SELECTED BASIN CHARACTERISTICS AND WATER-QUALITY DATA FOR THE MINNESOTA RIVER BASIN

Thomas A. Winterstein, Gregory A. Payne, Rebecca A. Miller, and James R. Stark

---

U.S. GEOLOGICAL SURVEY

Open-File Report 93-164

Prepared in cooperation with the
MINNESOTA POLLUTION CONTROL AGENCY and the
LEGISLATIVE COMMISSION ON MINNESOTA RESOURCES

Mounds View, Minnesota
1993

U.S. DEPARTMENT OF THE INTERIOR

Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
2280 Woodale Drive
Mounds View, MN 55112

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports
Box 25425, Mail Stop 517
Federal Center
Denver, CO 80225-0425

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4047	$hectometer^2$
$mile^2$ (mi^2)	2.590	$kilometer^2$

Selected Basin Characteristics and Water-Quality Data for the Minnesota River Basin

ABSTRACT

Selected basin characteristics and water-quality data for the Minnesota River Basin are presented in this report as 71 maps, 22 graphs, and 8 tables. The data were compiled as part of a four-year study to identify non-point sources of pollution and the effect of this pollution on water quality. The maps were prepared from geographic information system data bases. Federal, State, and local agencies, and colleges and universities collected and assembled these data as part of the Minnesota River Assessment Project.

INTRODUCTION

The Minnesota River drains nearly 17,000 square miles in southwestern Minnesota and parts of eastern South Dakota, northern Iowa, and southeastern North Dakota (fig. 1). A study by the Minnesota Pollution Control Agency (MPCA) demonstrated that the Minnesota River and its tributaries are significantly affected by non-point source pollution (Minnesota Pollution Control Agency, 1982). High concentrations of suspended solids, nitrate, phosphorus, and fecal coliform bacteria impair industrial, domestic, and recreational use of the river, as well as the esthetics of the riverine environment. A waste-load allocation study in the Lower Minnesota River Basin (Minnesota Pollution Control Agency, 1985) identified a need for a basin-wide program to control surface-runoff-related non-point source pollutants.

The MPCA coordinated a multiagency effort to study the Minnesota River and its tributaries. The Minnesota River Assessment Project (MRAP) was a four-year study to assess the potential for non-point source pollution, to inventory information about physical characteristics of the basin, and to identify areas of non-point source pollution and the effect of non-point source pollution on water quality. This was done by (1) physical and chemical monitoring, (2) biological and toxicological monitoring, and (3) land-use assessment. This report presents selected basin characteristics and water-quality data for the Minnesota River Basin as 71 maps, 22 graphs, and 8 tables. This report was prepared by the U.S. Geological Survey (USGS) in cooperation with the MPCA. This project was initiated by the Minnesota Legislature as recommended by the Legislative Commission on Minnesota Resources (LCMR). The MPCA was delegated the responsibility to manage this project. Federal, State, and local agencies, and colleges and universities collected and assembled data. The following took part in this study:

Legislative Commission on Minnesota Resources
Minnesota Pollution Control Agency

Board of Water and Soil Resources
Gustavus Adolphus College
Mankato State University
Metropolitan Council of the Twin Cities
Metropolitan Waste Control Commission
Minnesota Department of Agriculture
Minnesota Department of Natural Resources
Minnesota Land Management Information Center
St. Olaf College
South Central Minnesota Counties Water Planning Project
U.S. Department of Agriculture, Forest Service
U.S. Department of Agriculture, Soil Conservation Service
U.S. Department of Interior, U.S. Fish and Wildlife Service
U.S. Department of Interior, U.S. Geological Survey
U.S. Environmental Protection Agency, Environmental Research Laboratory-Duluth
University of Minnesota
University of Minnesota-Duluth
University of Wisconsin-Madison

Blue Earth County Soil and Water Conservation District
Brown County Soil and Water Conservation District
Chippewa County Soil and Water Conservation District
Cottonwood County Soil and Water Conservation District
Faribault County Soil and Water Conservation District
Kandiyohi County Soil and Water Conservation District
Lincoln County Soil and Water Conservation District
Lyon County Soil and Water Conservation District
Martin County Soil and Water Conservation District
Murray County Soil and Water Conservation District
Nicollet County Soil and Water Conservation District
Redwood County Soil and Water Conservation District
Renville County Soil and Water Conservation District
Sibley County Soil and Water Conservation District
Swift County Soil and Water Conservation District
Watonwan County Soil and Water Conservation District
Yellow Medicine County Soil and Water Conservation District

