.00
Cadmium, dissolved (µg/L as Cd)	17	3	2.00	.18	1.24
Chromium, dissolved (µg/L as Cr)	14	5	10.00	1.43	7.86
Lead, dissolved (µg/L as Pb)	16	4	11.00	1.56	2.12
Mercury, dissolved (µg/L as Hg)	19	0	.80	.23	.28
Selenium, dissolved (µg/L as Se)	20	0	<1.00	0	.75

Table 24.--Statistical summary of selected water-quality data for the Sheyenne River near Warwick, North Dakota, gaging station, January 8, 1951, through July 8, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	562	1,550.00	210.00	743.64	237.47	1,047.00	911.00	726.50	566.75	440.00
Hardness (mg/L as $CaCO_3$)	492	570.00	71.00	243.85	71.54	330.00	280.00	240.00	210.00	153.00
Alkalinity, total (mg/L as $CaCO_3$)	410	636.00	63.00	290.03	91.94	399.90	354.25	289.00	230.00	174.10
Dissolved solids, sum (mg/L)	144	770.00	130.00	439.51	153.97	645.00	560.00	430.00	320.00	245.00
Dissolved solids, residue (mg/L)	487	1,010.00	150.00	480.17	159.07	689.20	597.00	469.00	360.00	281.00
Calcium, dissolved (mg/L as Ca)	246	110.00	16.00	52.85	16.88	78.00	61.00	52.00	43.00	32.00
Magnesium, dissolved (mg/L as Mg)	246	54.00	6.90	27.42	9.09	38.30	34.00	29.00	21.00	15.00
Sodium, dissolved (mg/L as Na)	492	230.00	10.00	73.17	39.99	130.00	100.00	68.50	40.25	24.30
Potassium, dissolved (mg/L as K)	240	17.00	1.80	7.52	2.63	11.00	9.20	7.70	5.92	3.80
Bicarbonate, total (mg/L as HCO_3)	470	780.00	100.00	351.79	113.11	490.00	430.00	350.00	280.00	210.00
Sulfate, dissolved (mg/L as SO_4)	243	210.00	28.00	95.02	43.40	170.00	120.00	85.00	60.00	45.00
Chloride, dissolved (mg/L as Cl)	213	37.00	.60	12.57	5.84	20.00	17.00	13.00	8.00	5.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	46	4.20	0.35	0.35
Nitrogen, nitrite, dissolved (mg/L as N)	16	.04	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	98	4.20	.21	.22
Phosphorus, dissolved (mg/L as P)	106	10.00	.25	.25
Phosphorus, orthophosphate, dissolved (mg/L as P)	2	.11	.06	.06

Table 24.--Statistical summary of selected water-quality data for the Sheyenne River near Warwick, North Dakota, gaging station, January 8, 1951, through July 8, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	31	0	13.00	5.71	5.74
Barium, dissolved (µg/L as Ba)	22	0	200.00	30.00	80.00
Cadmium, dissolved (µg/L as Cd)	20	2	3.00	.35	1.45
Chromium, dissolved (µg/L as Cr)	9	13	<20.00	0	4.44
Lead, dissolved (µg/L as Pb)	27	2	16.00	1.67	2.15
Mercury, dissolved (µg/L as Hg)	26	0	6.50	.67	.84
Selenium, dissolved (µg/L as Se)	31	0	23.00	3.71	4.10
Silver, dissolved (µg/L as Ag)	5	10	4.00	.80	.80

Table 25.--Statistical summary of selected water-quality data for the Sheyenne River near Cooperstown, North Dakota, gaging station, October 10, 1959, through August 7, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	400	1,880.00	213.00	853.87	249.82	1,100.00	998.00	898.50	741.25	461.70
Hardness (mg/L as $CaCO_3$)	344	680.00	74.00	295.59	87.38	400.00	340.00	300.00	260.00	160.00
Alkalinity, total (mg/L as $CaCO_3$)	308	700.00	64.00	313.27	95.79	422.10	372.00	232.00	270.00	173.20
Dissolved solids, sum (mg/L)	279	1,400.00	120.00	557.67	169.12	720.00	650.00	590.00	490.00	310.00
Dissolved solids, residue (mg/L)	342	1,240.00	143.00	580.22	186.72	742.40	671.25	597.50	509.25	333.10
Calcium, dissolved (mg/L as Ca)	311	150.00	19.00	67.15	21.26	95.80	78.00	67.00	57.00	33.20
Magnesium, dissolved (mg/L as Mg)	311	72.00	6.50	30.97	9.30	40.00	37.00	33.00	27.00	17.00
Sodium, dissolved (mg/L as Na)	344	920.00	10.00	83.97	53.41	110.00	99.00	84.00	65.25	39.50
Potassium, dissolved (mg/L as K)	326	28.00	0	8.71	1.98	11.00	9.60	8.50	7.70	7.10
Bicarbonate, total (mg/L as HCO_3)	257	850.00	80.00	381.14	117.23	520.00	450.00	390.00	330.00	208.00
Sulfate, dissolved (mg/L as SO_4)	293	360.00	21.00	141.69	44.95	190.00	170.00	140.00	120.00	78.00
Chloride, dissolved (mg/L as Cl)	279	39.00	.10	16.12	5.58	22.00	19.00	17.00	13.00	7.70

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	126	1.70	0.20	0.20
Nitrogen, nitrite, dissolved (mg/L as N)	85	.11	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	161	1.70	.19	.19
Phosphorus, dissolved (mg/L as P)	172	.78	.17	.17
Phosphorus, orthophosphate, dissolved (mg/L as P)	70	.44	.14	.14

Table 25.--Statistical summary of selected water-quality data for the Sheyenne River near Cooperstown, North Dakota, gaging station, October 10, 1959, through August 7, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	34	0	12.00	4.06	4.12
Barium, dissolved (µg/L as Ba)	24	0	200.00	17.83	67.83
Cadmium, dissolved (µg/L as Cd)	20	4	11.00	.75	1.80
Chromium, dissolved (µg/L as Cr)	10	12	<20.00	0	6.00
Lead, dissolved (µg/L as Pb)	30	3	200.00	12.87	13.17
Mercury, dissolved (µg/L as Hg)	31	0	.90	.12	.29
Selenium, dissolved (µg/L as Se)	34	0	18.00	2.32	2.74
Silver, dissolved (µg/L as Ag)	5	8	4.00	.80	1.20

Table 26.--Statistical summary of selected water-quality data for the Baldhill Creek near Dazey, North Dakota, gaging station, October 5, 1971, through June 25, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, indicates no value]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	176	1,600.00	204.00	864.15	331.76	1,383.00	1,010.00	895.00	695.50	318.50
Hardness (mg/L as $CaCO_3$)	63	660.00	77.00	299.59	133.37	468.00	370.00	310.00	180.00	104.00
Alkalinity, total (mg/L as $CaCO_3$)	44	560.00	57.00	257.09	119.73	412.50	313.75	280.00	129.75	77.00
Dissolved solids, sum (mg/L)	63	1,000.00	110.00	503.81	227.91	796.00	650.00	530.00	280.00	164.00
Dissolved solids, residue (mg/L)	63	991.00	135.00	514.05	221.26	799.80	651.00	540.00	296.00	174.80
Calcium, dissolved (mg/L as Ca)	63	160.00	20.00	65.29	31.36	110.00	82.00	62.00	40.00	26.40
Magnesium, dissolved (mg/L as Mg)	63	63.00	6.40	33.25	15.08	49.00	44.00	38.00	17.00	9.70
Sodium, dissolved (mg/L as Na)	63	150.00	4.70	56.98	36.35	106.00	79.00	60.00	20.00	7.66
Potassium, dissolved (mg/L as K)	63	16.00	4.80	9.13	2.36	12.00	10.00	8.80	7.50	6.32
Bicarbonate, total (mg/L as HCO_3)	17	590.00	89.00	330.53	128.45	526.00	380.00	350.00	285.00	105.80
Sulfate, dissolved (mg/L as SO_4)	63	300.00	8.00	155.11	73.95	246.00	210.00	170.00	97.00	38.00
Chloride, dissolved (mg/L as Cl)	63	51.00	2.10	17.77	11.59	35.80	23.00	16.00	7.80	4.10

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	49	1.70	0.28	0.28
Nitrogen, nitrite, dissolved (mg/L as N)	37	.06	.01	.02
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	39	1.20	.24	.25
Phosphorus, dissolved (mg/L as P)	38	.36	.09	.09
Phosphorus, orthophosphate, dissolved (mg/L as P)	44	.33	.07	.07

Table 26.--Statistical summary of selected water-quality data for the Baldhill Creek near Dazey, North Dakota, gaging station, October 5, 1971, through June 25, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	10	0	9.00	3.00	3.10
Barium, dissolved (µg/L as Ba)	1	0	170.00	170.00	170.00
Cadmium, dissolved (µg/L as Cd)	1	0	<1.00	0	1.00
Lead, dissolved (µg/L as Pb)	10	0	3.00	.40	.60
Mercury, dissolved (µg/L as Hg)	10	0	10.00	1.18	1.20
Selenium, dissolved (µg/L as Se)	10	0	<1.00	0	.30

Table 27.--Statistical summary of selected water-quality data for the Lake Ashtabula at Baldhill Dam, North Dakota, gaging station, February 19, 1960, through April 8, 1971