APPROACH AND METHODS

Information contained in this report is from a variety of sources. All maps were prepared from Geographic Information System (GIS) data bases. Many of the maps in this report are derived from a project to digitize physical information for the State (Land Management Information Center, 1989). The data bases created through this effort of the Land Management Information Center (LMIC) are termed the MLMIS40 and MLMIS100 data bases. The MLMIS40 data base contains information on Minnesota's environmental and natural-resource characteristics. The data base contains resource-characteristic information for every 40-acre parcel of land in the State, and uses the Public Land Survey as its reference system. Data in MLMIS40 generally are from map sources that range in scale from 1:24,000 to 1:1,000,000. Because data compilation and entry was started in the late 1960's, grid-cell overlay techniques were used. More recently, data entry has been done by first digitizing the data as vectors and then converting to a 40-acre raster grid cell. The MLMIS40 data base was designed for use in regional and statewide planning and was not intended to be used on a site-specific basis.

MLMIS100 is the spatially corrected 100-meter on a side grid-cell version of the MLMIS40 acre data base. It was created to give better geographical reference to the 40-acre data; however, the data collection unit for nearly all variables is still the 40-acre parcel.

Information pertaining to the physical and chemical characteristics of the Minnesota River is from data collected for this study by the MPCA and the USGS. The USGS, in cooperation with the MPCA and the LCMR, monitored selected physical characteristics and chemical constituents of river water as part of the study. The physical and chemical characteristic monitoring has focused on four primary objectives:

1. Determine concentrations and loads of suspended sediment, major nutrients, biochemical oxygen demand (BOD), and organic carbon, identify their source areas, and identify the effects of specific source areas on water quality.

2. Determine the relation of suspended sediment to major nutrients, BOD, algal productivity, and organic carbon to better define the interactions of these constituents in the Minnesota River.

3. Quantify the transport of sediment and associated contaminants.

4. Identify areas of bank erosion and sediment deposition to determine the relative significance of instream sediment loading as compared to non-point source sediment loading from the river basin.

The sampling during 1989-90 was designed to provide information about both areal and temporal variability in water quality. Sampling included measuring chemical concentrations and determining sediment loads at the mouths of 10 major tributaries so that each tributary could be ranked by the magnitude of its contribution to the Minnesota River. Twelve mainstem water-quality sampling sites were established (fig. 1, table 1). Mainstem water-quality sites on the Minnesota River were established at intervals ranging from 13 to 33 miles. Twenty one springs, selected to characterize ground-water inputs to the Minnesota River, were sampled (fig. 1, table 2).

The sampling approach during 1991-92 was adjusted on the basis of findings during 1989-90 to provide more detailed information about processes associated with the origin, transport, and transformation of water-quality constituents. Seven water-quality sampling sites (fig. 1, table 1) were added in the Blue Earth and Redwood River Basins and sampling efforts were redirected to fully address all four study objectives as more data were collected.

Water samples were collected from a range of streamflow conditions to characterize the change in water quality as the streams responded to both dry and wet conditions. Accordingly, samples were collected at all spring and stream sites during low flow in late summer 1989, in winter 1989-90, and in late summer 1990. These samples were collected during a short time period (2-3 weeks), progressing from upstream to downstream to obtain a synoptic appraisal of water quality during low streamflow. Samples were collected at selected tributary and mainstem water-quality sampling sites during snowmelt (March-April) and during runoff from summer rainfall (May-July). The Minnesota River at Montevideo and the Blue Earth River at Mankato were sampled frequently throughout 1989-92 (weekly from March through July, and monthly from August through February) to more precisely determine short-term changes in water quality. Suspended-sediment samples were collected daily from March through November 1989-92 at the Minnesota River at Mankato and at the Blue Earth River at Mankato. From August 1989 through September 1992, 404 water samples from streams and 36 samples from springs were collected for chemical analysis.

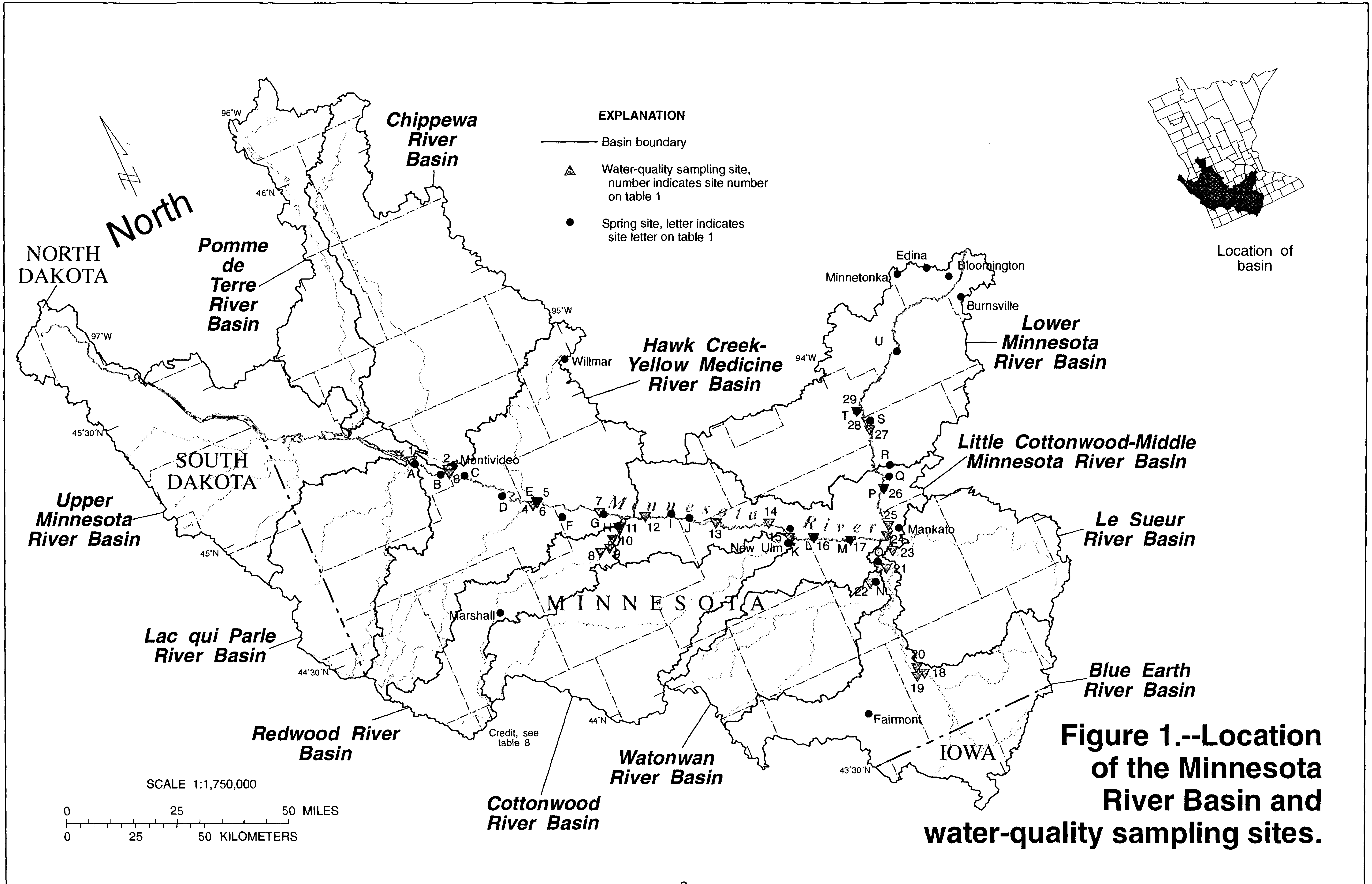


Figure 1.--Location of the Minnesota River Basin and water-quality sampling sites.

Water samples were collected and analyzed according to methods adopted by the USGS that are described in Buchanan and Somers (1969), Fishman and Friedman (1989), Wershaw and others (1983), Edwards and Glysson (1988), Ward and Harr (1990), and Britton and Greeson (1989). Streams were sampled at multiple intervals across the stream using depth-integrating samplers to obtain samples that were representative of total stream discharge. Stream discharge was determined for each sample to calculate chemical constituent loads. Stream discharge was determined by current-meter measurements or derived from USGS stream discharge gaging-station records.

Water samples and bottom-material samples were analyzed for chemical constituents at the USGS National Water-Quality Laboratory at Arvada, Colorado. Samples for suspended-sediment concentrations and particle-size determinations for suspended sediment and bottom material were analyzed by the USGS Sediment Laboratory at Iowa City, Iowa.

Specific conductance, pH, temperature, and dissolved-oxygen concentration were determined in the field using portable meters that were calibrated at the beginning and end of each sampling day. Five-day BOD and bacteria counts were determined in field laboratories. BOD analyses were performed on natural (unseeded) water samples; some samples required dilution with deionized water.