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	6	1,100.00	529.00	777.00	217.94	1,100.00	953.00	758.50	591.25	529.00
Hardness (mg/L as $CaCO_3$)	6	350.00	180.00	250.00	64.81	350.00	305.00	240.00	195.00	180.00
Alkalinity, total (mg/L as $CaCO_3$)	6	336.00	189.00	248.33	58.3	336.00	311.25	225.50	205.50	189.00
Dissolved solids, sum (mg/L)	6	720.00	310.00	488.33	154.33	720.00	615.00	470.00	362.50	310.00
Dissolved solids, residue (mg/L)	6	713.00	326.00	507.50	149.67	713.00	627.50	505.50	378.50	326.00
Calcium, dissolved (mg/L as Ca)	6	66.00	40.00	49.17	10.23	66.00	59.25	45.00	41.50	40.00
Magnesium, dissolved (mg/L as Mg)	6	44.00	20.00	30.83	9.81	44.00	39.50	30.50	21.50	20.00
Sodium, dissolved (mg/L as Na)	6	120.00	41.00	74.50	29.00	120.00	96.75	71.50	50.75	41.00
Potassium, dissolved (mg/L as K)	6	13.00	8.40	10.00	1.76	13.00	11.50	9.40	8.70	8.40
Bicarbonate, total (mg/L as HCO_3)	6	410.00	230.00	301.67	71.39	410.00	380.00	270.00	252.50	230.00
Sulfate, dissolved (mg/L as SO_4)	6	240.00	76.00	146.33	64.90	240.00	210.00	135.00	88.00	76.00
Chloride, dissolved (mg/L as Cl)	6	23.00	9.00	15.50	5.96	23.00	22.25	14.50	9.75	9.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	5	0.56	0.29	0.29

Table 28.--Statistical summary of selected water-quality data for the Sheyenne River below Baldhill Dam, North Dakota, gaging station, June 5, 1959, through September 15, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, indicates no value]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	199	1,260.00	285.00	695.93	161.04	920.00	798.00	680.00	580.00	505.00
Hardness (mg/L as $CaCO_3$)	90	360.00	96.00	219.40	48.99	280.00	252.50	210.00	190.00	160.00
Alkalinity, total (mg/L as $CaCO_3$)	72	340.00	86.00	219.87	51.57	294.20	257.25	216.00	190.00	153.00
Dissolved solids, sum (mg/L)	89	750.00	180.00	421.80	105.35	560.00	480.00	410.00	350.00	290.00
Dissolved solids, residue (mg/L)	90	750.00	196.00	432.38	106.18	572.10	489.50	426.00	365.00	310.30
Calcium, dissolved (mg/L as Ca)	90	73.00	22.00	45.61	9.08	56.90	52.25	44.00	39.00	35.10
Magnesium, dissolved (mg/L as Mg)	90	46.00	2.00	25.51	7.03	34.80	30.00	25.00	22.00	18.00
Sodium, dissolved (mg/L as Na)	90	120.00	20.00	62.43	18.94	86.60	73.50	62.50	49.00	40.10
Potassium, dissolved (mg/L as K)	90	16.00	1.80	9.71	1.84	11.90	10.00	9.60	8.80	8.31
Bicarbonate, total (mg/L as HCO_3)	52	410.00	170.00	273.85	58.38	367.00	315.00	270.00	232.50	193.00
Sulfate, dissolved (mg/L as SO_4)	90	230.00	48.00	113.29	32.06	150.00	130.00	110.00	88.75	73.30
Chloride, dissolved (mg/L as Cl)	90	26.00	4.70	13.54	4.35	19.00	16.00	13.00	11.00	8.33

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	50	2.20	0.27	0.27
Nitrogen, nitrite, dissolved (mg/L as N)	30	.05	.02	.02
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	30	.78	.16	.16
Phosphorus, dissolved (mg/L as P)	30	.29	.16	.16
Phosphorus, orthophosphate, dissolved (mg/L as P)	36	.28	.12	.12

Table 28.--Statistical summary of selected water-quality data for the Sheyenne River below Baldhill Dam, North Dakota, gaging station, June 5, 1959, through September 15, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	9	0	8.00	4.56	4.56
Lead, dissolved (µg/L as Pb)	8	0	2.00	.50	.62
Mercury, dissolved (µg/L as Hg)	9	0	.60	.20	.20
Selenium, dissolved (µg/L as Se)	9	0	1.00	.22	.22

Table 29.--Statistical summary of selected water-quality data for the Sheyenne River at Valley City, North Dakota, gaging station, November 3, 1971, through March 22, 1985

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	63	1,000.00	235.00	682.49	135.50	830.00	780.00	700.00	610.00	532.00
Hardness (mg/L as $CaCO_3$)	14	310.00	160.00	232.86	38.11	295.00	250.00	240.00	205.00	175.00
Alkalinity, total (mg/L as $CaCO_3$)	10	260.00	146.00	217.40	36.25	259.80	252.75	216.00	193.00	149.80
Dissolved solids, sum (mg/L)	14	650.00	300.00	443.57	84.91	585.00	485.00	445.00	387.50	325.00
Dissolved solids, residue (mg/L)	14	650.00	287.00	457.00	90.53	597.00	506.75	473.50	392.25	321.00
Calcium, dissolved (mg/L as Ca)	14	60.00	37.00	47.14	6.42	57.00	51.25	47.50	41.75	37.50
Magnesium, dissolved (mg/L as Mg)	14	39.00	16.00	28.00	5.83	37.50	31.25	28.00	25.25	18.50
Sodium, dissolved (mg/L as Na)	14	100.00	35.00	65.64	16.68	94.00	74.25	63.50	51.50	42.50
Potassium, dissolved (mg/L as K)	14	13.00	6.40	9.08	2.58	13.00	12.25	8.40	6.50	6.45
Bicarbonate, total (mg/L as HCO_3)	10	320.00	180.00	266.00	44.27	319.00	310.00	265.00	235.00	184.00
Sulfate, dissolved (mg/L as SO_4)	14	200.00	86.00	125.57	28.43	175.00	135.00	120.00	107.50	89.00
Chloride, dissolved (mg/L as Cl)	14	21.00	6.70	14.41	3.89	20.50	17.25	14.50	12.00	7.90

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	13	1.00	0.40	0.40
Phosphorus, orthophosphate, dissolved (mg/L as P)	6	.39	.21	.21

Table 29.--Statistical summary of selected water-quality data for the Sheyenne River at Valley City, North Dakota, gaging station, November 3, 1971, through March 22, 1985--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	4	0	6.00	4.25	4.25
Lead, dissolved (µg/L as Pb)	4	0	1.00	.25	.25
Mercury, dissolved (µg/L as Hg)	4	0	.80	.40	.40
Selenium, dissolved (µg/L as Se)	4	0	1.00	.25	.25

Table 30.--Statistical summary of selected water-quality data for the Sheyenne River at Lisbon, North Dakota, gaging station, August 2, 1956, through September 10, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	605	5,230.00	289.00	828.85	276.03	1,090.00	969.50	824.00	682.50	545.80
Hardness (mg/L as $CaCO_3$)	569	530.00	100.00	272.93	62.94	360.00	320.00	270.00	230.00	200.00
Alkalinity, total (mg/L as $CaCO_3$)	449	376.00	22.00	227.19	52.08	292.00	260.00	227.00	191.00	162.00
Dissolved solids, sum (mg/L)	287	1,000.00	190.00	528.43	137.81	700.00	620.00	520.00	450.00	358.00
Dissolved solids, residue (mg/L)	554	1,000.00	185.00	544.50	139.26	727.50	637.25	539.50	447.50	371.50
Calcium, dissolved (mg/L as Ca)	322	130.00	30.00	60.42	13.41	77.00	68.25	59.00	51.00	45.00
Magnesium, dissolved (mg/L as Mg)	322	53.00	8.60	29.10	7.49	39.00	34.00	28.50	25.00	19.00
Sodium, dissolved (mg/L as Na)	569	560.00	13.00	75.94	31.89	110.00	91.50	76.00	59.00	42.00
Potassium, dissolved (mg/L as K)	338	22.00	4.90	10.82	2.05	13.00	12.00	11.00	9.60	8.40
Bicarbonate, total (mg/L as HCO_3)	491	460.00	100.00	279.59	60.51	350.00	320.00	280.00	240.00	200.00
Sulfate, dissolved (mg/L as SO_4)	503	450.00	39.00	161.79	56.27	230.00	200.00	150.00	120.00	99.00
Chloride, dissolved (mg/L as Cl)	290	110.00	8.00	31.44	15.94	51.90	40.00	27.50	20.00	15.10

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	32	1.50	0.33	0.33
Nitrogen, nitrite, dissolved (mg/L as N)	13	.16	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	154	1.50	.35	.36
Phosphorus, dissolved (mg/L as P)	166	.49	.13	.13

Table 30.--Statistical summary of selected water-quality data for the Sheyenne River at Lisbon, North Dakota, gaging station, August 2, 1956, through September 10, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	24	0	20.00	3.71	3.71
Barium, dissolved (µg/L as Ba)	22	0	400.00	21.36	75.91
Cadmium, dissolved (µg/L as Cd)	14	5	3.00	.50	1.07
Chromium, dissolved (µg/L as Cr)	11	11	<20.00	0	5.45
Lead, dissolved (µg/L as Pb)	15	4	40.00	5.80	5.93
Mercury, dissolved (µg/L as Hg)	18	0	1.60	.15	.42
Selenium, dissolved (µg/L as Se)	22	0	14.00	2.50	2.73
Silver, dissolved (µg/L as Ag)	4	9	2.00	.75	.75