Within the Minnesota River Basin 37 subbasins were selected by the MPCA for detailed mapping and land-use surveys. These subbasins were selected to represent a variety of non-point source pollution potentials and specific land uses. These subbasins are shown in figure 2.

MINNESOTA RIVER BASIN

The Minnesota River drains nearly 17,000 square miles in Minnesota and parts of eastern South Dakota, northern Iowa, and southeastern North Dakota. The Minnesota River Basin contains 12 river basins that range in size from 700 square miles (Redwood River Basin) to 2,090 square miles (Upper Minnesota River Basin) (Table 3). The 12 basins in the Minnesota River Basin, as defined by the USGS and the U.S. Water-Resources Council (U.S. Geological Survey, 1976), are shown in figure 1. The basins were defined by height-of-land determinations from USGS 1:24,000-scale topographic maps by the Minnesota District of the USGS. GIS data bases of basin boundaries are available from the USGS. The Minnesota River Basin is covered by glacial deposits of Pleistocene age. Land use in the basin, except for the Twin Cities Metropolitan Area, primarily is agricultural.

SUBBASINS IN THE MINNESOTA RIVER BASIN

The MDNR defined 1,208 basins (5 square miles and greater) as subbasins to the 12 river basins using USGS 1:24,000- and 1:62,500-scale topographic maps (Land Management Information Center, 1989). The USGS, in cooperation with Minnesota Department of Transportation, redelineated the subbasins defined by the MDNR using USGS 1:24,000-scale topographic maps. The most recent maps of drainage ditches and municipal storm sewers were used to determine basin boundaries that had been changed because of human activities. Because of the additional information available, basin boundaries were changed from the boundaries established by the MDNR. The 1,186 subbasins delineated by the USGS are shown in figure 2. The GIS data bases of the subbasins delineated by the MDNR are available from the LMIC and those GIS data bases redelineated by the USGS are available from the Minnesota District of the USGS.

POLITICAL AND HYDROLOGIC FEATURES

Figures 3a-14b show the political and hydrologic features of the 12 basins in the Minnesota River Basin. The roads and streams in these figures are from digital line graphs (U.S. Geological Survey, 1989). Only the longest stream in each subbasin is shown. Discontinuous stream segments on maps reflect either streams that flow into lakes or wetlands or incomplete digital line-graph data. Subbasins for which no drainage is shown have poorly developed drainage with no discernible major stream. County boundaries are from TIGER/Line Census Files (Bureau of the Census, 1991). Cities with population greater than 1,000 are shown.

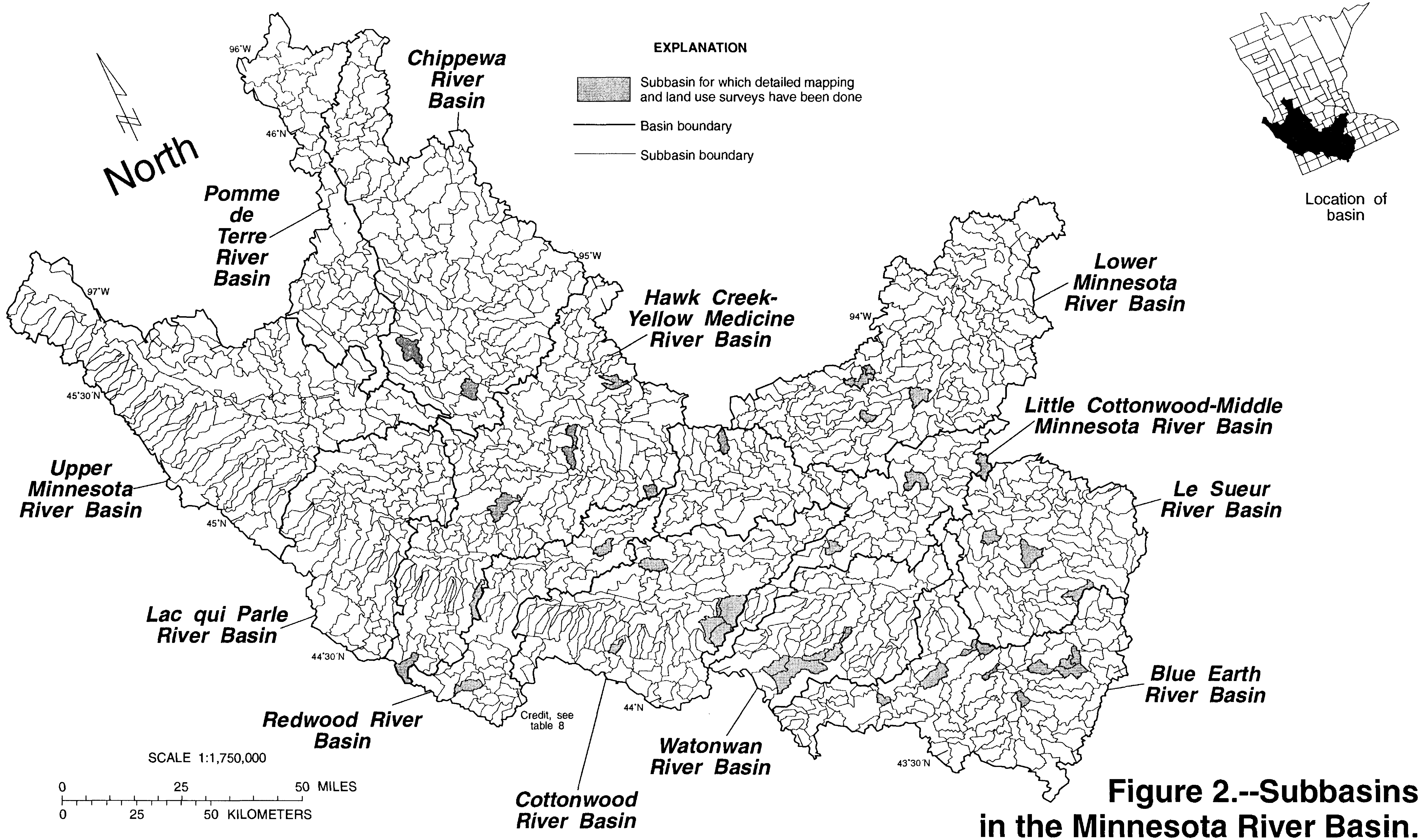


Figure 2.--Subbasins in the Minnesota River Basin.