Table 31.--Statistical summary of selected water-quality data for the Sheyenne River near Kindred, North Dakota, gaging station, September 15, 1969, through September 17, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, indicates no value]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	357	1,210.00	180.00	755.97	160.02	950.00	855.00	749.00	650.00	558.00
Hardness (mg/L as $CaCO_3$)	149	430.00	120.00	292.48	59.85	350.00	330.00	300.00	260.00	210.00
Alkalinity, total (mg/L as $CaCO_3$)	129	340.00	83.00	234.22	56.87	293.00	270.00	250.00	205.00	150.00
Dissolved solids, sum (mg/L)	149	780.00	190.00	511.21	107.32	630.00	585.00	520.00	455.00	360.00
Dissolved solids, residue (mg/L)	152	771.00	200.00	513.22	110.88	630.70	585.00	526.50	460.25	350.00
Calcium, dissolved (mg/L as Ca)	149	110.00	28.00	71.79	15.99	89.00	84.00	76.00	63.00	48.00
Magnesium, dissolved (mg/L as Mg)	149	42.00	11.00	27.45	5.94	34.00	31.00	28.00	25.00	20.00
Sodium, dissolved (mg/L as Na)	149	110.00	9.50	62.45	18.50	85.00	75.00	63.00	51.50	36.00
Potassium, dissolved (mg/L as K)	148	15.00	3.80	8.73	1.65	11.00	9.57	8.55	7.82	6.90
Bicarbonate, total (mg/L as HCO_3)	86	410.00	110.00	291.86	62.26	360.00	330.00	310.00	260.00	190.00
Sulfate, dissolved (mg/L as SO_4)	149	240.00	50.00	145.33	33.48	180.00	170.00	150.00	120.00	100.00
Chloride, dissolved (mg/L as Cl)	149	74.00	5.70	29.74	13.06	48.00	36.50	29.00	20.00	14.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	109	1.60	0.30	0.30
Nitrogen, nitrite, dissolved (mg/L as N)	105	.21	.01	.02
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	144	1.00	.26	.28
Phosphorus, dissolved (mg/L as P)	144	.23	.08	.08
Phosphorus, orthophosphate, dissolved (mg/L as P)	125	.20	.06	.06

Table 31.--Statistical summary of selected water-quality data for the Sheyenne River near Kindred, North Dakota, gaging station, September 15, 1969, through September 17, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	39	0	10.00	4.33	4.33
Barium, dissolved (µg/L as Ba)	38	0	300.00	96.71	125.66
Cadmium, dissolved (µg/L as Cd)	32	2	27.00	1.06	2.06
Chromium, dissolved (µg/L as Cr)	27	11	10.00	1.11	3.85
Lead, dissolved (µg/L as Pb)	29	4	350.00	13.86	14.03
Mercury, dissolved (µg/L as Hg)	45	0	20.00	1.35	1.40
Selenium, dissolved (µg/L as Se)	39	0	1.00	.26	.79
Silver, dissolved (µg/L as Ag)	26	12	<1.00	0	.69

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Aldrin, total (µg/L)	5	0.01	0	<0.01
Chlordane, total (µg/L)	5	.1	0	<.01
DDD, total (µg/L)	5	.01	0	<.01
DDE, total (µg/L)	5	.01	1	.01
DDT, total (µg/L)	5	.01	0	<.01
Diazinon, total (µg/L)	5	.01	0	<.01
Dieldrin, total (µg/L)	5	.01	0	<.01
Endosulfan, total (µg/L)	5	.01	0	<.01
Endrin, total (µg/L)	5	.01	0	<.01
Ethion, total (µg/L)	5	.01	0	<.01
Heptachlor, total (µg/L)	5	.01	0	<.01
Heptachlor epoxide, total (µg/L)	5	.01	0	<.01
Lindane, total (µg/L)	5	.01	0	<.01
Malathion, total (µg/L)	5	.01	0	<.01

Table 31.--Statistical summary of selected water-quality data for the Sheyenne River near Kindred, North Dakota, gaging station, September 15, 1969, through September 17, 1986--Continued

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Methyl parathion, total (µg/L)	5	0.01	0	<0.01
Methyl trithion, total (µg/L)	5	.01	0	<.01
Mirex, total (µg/L)	3	.01	0	<0.01
Naphthalenes, polychlorinated (µg/L)	3	.1	0	<.1
PCB, total (µg/L)	5	.1	0	<.01
Parathion, total (µg/L)	5	.01	0	<.01
Perthane, total (µg/L)	2	.1	0	<.1
Toxaphene, total (µg/L)	5	1	0	<1
Trithion, total (µg/L)	5	.01	0	<.01

Table 32.--Statistical summary of selected water-quality data for the Sheyenne River at West Fargo, North Dakota, gaging station, September 16, 1969, through September 5, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	202	1,700.00	237.00	779.59	232.87	1,047.00	938.50	810.00	628.75	454.40
Hardness (mg/L as $CaCO_3$)	39	400.00	130.00	267.95	78.51	350.00	340.00	290.00	190.00	150.00
Alkalinity, total (mg/L as $CaCO_3$)	29	310.00	124.00	227.97	56.33	282.00	270.50	250.00	172.00	130.00
Dissolved solids, sum (mg/L)	39	650.00	220.00	456.41	129.30	610.00	570.00	520.00	320.00	260.00
Dissolved solids, residue (mg/L)	39	666.00	222.00	461.74	131.36	623.00	570.00	496.00	328.00	263.00
Calcium, dissolved (mg/L as Ca)	39	100.00	24.00	66.23	22.20	96.00	86.00	68.00	46.00	38.00
Magnesium, dissolved (mg/L as Mg)	39	42.00	13.00	24.74	6.49	32.00	30.00	26.00	19.00	16.00
Sodium, dissolved (mg/L as Na)	39	86.00	23.00	54.92	17.57	77.00	69.00	59.00	39.00	30.00
Potassium, dissolved (mg/L as K)	39	14.00	3.30	8.03	1.92	10.00	9.50	7.80	6.90	5.70
Bicarbonate, total (mg/L as HCO_3)	29	380.00	150.00	278.28	68.98	340.00	330.00	310.00	210.00	160.00
Sulfate, dissolved (mg/L as SO_4)	39	190.00	8.60	123.76	42.31	170.00	150.00	130.00	95.00	69.00
Chloride, dissolved (mg/L as Cl)	39	57.00	7.80	27.23	13.28	45.00	38.00	27.00	15.00	9.20

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	14	1.50	0.54	0.54
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	1	.02	.02	.02
Phosphorus, orthophosphate, dissolved (mg/L as P)	7	.30	.14	.14

Table 32.--Statistical summary of selected water-quality data for the Sheyenne River at West Fargo, North Dakota, gaging station, September 16, 1969, through September 5, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	9	0	10.00	4.89	4.89
Lead, dissolved (µg/L as Pb)	9	0	4.00	1.00	1.22
Mercury, dissolved (µg/L as Hg)	9	0	.40	.17	.17
Selenium, dissolved (µg/L as Se)	9	0	<1.00	0	.22

Table 33.--Statistical summary of selected water-quality data for the Maple River near Enderlin, North Dakota, gaging station, October 6, 1971, through September 16, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	186	2,250.00	275.00	1,294.20	460.48	1,750.00	1,600.00	1,480.00	991.25	522.00
Hardness (mg/L as $CaCO_3$)	57	910.00	100.00	590.53	218.20	772.00	735.00	690.00	475.00	158.00
Alkalinity, total (mg/L as $CaCO_3$)	45	431.00	81.00	305.36	87.92	384.00	372.00	340.00	269.50	149.00
Dissolved solids, sum (mg/L)	57	1,500.00	180.00	941.40	337.04	1,200.00	1,150.00	1,100.00	805.00	274.00
Dissolved solids, residue (mg/L)	56	1,570.00	182.00	968.50	346.11	1,290.00	1,180.00	1,105.00	823.50	284.20
Calcium, dissolved (mg/L as Ca)	57	200.00	26.00	144.46	54.48	200.00	180.00	170.00	120.00	38.20
Magnesium, dissolved (mg/L as Mg)	57	110.00	9.50	55.80	22.41	76.40	66.00	62.00	46.00	14.80
Sodium, dissolved (mg/L as Na)	57	160.00	12.00	78.95	33.33	120.00	99.50	79.00	69.50	17.80
Potassium, dissolved (mg/L as K)	57	19.00	5.30	10.35	2.80	14.20	12.00	9.40	8.60	8.00
Bicarbonate, total (mg/L as HCO_3)	43	530.00	99.00	370.44	107.45	466.00	450.00	410.00	340.00	170.00
Sulfate, dissolved (mg/L as SO_4)	57	650.00	42.00	390.79	153.11	520.00	480.00	450.00	310.00	71.80
Chloride, dissolved (mg/L as Cl)	57	140.00	7.10	53.98	29.05	95.00	69.50	50.00	41.00	11.44

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	29	3.20	0.55	0.55
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	3	.10	.04	.04
Phosphorus, dissolved (mg/L as P)	2	.09	.05	.05
Phosphorus, orthophosphate, dissolved (mg/L as P)	17	.31	.11	.11

Table 33.--Statistical summary of selected water-quality data for the Maple River near Enderlin, North Dakota, gaging station, October 6, 1971, through September 16, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	10	0	20.00	5.20	5.20
Lead, dissolved (µg/L as Pb)	9	0	2.00	.56	.67
Mercury, dissolved (µg/L as Hg)	10	0	.50	.22	.22
Selenium, dissolved (µg/L as Se)	10	0	1.00	.20	.30

Table 34.--Statistical summary of selected water-quality data for the Rush River at Amenia, North Dakota, gaging station, November 3, 1971, through September 16, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	105	2,700.00	210.00	1,058.13	567.39	1,720.00	1,430.00	1,100.00	510.00	398.00
Hardness (mg/L as $CaCO_3$)	23	770.00	100.00	429.13	243.98	730.00	660.00	520.00	170.00	138.00
Alkalinity, total (mg/L as $CaCO_3$)	15	374.00	89.00	232.47	97.76	356.00	320.00	279.00	124.00	92.00
Dissolved solids, sum (mg/L)	23	1,400.00	150.00	699.13	432.28	1,260.00	1,100.00	820.00	270.00	190.00
Dissolved solids, residue (mg/L)	23	1,450.00	137.00	737.74	440.48	1,350.00	1,150.00	812.00	299.00	244.00
Calcium, dissolved (mg/L as Ca)	23	180.00	27.00	101.61	55.25	170.00	150.00	120.00	44.00	35.00
Magnesium, dissolved (mg/L as Mg)	23	78.00	8.50	42.54	25.74	73.60	69.00	51.00	15.00	12.00
Sodium, dissolved (mg/L as Na)	23	200.00	7.60	62.52	51.85	126.00	110.00	67.00	15.00	8.16
Potassium, dissolved (mg/L as K)	23	19.00	5.70	11.50	3.61	16.00	15.00	11.00	8.40	6.40
Bicarbonate, total (mg/L as HCO_3)	15	460.00	110.00	282.67	119.55	436.00	390.00	330.00	150.00	110.00
Sulfate, dissolved (mg/L as SO_4)	23	670.00	37.00	295.48	215.49	610.00	480.00	320.00	82.00	52.60
Chloride, dissolved (mg/L as Cl)	23	120.00	2.30	30.75	27.82	63.20	42.00	27.00	7.50	3.62

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	11	3.40	0.61	0.61
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	1	.10	0	.10
Phosphorus, orthophosphate, dissolved (mg/L as P)	5	.22	.13	.13

Table 34.--Statistical summary of selected water-quality data for the Rush River at Amenia, North Dakota, gaging station, November 3, 1971, through September 16, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	9	0	19.00	6.56	6.56
Barium, dissolved (µg/L as Ba)	1	0	84.00	84.00	84.00
Cadmium, dissolved (µg/L as Cd)	1	0	<1.00	0	1.00
Lead, dissolved (µg/L as Pb)	8	0	3.00	.87	1.00
Mercury, dissolved (µg/L as Hg)	9	0	.90	.31	.32
Selenium, dissolved (µg/L as Se)	9	0	2.00	.44	.67

Table 35.--Statistical summary of selected water-quality data for the Buffalo River near Dilworth, Minnesota, gaging station, April 10, 1962, through April 1, 1978

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	116	1,100.00	260.00	634.82	130.02	793.00	747.50	620.00	570.00	448.50
Hardness (mg/L as $CaCO_3$)	10	600.00	120.00	381.00	148.43	594.00	465.00	415.00	275.00	125.00
Alkalinity, total (mg/L as $CaCO_3$)	5	330.00	98.00	256.20	97.42	330.00	330.00	293.00	164.00	98.00
Dissolved solids, sum (mg/L)	10	720.00	160.00	468.00	175.93	714.00	577.50	505.00	332.50	166.00
Dissolved solids, residue (mg/L)	10	736.00	168.00	485.60	177.10	730.20	588.75	527.00	347.25	175.80
Calcium, dissolved (mg/L as Ca)	10	140.00	28.00	83.30	33.81	138.00	99.00	88.50	56.75	29.00
Magnesium, dissolved (mg/L as Mg)	10	59.00	11.00	41.80	15.65	58.90	52.00	46.00	33.25	11.80
Sodium, dissolved (mg/L as Na)	10	27.00	4.50	16.50	6.59	26.40	20.25	18.00	11.62	4.80
Potassium, dissolved (mg/L as K)	10	7.40	4.60	6.02	.87	7.33	6.62	6.15	5.37	4.61
Bicarbonate, total (mg/L as HCO_3)	10	600.00	120.00	338.00	137.74	580.00	400.00	370.00	245.00	122.00
Sulfate, dissolved (mg/L as SO_4)	10	230.00	36.00	130.10	63.39	230.00	170.00	125.00	73.75	39.40
Chloride, dissolved (mg/L as Cl)	10	8.40	0	5.13	2.67	8.39	7.02	5.90	2.90	.26

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	3	0.87	0.40	0.40

Table 36.--Statistical summary of selected water-quality data for the Elm River near Kelso, North Dakota, gaging station, February 19, 1981, through August 1, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	27	1,530.00	248.00	684.85	363.40	1,212.00	1,000.00	520.00	388.00	301.80
Hardness (mg/L as $CaCO_3$)	8	450.00	120.00	232.50	127.36	450.00	365.00	180.00	137.50	120.00
Alkalinity, total (mg/L as $CaCO_3$)	1	174.00	174.00	174.00	--	174.00	174.00	174.00	174.00	174.00
Dissolved solids, sum (mg/L)	8	670.00	180.00	346.25	196.32	670.00	560.00	270.00	200.00	180.00
Dissolved solids, residue (mg/L)	8	710.00	180.00	377.00	210.04	710.00	615.25	292.50	226.50	180.00
Calcium, dissolved (mg/L as Ca)	8	100.00	28.00	56.12	28.93	100.00	90.75	42.50	35.75	28.00
Magnesium, dissolved (mg/L as Mg)	8	49.00	11.00	22.25	14.28	49.00	35.00	16.50	11.75	11.00
Sodium, dissolved (mg/L as Na)	8	59.00	5.90	22.87	20.30	59.00	43.00	14.50	8.52	5.90
Potassium, dissolved (mg/L as K)	8	16.00	8.80	12.01	2.60	16.00	14.50	12.00	9.57	8.80
Bicarbonate, total (mg/L as HCO_3)	1	210.00	210.00	210.00	0	210.00	210.00	210.00	210.00	210.00
Sulfate, dissolved (mg/L as SO_4)	8	210.00	35.00	92.50	65.36	210.00	152.50	69.50	42.00	35.00
Chloride, dissolved (mg/L as Cl)	8	41.00	4.50	16.35	12.51	41.00	25.50	13.50	7.02	4.50

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	4	6.6	2.10	2.10

Table 36.--Statistical summary of selected water-quality data for the Elm River near Kelso, North Dakota, gaging station, February 19, 1981, through August 1, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	8	0	10.00	5.12	5.12
Lead, dissolved (µg/L as Pb)	8	0	1.00	.12	.38
Mercury, dissolved (µg/L as Hg)	8	0	1.00	.38	.39
Selenium, dissolved (µg/L as Se)	8	0	1.00	.12	.38

Table 37.--Statistical summary of selected water-quality data for the Wild Rice River at Hendrum, Minnesota, gaging station, October 1, 1962, through April 8, 1980

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	173	2,150.00	239.00	576.82	219.47	700.00	588.50	540.00	495.00	445.00
Hardness (mg/L as $CaCO_3$)	5	490.00	250.00	322.00	97.83	490.00	405.00	290.00	255.00	250.00
Alkalinity, total (mg/L as $CaCO_3$)	2	294.00	260.00	277.00	24.04	294.00	294.00	277.00	260.00	260.00
Dissolved solids, sum (mg/L)	5	590.00	290.00	380.00	123.69	590.00	490.00	330.00	295.00	290.00
Dissolved solids, residue (mg/L)	5	621.00	309.00	399.20	128.99	621.00	509.00	355.00	311.50	309.00
Calcium, dissolved (mg/L as Ca)	5	92.00	56.00	68.80	14.24	92.00	81.50	66.00	57.50	56.00
Magnesium, dissolved (mg/L as Mg)	5	63.00	26.00	36.60	15.04	63.00	48.50	31.00	27.50	26.00
Sodium, dissolved (mg/L as Na)	5	31.00	8.00	15.80	9.71	31.00	25.50	10.00	9.00	8.00
Potassium, dissolved (mg/L as K)	5	6.50	3.70	4.66	1.11	6.50	5.60	4.50	3.80	3.70
Bicarbonate, total (mg/L as HCO_3)	5	550.00	280.00	362.00	108.03	550.00	450.00	320.00	295.00	280.00
Sulfate, dissolved (mg/L as SO_4)	6	85.00	28.00	49.83	19.64	85.00	61.75	48.00	34.00	28.00
Chloride, dissolved (mg/L as Cl)	116	31.00	0	5.10	3.64	7.96	5.57	4.20	3.40	2.84

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	1	0.10	0.10	0.10
Phosphorus, dissolved (mg/L as P)	105	.31	.05	.05