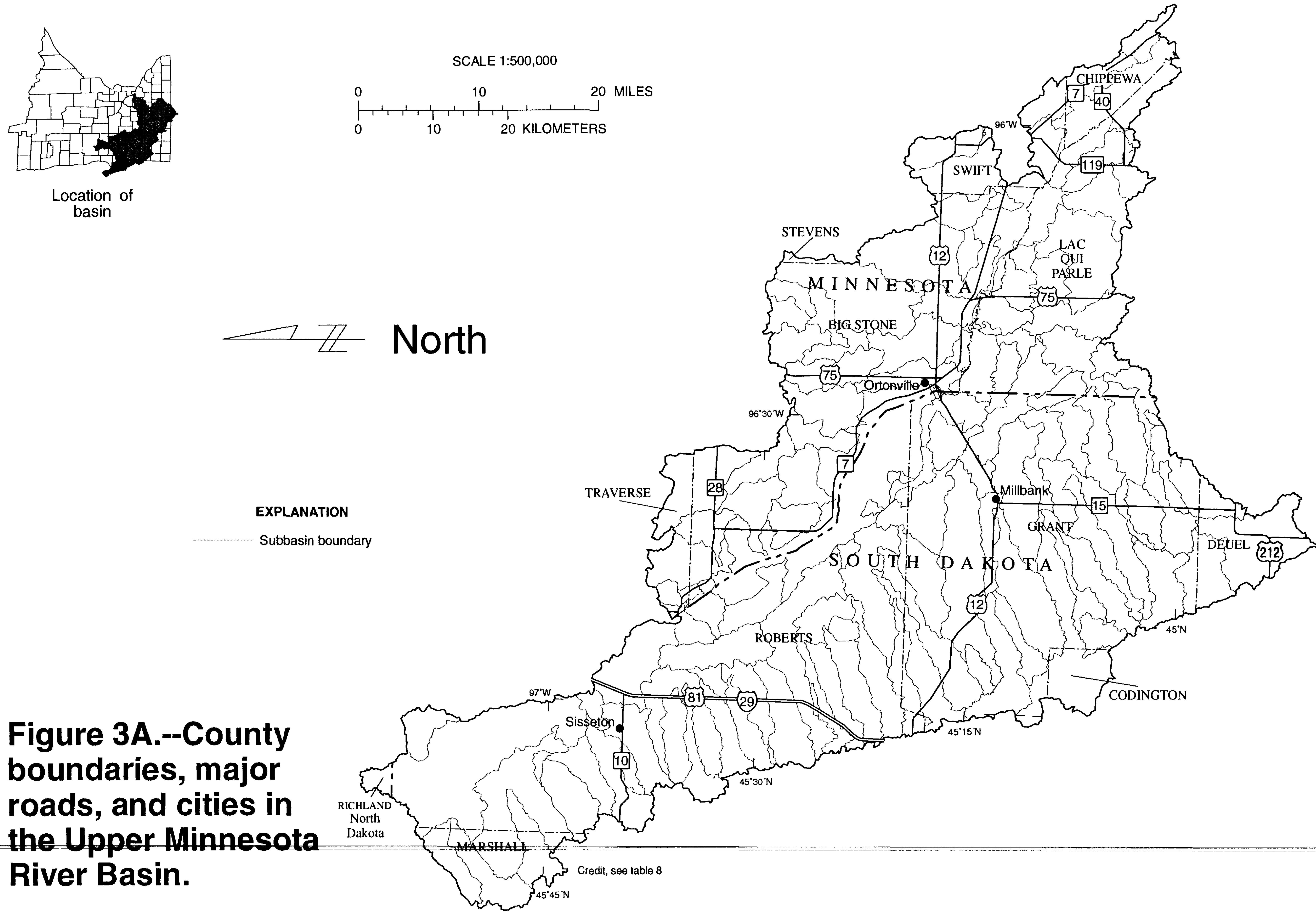


Figure 3A.--County boundaries, major roads, and cities in the Upper Minnesota River Basin.