Table 38.--Statistical summary of selected water-quality data for the Red River of the North at Halstad, Minnesota, gaging station, July 8, 1961, through July 2, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	346	1,650.00	245.00	643.83	171.43	826.00	708.25	650.00	570.00	409.70
Hardness (mg/L as $CaCO_3$)	94	410.00	120.00	279.68	64.20	370.00	320.00	280.00	247.50	200.00
Alkalinity, total (mg/L as $CaCO_3$)	63	690.00	89.00	222.17	82.24	306.00	242.00	220.00	180.00	130.40
Dissolved solids, sum (mg/L)	94	840.00	160.00	399.68	109.59	535.00	470.00	390.00	337.50	280.00
Dissolved solids, residue (mg/L)	94	656.00	176.00	412.07	100.33	546.00	471.75	408.50	353.75	280.50
Calcium, dissolved (mg/L as Ca)	94	89.00	28.00	59.09	12.79	77.50	66.00	59.00	50.75	44.50
Magnesium, dissolved (mg/L as Mg)	94	49.00	12.00	32.05	8.19	42.00	37.00	32.50	28.50	20.00
Sodium, dissolved (mg/L as Na)	94	69.00	7.60	29.93	13.90	49.50	35.25	28.00	21.75	15.00
Potassium, dissolved (mg/L as K)	94	11.00	3.90	6.99	1.60	9.45	8.05	6.85	5.90	4.95
Bicarbonate, total (mg/L as HCO_3)	28	380.00	18.00	218.68	90.35	322.00	280.00	235.00	145.00	101.50
Sulfate, dissolved (mg/L as SO_4)	94	220.00	36.00	102.17	41.48	160.00	130.00	100.00	75.75	48.50
Chloride, dissolved (mg/L as Cl)	94	52.00	4.00	16.56	8.47	29.50	20.00	14.00	11.00	8.20

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	10	3.80	0.85	0.85
Nitrogen, nitrite, dissolved (mg/L as N)	4	.09	.02	.03
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	48	1.80	.43	.43
Phosphorus, dissolved (mg/L as P)	67	1.80	.22	.22
Phosphorus, orthophosphate, dissolved (mg/L as P)	28	.37	.15	.15

Table 38.--Statistical summary of selected water-quality data for the Red River of the North at Halstad, Minnesota, gaging station, July 8, 1961, through July 2, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	35	0	7.00	3.91	3.91
Barium, dissolved (µg/L as Ba)	35	0	200.00	85.66	99.94
Cadmium, dissolved (µg/L as Cd)	31	1	26.00	1.13	2.06
Chromium, dissolved (µg/L as Cr)	27	8	1.00	.04	2.00
Lead, dissolved (µg/L as Pb)	28	3	190.00	8.46	8.75
Mercury, dissolved (µg/L as Hg)	34	0	6.90	.33	.39
Selenium, dissolved (µg/L as Se)	35	0	1.00	.23	.80
Silver, dissolved (µg/L as Ag)	28	7	2.00	.07	.79

Table 39.--Statistical summary of selected water-quality data for the Goose River at Hillsboro, North Dakota, gaging station, September 15, 1969, through August 4, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	196	3,400.00	260.00	1,390.94	605.74	2,153.00	1,750.00	1,370.00	1,047.50	452.50
Hardness (mg/L as $CaCO_3$)	64	930.00	120.00	571.25	203.73	850.00	700.00	600.00	490.00	205.00
Alkalinity, total (mg/L as $CaCO_3$)	56	464.00	91.00	302.87	91.66	431.60	371.50	304.00	260.25	150.80
Dissolved solids, sum (mg/L)	64	2,100.00	180.00	1,003.44	410.05	1,550.00	1,200.00	985.00	832.50	375.00
Dissolved solids, residue (mg/L)	64	2,190.00	184.00	1,051.87	437.47	1,625.00	1,352.50	1,010.50	874.50	358.00
Calcium, dissolved (mg/L as Ca)	64	230.00	32.00	133.33	50.36	205.00	160.00	140.00	110.00	50.00
Magnesium, dissolved (mg/L as Mg)	64	98.00	10.00	57.98	20.98	83.00	72.75	62.00	47.50	20.50
Sodium, dissolved (mg/L as Na)	64	330.00	8.50	113.84	73.47	235.00	137.50	100.00	71.00	23.00
Potassium, dissolved (mg/L as K)	64	20.00	5.90	11.31	3.14	16.00	13.00	11.00	9.20	8.00
Bicarbonate, total (mg/L as HCO_3)	56	570.00	110.00	368.04	112.61	530.00	450.00	370.00	310.00	181.00
Sulfate, dissolved (mg/L as SO_4)	64	800.00	49.00	407.92	166.23	595.00	535.00	415.00	340.00	120.00
Chloride, dissolved (mg/L as Cl)	64	310.00	5.40	84.87	65.40	190.00	100.00	70.00	39.25	18.50

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	35	2.70	0.80	0.80
Phosphorus, orthophosphate, dissolved (mg/L as P)	10	.91	.16	.16

Table 39.--Statistical summary of selected water-quality data for the Goose River at Hillsboro, North Dakota, gaging station, September 15, 1969, through August 4, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	8	0	19.00	8.25	8.25
Lead, dissolved (µg/L as Pb)	8	0	2.00	.37	.62
Mercury, dissolved (µg/L as Hg)	8	0	.60	.20	.21
Selenium, dissolved (µg/L as Se)	8	0	1.00	.12	.37

Table 40.--Statistical summary of selected water-quality data for the Sand Hill River at Climax, Minnesota, gaging station, November 1, 1966, through April 22, 1979

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	1	706.00	706.00	706.00	0	706.00	706.00	706.00	706.00	706.00
Hardness (mg/L as $CaCO_3$)	1	360.00	360.00	360.00	0	360.00	360.00	360.00	360.00	360.00
Alkalinity, total (mg/L as $CaCO_3$)	1	380.00	380.00	380.00	--	380.00	380.00	380.00	380.00	380.00
Dissolved solids, sum (mg/L)	1	440.00	440.00	440.00	0	440.00	440.00	440.00	440.00	440.00
Dissolved solids, residue (mg/L)	1	445.00	445.00	445.00	0	445.00	445.00	445.00	445.00	445.00
Calcium, dissolved (mg/L as Ca)	1	84.00	84.00	84.00	0	84.00	84.00	84.00	84.00	84.00
Magnesium, dissolved (mg/L as Mg)	1	37.00	37.00	37.00	0	37.00	37.00	37.00	37.00	37.00
Sodium, dissolved (mg/L as Na)	1	19.00	19.00	19.00	0	19.00	19.00	19.00	19.00	19.00
Potassium, dissolved (mg/L as K)	1	4.10	4.10	4.10	0	4.10	4.10	4.10	4.10	4.10
Bicarbonate, total (mg/L as HCO_3)	1	380.00	380.00	380.00	0	380.00	380.00	380.00	380.00	380.00
Sulfate, dissolved (mg/L as SO_4)	1	69.00	69.00	69.00	0	69.00	69.00	69.00	69.00	69.00
Chloride, dissolved (mg/L as Cl)	1	15.00	15.00	15.00	0	15.00	15.00	15.00	15.00	15.00

Table 41.--Statistical summary of selected water-quality data for the Red Lake River at Crookston, Minnesota, gaging station, April 11, 1962, through August 12, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; <, less than; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	106	568.00	195.00	386.65	65.89	478.00	415.25	378.50	350.00	310.00
Hardness (mg/L as $CaCO_3$)	106	300.00	100.00	199.91	34.93	250.00	220.00	200.00	180.00	160.00
Alkalinity, total (mg/L as $CaCO_3$)	64	212.00	80.00	165.95	24.72	197.50	180.75	170.00	155.20	132.00
Dissolved solids, sum (mg/L)	107	360.00	68.00	221.38	45.57	282.00	240.00	220.00	190.00	170.00
Dissolved solids, residue (mg/L)	107	388.00	145.00	254.40	48.27	320.40	278.00	242.00	222.00	202.00
Calcium, dissolved (mg/L as Ca)	106	76.00	25.00	50.10	8.74	62.00	54.25	50.00	45.00	40.70
Magnesium, dissolved (mg/L as Mg)	106	28.00	8.40	18.00	3.56	22.30	19.25	18.00	16.00	14.00
Sodium, dissolved (mg/L as Na)	107	14.00	2.30	5.16	1.97	7.02	5.70	4.80	4.00	3.50
Potassium, dissolved (mg/L as K)	107	5.70	1.70	3.23	.90	4.62	3.80	3.00	2.60	2.20
Bicarbonate, total (mg/L as HCO_3)	55	260.00	98.00	198.87	35.83	234.00	220.00	210.00	190.00	130.00
Sulfate, dissolved (mg/L as SO_4)	107	120.00	7.00	34.39	25.34	70.20	48.00	26.00	14.00	11.00
Chloride, dissolved (mg/L as Cl)	107	9.10	0	3.45	1.52	5.34	4.00	3.20	2.70	2.10

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrite, dissolved (mg/L as N)	6	<0.01	0.00	0.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	50	.97	.11	.14
Phosphorus, dissolved (mg/L as P)	51	.97	.05	.05
Phosphorus, orthophosphate, dissolved (mg/L as P)	29	.05	.01	.02

Table 41.--Statistical summary of selected water-quality data for the Red Lake River at Crookston, Minnesota, gaging station, April 11, 1962, through August 12, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	31	0	6.00	2.13	2.16
Barium, dissolved (µg/L as Ba)	30	0	100.00	48.60	60.30
Cadmium, dissolved (µg/L as Cd)	28	3	4.00	.39	1.04
Chromium, dissolved (µg/L as Cr)	29	1	30.00	4.97	7.34
Lead, dissolved (µg/L as Pb)	29	2	5.00	1.41	1.86
Mercury, dissolved (µg/L as Hg)	30	0	2.00	.13	.24
Selenium, dissolved (µg/L as Se)	31	0	10.00	.32	1.06
Silver, dissolved (µg/L as Ag)	30	0	<1.00	0	.63

Table 42.--Statistical summary of selected water-quality data for the Red River of the North at Grand Forks, North Dakota, gaging station, June 22, 1949, through September 26, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, indicates no value; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	723	976.00	200.00	515.90	106.65	640.00	578.00	515.00	451.00	371.40
Hardness (mg/L as $CaCO_3$)	492	790.00	130.00	251.42	61.69	300.00	280.00	250.00	220.00	193.00
Alkalinity, total (mg/L as $CaCO_3$)	460	394.00	83.00	199.94	41.57	243.90	221.00	199.00	176.00	153.00
Dissolved solids, sum (mg/L)	211	1,900.00	160.00	318.20	126.34	400.00	360.00	310.00	270.00	230.00
Dissolved solids, residue (mg/L)	470	540.00	162.00	338.46	61.93	419.80	380.00	334.00	300.00	259.00
Calcium, dissolved (mg/L as Ca)	244	83.00	33.00	54.98	9.34	68.00	61.00	54.00	49.00	43.50
Magnesium, dissolved (mg/L as Mg)	243	40.00	5.70	25.14	5.85	33.00	29.00	25.00	21.00	18.00
Sodium, dissolved (mg/L as Na)	491	43.00	2.60	17.03	6.00	25.00	20.00	16.00	13.00	10.00
Potassium, dissolved (mg/L as K)	212	20.00	.80	5.10	1.84	6.80	5.70	4.90	4.12	3.60
Bicarbonate, total (mg/L as HCO_3)	477	480.00	110.00	243.92	50.01	300.00	270.00	240.00	220.00	190.00
Sulfate, dissolved (mg/L as SO_4)	426	150.00	18.00	71.94	28.08	110.00	94.00	68.00	49.00	37.00
Chloride, dissolved (mg/L as Cl)	213	34.00	0	9.03	4.30	14.00	10.50	8.60	6.40	5.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	117	8.40	1.06	1.06
Nitrogen, nitrite, dissolved (mg/L as N)	14	.02	0	0
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	29	1.80	.38	.39
Phosphorus, dissolved (mg/L as P)	48	.27	.12	.12
Phosphorus, orthophosphate, dissolved (mg/L as P)	6	.20	.09	.09

Table 42.--Statistical summary of selected water-quality data for the Red River of the North at Grand Forks, North Dakota, gaging station, June 22, 1949, through September 26, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	26	0	13.00	3.08	3.12
Barium, dissolved (µg/L as Ba)	14	0	300.00	34.00	55.43
Cadmium, dissolved (µg/L as Cd)	17	3	7.00	.47	.76
Chromium, dissolved (µg/L as Cr)	16	4	0	0	0
Lead, dissolved (µg/L as Pb)	32	1	5.00	.47	.66
Mercury, dissolved (µg/L as Hg)	21	0	1.40	.21	.27
Selenium, dissolved (µg/L as Se)	26	0	23.00	3.31	3.46
Silver, dissolved (µg/L as Ag)	9	1	5.00	1.56	1.78

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Aldrin, total (µg/L)	7	0.01	0	<0.01
Aldrin, dissolved (µg/L)	7	.01	0	<.01
Chlordane, total (µg/L)	7	.1	0	<.1
Chlordane, dissolved (µg/L)	7	.1	0	<.1
DDD, total (µg/L)	7	.01	0	<.01
DDD, dissolved (µg/L)	7	.01	0	<.01
DDE, total (µg/L)	7	.01	1	.01
DDE, dissolved (µg/L)	7	.01	0	<.01
DDT, total (µg/L)	7	.01	0	<.01
DDT, dissolved (µg/L)	7	.01	0	<.01
Diazinon, total (µg/L)	5	.01	2	.01
Diazinon, dissolved (µg/L)	7	.01	3	.01
Dieldrin, total (µg/L)	7	.01	0	<.01
Dieldrin, dissolved (µg/L)	7	.01	0	<.01

Table 42.--Statistical summary of selected water-quality data for the Red River of the North at Grand Forks, North Dakota, gaging station, June 22, 1949, through September 26, 1986--Continued

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Endrin, total (µg/L)	7	0.01	0	<0.01
Endrin, dissolved (µg/L)	7	.01	0	<.01
Heptachlor, total (µg/L)	7	.01	0	<.01
Heptachlor, dissolved (µg/L)	7	.01	0	<.01
Heptachlor epoxide, total (µg/L)	7	.01	0	<.01
Heptachlor epoxide, dissolved (µg/L)	7	.01	0	<.01
Lindane, total (µg/L)	6	.01	0	<.01
Lindane, dissolved (µg/L)	7	.01	0	<.01
Malathion, total (µg/L)	5	.01	0	<.01
Malathion, dissolved (µg/L)	7	.01	0	<.01
Methyl parathion, total (µg/L)	5	.01	0	<.01
Methyl parathion, dissolved (µg/L)	7	.01	--	--
PCB, total (µg/L)	7	.1	0	<.01
PCB, dissolved (µg/L)	7	.1	0	<.1
Parathion, total (µg/L)	5	.01	0	<.01
Parathion, dissolved (µg/L)	7	.01	0	<.01
Silvex, dissolved (µg/L)	7	.01	0	<.01
2,4-D, dissolved (µg/L)	7	.01	3	.07
2,4,5-T, dissolved (µg/L)	7	.01	1	.02

Table 43.--Statistical summary of selected water-quality data for the Turtle River at Manvel, North Dakota, gaging station, October 15, 1971, through March 28, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	37	7,300.00	770.00	2,701.84	1,507.65	4,350.00	3,415.00	2,340.00	1,700.00	955.60
Hardness (mg/L as $CaCO_3$)	35	1,800.00	210.00	612.57	335.28	1,080.00	790.00	550.00	350.00	250.00
Alkalinity, total (mg/L as $CaCO_3$)	21	398.00	100.00	219.48	91.26	380.00	288.50	200.00	140.00	113.40
Dissolved solids, sum (mg/L)	35	8,100.00	450.00	1,838.57	1,452.40	3,460.00	2,000.00	1,400.00	940.00	548.00
Dissolved solids, residue (mg/L)	34	4,440.00	465.00	1,669.29	973.86	2,925.00	2,092.50	1,435.00	967.25	559.00
Calcium, dissolved (mg/L as Ca)	35	410.00	54.00	141.91	71.95	230.00	190.00	130.00	89.00	62.60
Magnesium, dissolved (mg/L as Mg)	35	200.00	18.00	63.06	40.05	128.00	77.00	56.00	32.00	23.00
Sodium, dissolved (mg/L as Na)	35	2,100.00	63.00	416.69	390.46	914.00	480.00	290.00	180.00	93.20
Potassium, dissolved (mg/L as K)	35	83.00	8.10	18.49	12.76	27.80	18.00	16.00	13.00	11.00
Bicarbonate, total (mg/L as HCO_3)	13	490.00	150.00	319.23	110.49	482.00	415.00	330.00	240.00	154.00
Sulfate, dissolved (mg/L as SO_4)	35	1,600.00	100.00	400.86	280.53	760.00	450.00	330.00	240.00	142.00
Chloride, dissolved (mg/L as Cl)	35	3,600.00	89.00	650.54	670.91	1440.00	780.00	440.00	280.00	138.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	13	2.20	0.77	0.77
Nitrogen, nitrite, dissolved (mg/L as N)	1	0	0	0
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	18	2.20	.45	.46
Phosphorus, orthophosphate, dissolved (mg/L as P)	29	.45	.10	.10

Table 43.--Statistical summary of selected water-quality data for the Turtle River at Manvel, North Dakota, gaging station, October 15, 1971, through March 28, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	4	0	3.00	2.00	2.00
Lead, dissolved (µg/L as Pb)	4	0	1.00	.25	.25
Mercury, dissolved (µg/L as Hg)	4	0	.20	.15	.15
Selenium, dissolved (µg/L as Se)	4	0	2.00	.50	.75

Table 44.--Statistical summary of selected water-quality data for the Forest River at Minto, North Dakota, gaging station, October 6, 1971, through September 2, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	170	2,120.00	240.00	813.68	308.09	1,156.00	909.25	780.00	670.00	460.00
Hardness (mg/L as $CaCO_3$)	65	850.00	110.00	340.77	110.74	480.00	365.00	330.00	300.00	186.00
Alkalinity, total (mg/L as $CaCO_3$)	54	567.00	76.00	251.61	79.98	352.50	284.00	246.00	220.00	152.50
Dissolved solids, sum (mg/L)	65	1,400.00	150.00	499.23	171.58	648.00	550.00	490.00	435.00	294.00
Dissolved solids, residue (mg/L)	65	1,370.00	171.00	513.45	171.33	671.40	569.50	503.00	444.00	295.20
Calcium, dissolved (mg/L as Ca)	65	180.00	32.00	81.43	25.18	110.00	88.50	78.00	72.00	45.20
Magnesium, dissolved (mg/L as Mg)	65	140.00	7.30	33.43	16.52	46.20	36.00	33.00	29.00	17.60
Sodium, dissolved (mg/L as Na)	65	170.00	6.00	39.73	21.39	60.00	45.00	37.00	29.00	21.20
Potassium, dissolved (mg/L as K)	65	62.00	3.60	7.30	7.11	9.30	7.55	6.00	5.00	4.60
Bicarbonate, total (mg/L as HCO_3)	54	690.00	93.00	304.50	97.50	430.00	332.50	295.00	270.00	195.00
Sulfate, dissolved (mg/L as SO_4)	65	290.00	36.00	134.97	45.12	188.00	150.00	130.00	115.00	79.60
Chloride, dissolved (mg/L as Cl)	65	270.00	1.30	35.07	34.99	61.60	43.50	26.00	18.00	14.00