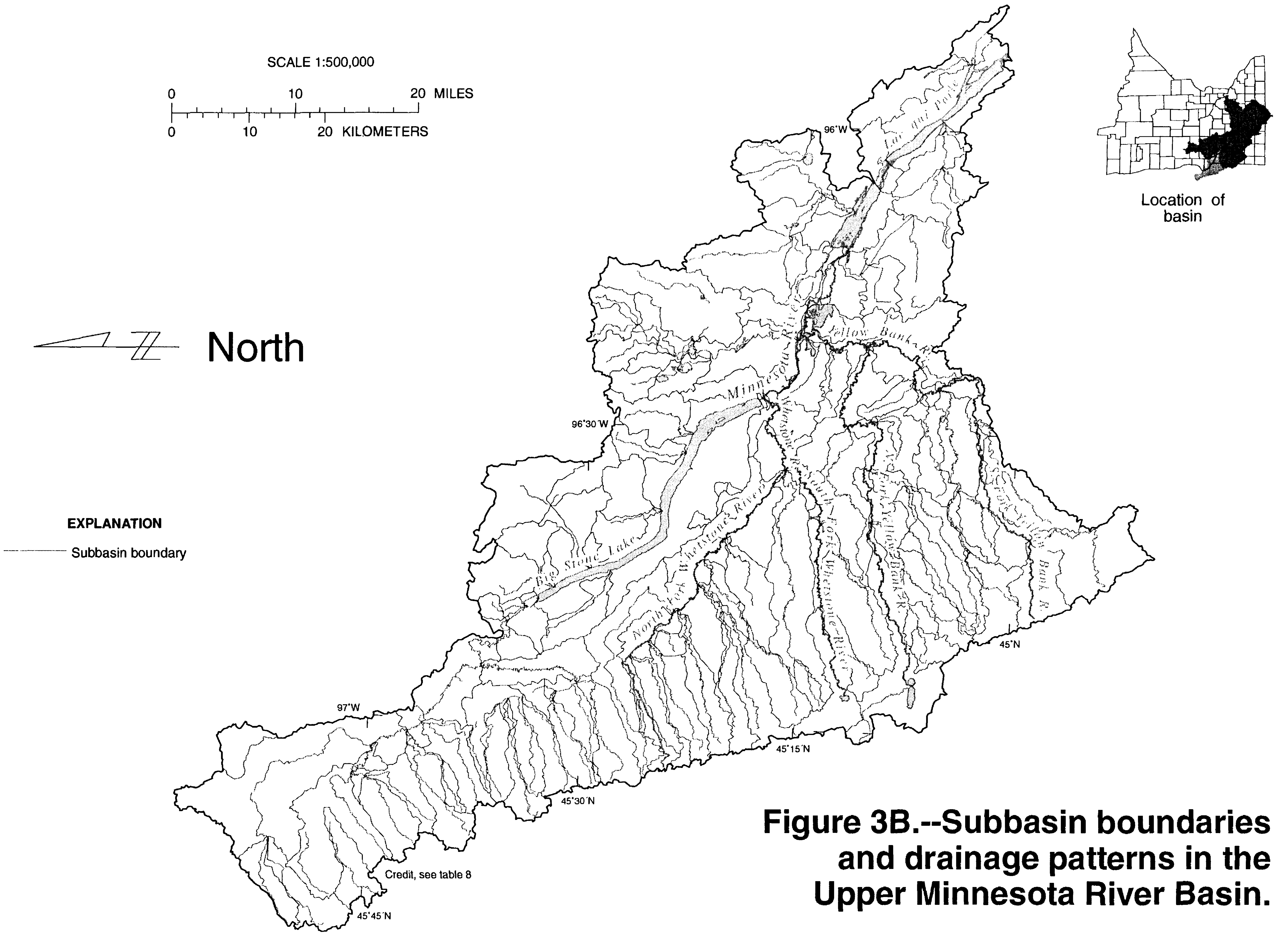


Figure 3B.--Subbasin boundaries and drainage patterns in the Upper Minnesota River Basin.

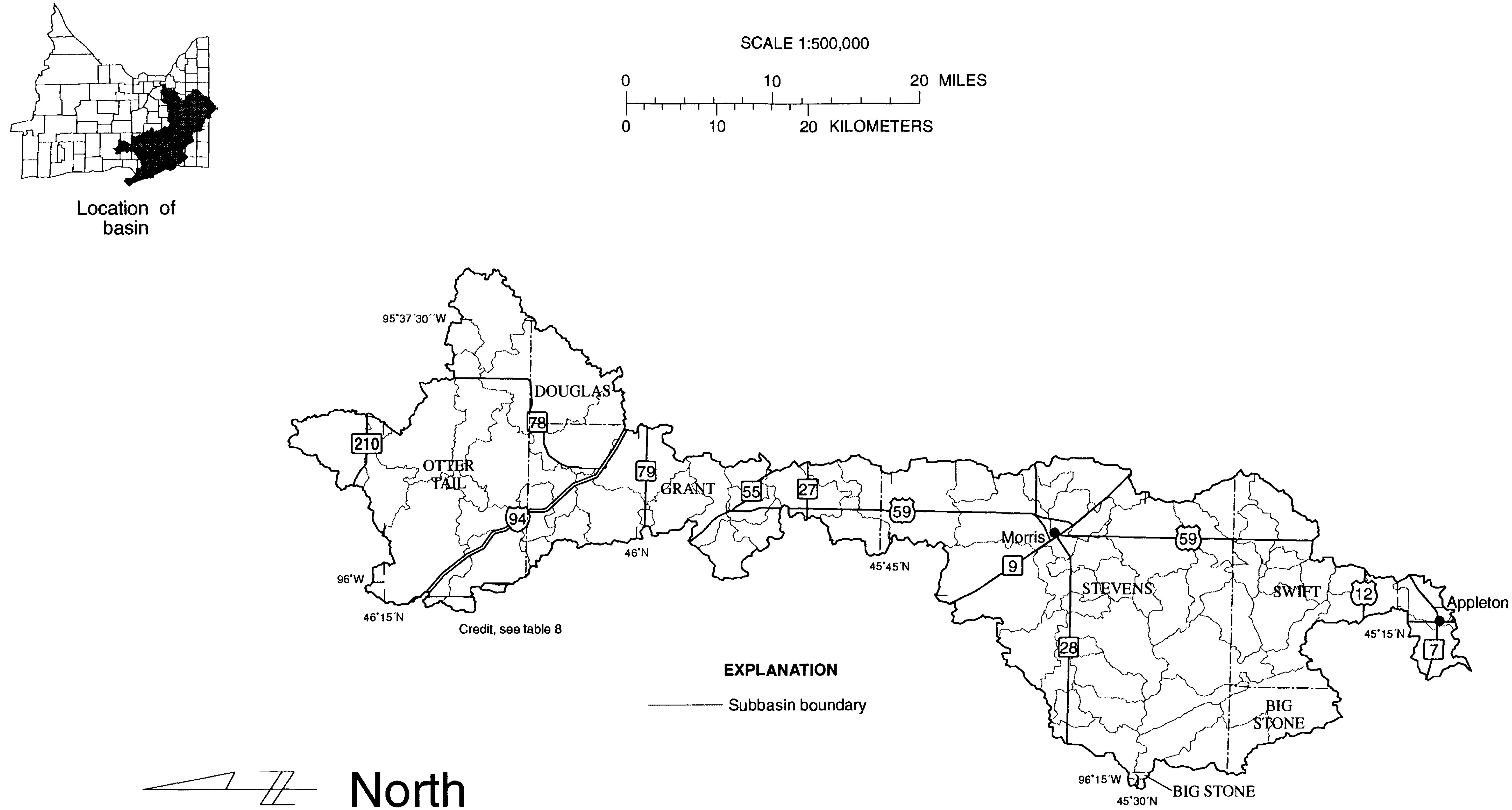


Figure 4A.--County boundaries, major roads, and cities in the Pomme de Terre River Basin.