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	39	2.70	0.64	0.64
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	3	.58	.19	.26
Phosphorus, orthophosphate, dissolved (mg/L as P)	27	.13	.03	.03

Table 44.--Statistical summary of selected water-quality data for the Forest River at Minto, North Dakota, gaging station, October 6, 1971, through September 2, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	13	0	11.00	3.92	3.92
Barium, dissolved (µg/L as Ba)	3	0	180.00	110.00	110.00
Cadmium, dissolved (µg/L as Cd)	3	0	<1.00	0	1.00
Lead, dissolved (µg/L as Pb)	13	0	2.00	.23	1.23
Mercury, dissolved (µg/L as Hg)	11	0	.80	.22	.23
Selenium, dissolved (µg/L as Se)	13	0	1.00	.46	.62

Table 45.--Statistical summary of selected water-quality data for the Snake River at Warren, Minnesota, gaging station, September 16, 1953, through July 29, 1955

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	16	1,090.00	302.00	733.81	188.03	950.00	854.25	766.50	628.00	421.00
Hardness, (mg/L as $CaCO_3$)	16	442.00	132.00	360.87	89.31	436.40	426.00	400.00	315.75	195.00
Dissolved solids, residue (mg/L)	15	684.00	195.00	492.20	125.87	633.60	579.00	518.00	433.00	258.00
Calcium, dissolved (mg/L as Ca)	9	93.00	50.00	80.78	14.09	93.00	92.00	84.00	72.50	50.00
Magnesium, dissolved (mg/L as Mg)	9	51.00	24.00	43.78	8.98	51.00	49.00	48.00	38.00	24.00
Bicarbonate, total (mg/L as HCO_3)	16	406.00	101.00	304.75	88.13	403.20	369.50	335.50	247.75	163.30
Sulfate, dissolved (mg/L as SO_4)	16	195.00	57.00	135.69	33.99	185.20	154.50	137.00	123.50	75.90
Chloride, dissolved (mg/L as Cl)	16	93.00	.50	14.12	23.29	54.50	14.25	5.75	2.25	.50

Table 46.--Statistical summary of selected water-quality data for the Middle River at Argyle, Minnesota, gaging station, April 10, 1954, through August 23, 1955

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	21	847.00	275.00	546.43	132.93	657.40	628.50	579.00	478.00	298.20
Hardness (mg/L as $CaCO_3$)	21	467.00	124.00	291.43	81.25	364.40	343.50	308.00	238.50	143.60
Dissolved solids, residue (mg/L)	21	533.00	180.00	360.95	89.11	444.80	428.50	367.00	305.50	194.80
Calcium, dissolved (mg/L as Ca)	11	101.00	30.00	69.64	22.36	97.80	84.00	75.00	52.00	30.60
Magnesium, dissolved (mg/L as Mg)	11	52.00	12.00	29.82	11.38	49.20	36.00	31.00	22.00	12.20
Bicarbonate, total (mg/L as HCO_3)	21	536.00	106.00	289.76	95.24	372.00	343.00	300.00	232.50	133.00
Sulfate, dissolved (mg/L as SO_4)	21	89.00	25.00	63.24	18.55	86.00	79.50	64.00	47.00	37.40
Chloride, dissolved (mg/L as Cl)	21	11.00	0	2.88	2.94	8.40	4.50	2.00	1.00	.20

Table 47.--Statistical summary of selected water-quality data for the Park River at Grafton, North Dakota, gaging station, September 22, 1969, through September 2, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	177	1,920.00	289.00	1,046.03	389.65	1,500.00	1,305.00	1,110.00	800.00	420.00
Hardness (mg/L as $CaCO_3$)	54	580.00	120.00	322.78	111.94	450.00	420.00	315.00	237.50	155.00
Alkalinity, total (mg/L as $CaCO_3$)	45	358.00	76.00	210.53	67.35	295.00	261.50	214.00	168.50	108.80
Dissolved solids, sum (mg/L)	54	1,200.00	190.00	647.59	249.84	940.00	812.50	720.00	402.50	285.00
Dissolved solids, residue (mg/L)	54	1,240.00	83.00	653.44	260.70	960.50	841.75	696.50	425.25	302.50
Calcium, dissolved (mg/L as Ca)	54	130.00	31.00	78.09	27.44	120.00	98.50	75.50	58.00	39.50
Magnesium, dissolved (mg/L as Mg)	54	61.00	8.10	30.95	12.56	47.00	39.25	33.00	20.00	14.50
Sodium, dissolved (mg/L as Na)	54	200.00	12.00	96.50	53.26	170.00	132.50	100.00	45.00	26.50
Potassium, dissolved (mg/L as K)	54	14.00	3.80	8.22	2.04	11.00	9.60	8.10	6.90	5.15
Bicarbonate, total (mg/L as HCO_3)	45	440.00	93.00	256.73	81.88	360.00	320.00	260.00	205.00	130.00
Sulfate, dissolved (mg/L as SO_4)	54	420.00	60.00	203.17	79.24	300.00	250.00	200.00	130.00	88.00
Chloride, dissolved (mg/L as Cl)	54	240.00	6.20	92.31	62.16	185.00	132.50	85.00	30.50	17.50

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	23	2.90	0.65	0.65
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	1	1.50	1.50	1.50
Phosphorus, orthophosphate, dissolved (mg/L as P)	8	.25	.08	.08

Table 47.--Statistical summary of selected water-quality data for the Park River at Grafton, North Dakota, gaging station, September 22, 1969, through September 2, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	11	0	12.00	4.36	4.36
Barium, dissolved (µg/L as Ba)	1	0	34.00	34.00	34.00
Cadmium, dissolved (µg/L as Cd)	1	0	<3.00	0	<3.00
Lead, dissolved (µg/L as Pb)	11	0	3.00	.36	.55
Mercury, dissolved (µg/L as Hg)	11	0	1.00	.33	.34
Selenium, dissolved (µg/L as Se)	11	0	1.00	.27	.36

Table 48.--Statistical summary of selected water-quality data for the Red River of the North at Drayton, North Dakota, gaging station, October 12, 1971, through August 28, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	226	2,010.00	275.00	611.99	240.16	860.00	690.00	580.00	471.50	364.10
Hardness (mg/L as $CaCO_3$)	27	320.00	120.00	225.19	54.16	294.00	270.00	230.00	190.00	154.00
Alkalinity, total (mg/L as $CaCO_3$)	18	233.00	93.00	166.39	44.03	227.60	198.20	175.00	128.25	102.00
Dissolved solids, sum (mg/L)	26	570.00	170.00	336.54	102.02	477.00	407.50	325.00	265.00	201.00
Dissolved solids, residue (mg/L)	27	651.00	197.00	366.00	118.26	568.80	452.00	343.00	272.00	208.00
Calcium, dissolved (mg/L as Ca)	27	95.00	29.00	53.48	14.11	68.40	63.00	53.00	42.00	35.20
Magnesium, dissolved (mg/L as Mg)	27	35.00	3.20	22.23	7.34	31.40	29.00	22.00	18.00	12.00
Sodium, dissolved (mg/L as Na)	27	120.00	7.30	35.37	27.83	80.00	43.00	26.00	17.00	11.34
Potassium, dissolved (mg/L as K)	27	8.30	3.10	5.80	1.60	7.68	7.30	5.20	4.50	3.60
Bicarbonate, total (mg/L as HCO_3)	18	280.00	110.00	201.11	54.87	271.00	242.50	210.00	152.50	119.00
Sulfate, dissolved (mg/L as SO_4)	27	120.00	35.00	72.93	25.86	120.00	91.00	69.00	51.00	37.00
Chloride, dissolved (mg/L as Cl)	27	160.00	4.80	43.65	40.72	116.00	54.00	30.00	18.00	8.12

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	14	3.60	0.91	0.91
Phosphorus, orthophosphate, dissolved (mg/L as P)	4	.17	.09	.09

Table 48.--Statistical summary of selected water-quality data for the Red River of the North at Drayton, North Dakota, gaging station, October 12, 1971, through August 28, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	10	0	5.00	2.90	2.90
Lead, dissolved (µg/L as Pb)	10	0	4.00	.40	.60
Mercury, dissolved (µg/L as Hg)	10	0	.60	.25	.25
Selenium, dissolved (µg/L as Se)	10	0	3.00	.50	.60

Table 49.--Statistical summary of selected water-quality data for the Pembina River at Neche, North Dakota, gaging station, October 13, 1971, through August 21, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	166	1,700.00	250.00	785.72	260.84	1,100.00	950.00	827.50	621.75	410.00
Hardness (mg/L as $CaCO_3$)	27	570.00	98.00	282.15	112.52	392.00	370.00	280.00	180.00	138.00
Alkalinity, total (mg/L as $CaCO_3$)	18	278.00	88.00	186.94	72.21	272.60	262.00	171.00	121.50	99.70
Dissolved solids, sum (mg/L)	27	760.00	200.00	442.96	152.13	600.00	580.00	440.00	300.00	218.00
Dissolved solids, residue (mg/L)	27	763.00	194.00	454.00	152.89	617.40	576.00	466.00	308.00	220.00
Calcium, dissolved (mg/L as Ca)	27	140.00	26.00	68.78	26.89	97.20	90.00	69.00	46.00	34.00
Magnesium, dissolved (mg/L as Mg)	27	53.00	8.00	26.57	11.40	39.20	35.00	26.00	17.00	9.70
Sodium, dissolved (mg/L as Na)	27	55.00	19.00	37.89	11.16	52.20	48.00	39.00	28.00	19.80
Potassium, dissolved (mg/L as K)	27	13.00	3.20	7.32	2.56	11.20	9.10	7.40	5.20	3.84
Bicarbonate, total (mg/L as HCO_3)	18	340.00	110.00	225.00	85.97	331.00	320.00	205.00	147.50	119.00
Sulfate, dissolved (mg/L as SO_4)	27	250.00	56.00	149.67	51.00	210.00	190.00	160.00	110.00	72.20
Chloride, dissolved (mg/L as Cl)	27	34.00	3.40	13.73	7.61	24.60	18.00	14.00	7.30	5.40

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	15	1.70	0.57	0.57
Phosphorus, orthophosphate, dissolved (mg/L as P)	5	.20	.12	.12

Table 49.--Statistical summary of selected water-quality data for the Pembina River at Neche, North Dakota, gaging station, October 13, 1971, through August 21, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	10	0	12.0	3.60	3.60
Lead, dissolved (µg/L as Pb)	10	0	1.0	.20	.40
Mercury, dissolved (µg/L as Hg)	10	0	.7	.23	.23
Selenium, dissolved (µg/L as Se)	10	0	2.0	.60	.60

Table 50.--Statistical summary of selected water-quality data for the Tongue River at Akra, North Dakota, gaging station, October 14, 1971, through September 30, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, indicates no value]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	157	923.00	235.00	566.05	119.09	717.00	650.00	561.00	507.50	409.00
Hardness (mg/L as $CaCO_3$)	51	340.00	100.00	230.78	56.63	310.00	260.00	230.00	200.00	140.00
Alkalinity, total (mg/L as $CaCO_3$)	42	309.00	80.00	199.81	55.99	283.40	245.00	190.50	162.75	124.20
Dissolved solids, sum (mg/L)	51	460.00	170.00	332.16	66.10	410.00	380.00	340.00	300.00	232.00
Dissolved solids, residue (mg/L)	50	503.00	172.00	346.72	71.00	435.70	398.50	350.50	310.75	237.70
Calcium, dissolved (mg/L as Ca)	51	98.00	28.00	61.49	15.12	81.60	70.00	62.00	55.00	39.40
Magnesium, dissolved (mg/L as Mg)	51	35.00	6.70	18.93	5.57	26.00	22.00	20.00	16.00	11.20
Sodium, dissolved (mg/L as Na)	51	37.00	11.00	24.69	5.38	30.00	28.00	25.00	21.00	17.00
Potassium, dissolved (mg/L as K)	51	12.00	2.80	5.89	1.47	7.58	6.70	5.80	5.00	4.34
Bicarbonate, total (mg/L as HCO_3)	34	380.00	97.00	240.21	73.39	345.00	310.00	230.00	197.50	140.00
Sulfate, dissolved (mg/L as SO_4)	51	110.00	37.00	81.41	18.44	100.00	95.00	86.00	70.00	51.40
Chloride, dissolved (mg/L as Cl)	51	25.00	2.20	9.28	3.27	13.00	11.00	8.90	7.40	6.32

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	30	2.30	0.57	0.57
Nitrogen, nitrite, dissolved (mg/L as N)	8	.06	.02	.02
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	8	.34	.12	.12
Phosphorus, dissolved (mg/L as P)	8	.20	.07	.07
Phosphorus, orthophosphate, dissolved (mg/L as P)	20	.16	.06	.06

Table 50.--Statistical summary of selected water-quality data for the Tongue River at Akra, North Dakota, gaging station, October 14, 1971, through September 30, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	9	0	11.00	4.33	4.33
Lead, dissolved (µg/L as Pb)	9	0	1.00	.33	.44
Mercury, dissolved (µg/L as Hg)	9	0	.50	.20	.20
Selenium, dissolved (µg/L as Se)	9	0	2.00	.56	.67

Table 51.--Statistical summary of selected water-quality data for the Red River of the North at Emerson, Manitoba, gaging station, September 15, 1969, through September 23, 1986

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, indicates no value; µg/L, micrograms per liter; <, less than]

Property or chemical constituent	Number of samples	Descriptive statistics				Percentage of samples in which values were less than or equal to that shown				
		Maximum	Minimum	Mean	Standard deviation	90	75	50	25	10
Specific conductance (µS/cm)	314	1,810.00	130.00	577.75	170.32	685.00	648.00	532.00	505.00	494.00
Hardness (mg/L as $CaCO_3$)	72	500.00	170.00	267.22	56.37	347.00	297.50	260.00	230.00	200.00
Alkalinity, total (mg/L as $CaCO_3$)	43	290.00	110.00	206.49	38.62	250.60	230.00	210.00	180.00	164.00
Dissolved solids, sum (mg/L)	71	1,100.00	200.00	402.68	140.15	556.00	450.00	370.00	330.00	264.00
Dissolved solids, residue (mg/L)	72	1,100.00	251.00	430.29	143.00	571.20	469.75	408.00	349.75	303.50
Calcium, dissolved (mg/L as Ca)	72	110.00	40.00	61.06	11.85	78.00	68.00	60.00	52.25	48.00
Magnesium, dissolved (mg/L as Mg)	72	54.00	16.00	27.89	6.65	37.00	31.00	27.00	24.00	19.30
Sodium, dissolved (mg/L as Na)	72	190.00	11.00	42.75	34.22	81.50	49.50	30.50	24.00	19.30
Potassium, dissolved (mg/L as K)	72	13.00	3.80	6.16	1.87	7.87	6.70	5.80	4.92	4.30
Bicarbonate, total (mg/L as HCO_3)	7	350.00	34.00	240.57	110.40	350.00	330.00	260.00	160.00	34.00
Sulfate, dissolved (mg/L as SO_4)	72	220.00	6.00	84.92	38.22	140.00	100.00	77.50	58.00	47.00
Chloride, dissolved (mg/L as Cl)	72	240.00	9.80	50.09	47.33	106.70	59.50	33.50	22.00	15.30

Nutrients	Number of samples	Maximum	Estimated mean	
			Lower bound	Upper bound
Nitrogen, nitrate, dissolved (mg/L as N)	1	0.98	0.98	0.98
Nitrogen, nitrite, dissolved (mg/L as N)	3	.02	.01	.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	52	2.20	.39	.40
Phosphorus, dissolved (mg/L as P)	69	.75	.13	.13
Phosphorus, orthophosphate, dissolved (mg/L as P)	27	.25	.09	.09

Table 51.--Statistical summary of selected water-quality data for the Red River of the North at Emerson, Manitoba, gaging station, September 15, 1969 through September 23, 1986--Continued

Trace elements	Number of samples		Maximum	Estimated mean	
	With known detection limit	With unknown detection limit		Lower bound	Upper bound
Arsenic, dissolved (µg/L as As)	33	0	11.00	3.18	3.21
Barium, dissolved (µg/L as Ba)	32	0	240.00	88.00	106.75
Cadmium, dissolved (µg/L as Cd)	29	3	2.00	.07	1.17
Chromium, dissolved (µg/L as Cr)	25	7	10.00	1.04	2.60
Lead, dissolved (µg/L as Pb)	27	2	5.00	1.19	1.63
Mercury, dissolved (µg/L as Hg)	32	0	.30	.04	.09
Selenium, dissolved (µg/L as Se)	33	0	1.00	.33	.82
Silver, dissolved (µg/L as Ag)	26	6	1.00	.04	.65

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Aldrin, total (µg/L)	15	0.01	0	<0.01
Atrazine, total (µg/L)	3	.1	0	<.1
Chlordane, total (µg/L)	15	.1	0	<.1
DDD, total (µg/L)	15	.01	0	<.01
DDE, total (µg/L)	14	.01	0	<.01
DDT, total (µg/L)	15	.01	0	<.01
Diazinon, total (µg/L)	13	.01	0	<.01
Dieldrin, total (µg/L)	15	.01	0	<.01
Endosulfan, total (µg/L)	3	.01	0	<.01
Endrin, total (µg/L)	15	.01	0	<.01
Ethion, total (µg/L)	13	.01	0	<.01
Heptachlor, total (µg/L)	15	.01	0	<.01
Heptachlor epoxide, total (µg/L)	15	.01	0	<.01
Lindane, total (µg/L)	15	.01	0	<.01

Table 51.--Statistical summary of selected water-quality data for the Red River of the North at Emerson, Manitoba, gaging station, July 9, 1974, through September 23, 1986--Continued

Pesticides	Number of samples	Detection limit (micrograms per liter)	Number of samples exceeding detection limit	Maximum (micrograms per liter)
Malathion, total (µg/L)	13	0.01	0	<0.01
Methoxychlor, total (µg/L)	15	.01	1	.01
Methyl parathion, total (µg/L)	13	.01	0	<.01
Methyl trithion, total (µg/L)	13	.01	0	<.01
Mirex, total (µg/L)	3	.01	0	<.01
Naphthalenes, polychlorinated (µg/L)	2	.1	--	--
PCB, total (µg/L)	13	.1	0	<.1
Parathion, total (µg/L)	13	.01	0	<.01
Perthane, total (µg/L)	2	.1	0	<.1
Silvex, dissolved (µg/L)	1	.01	0	<.01
Toxaphene, total (µg/L)	14	1	0	<1
Trithion, total (µg/L)	13	.01	0	<.01