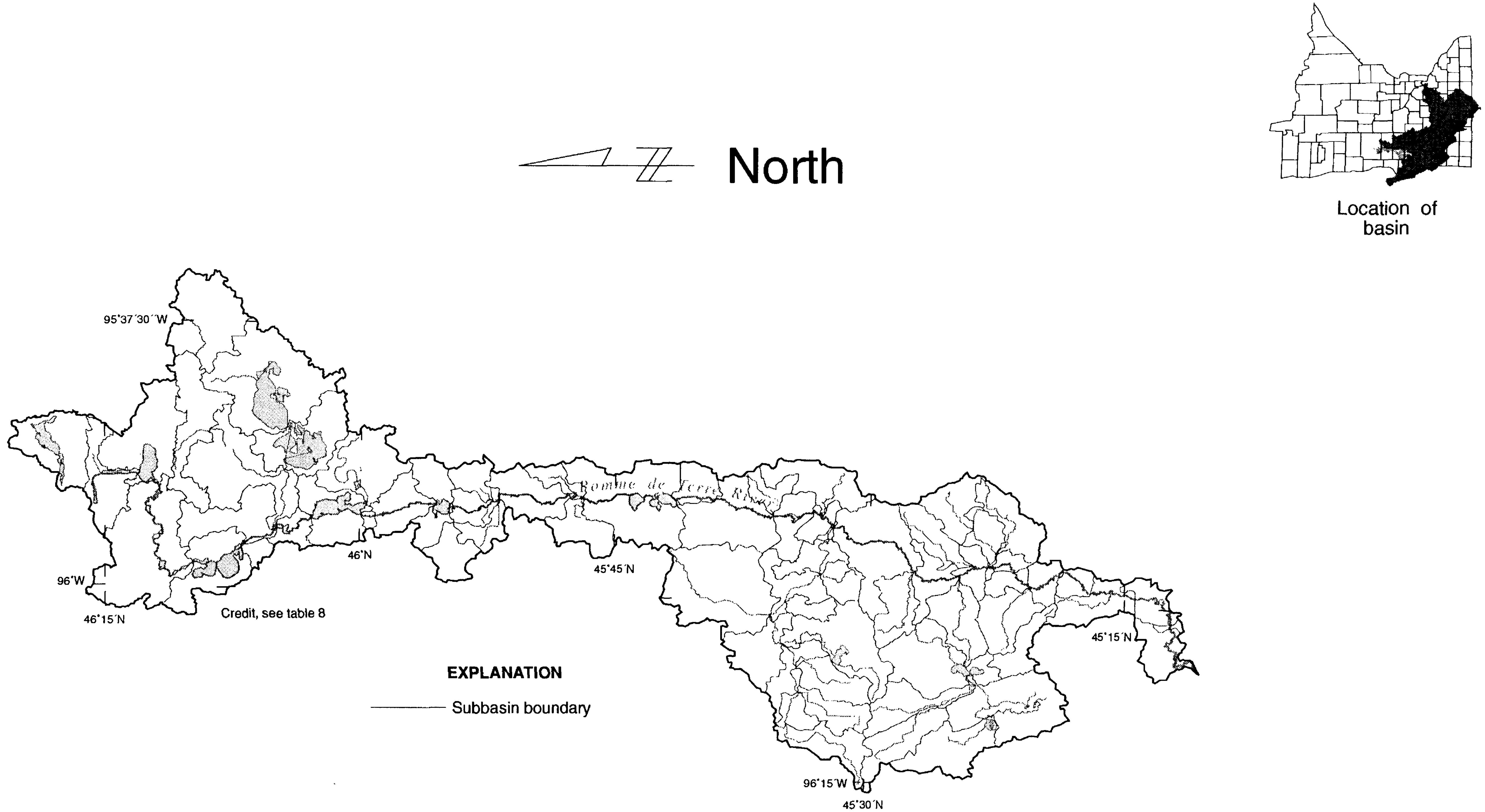


Figure 4B.--Subbasin boundaries and drainage patterns in the Pomme de Terre River Basin.

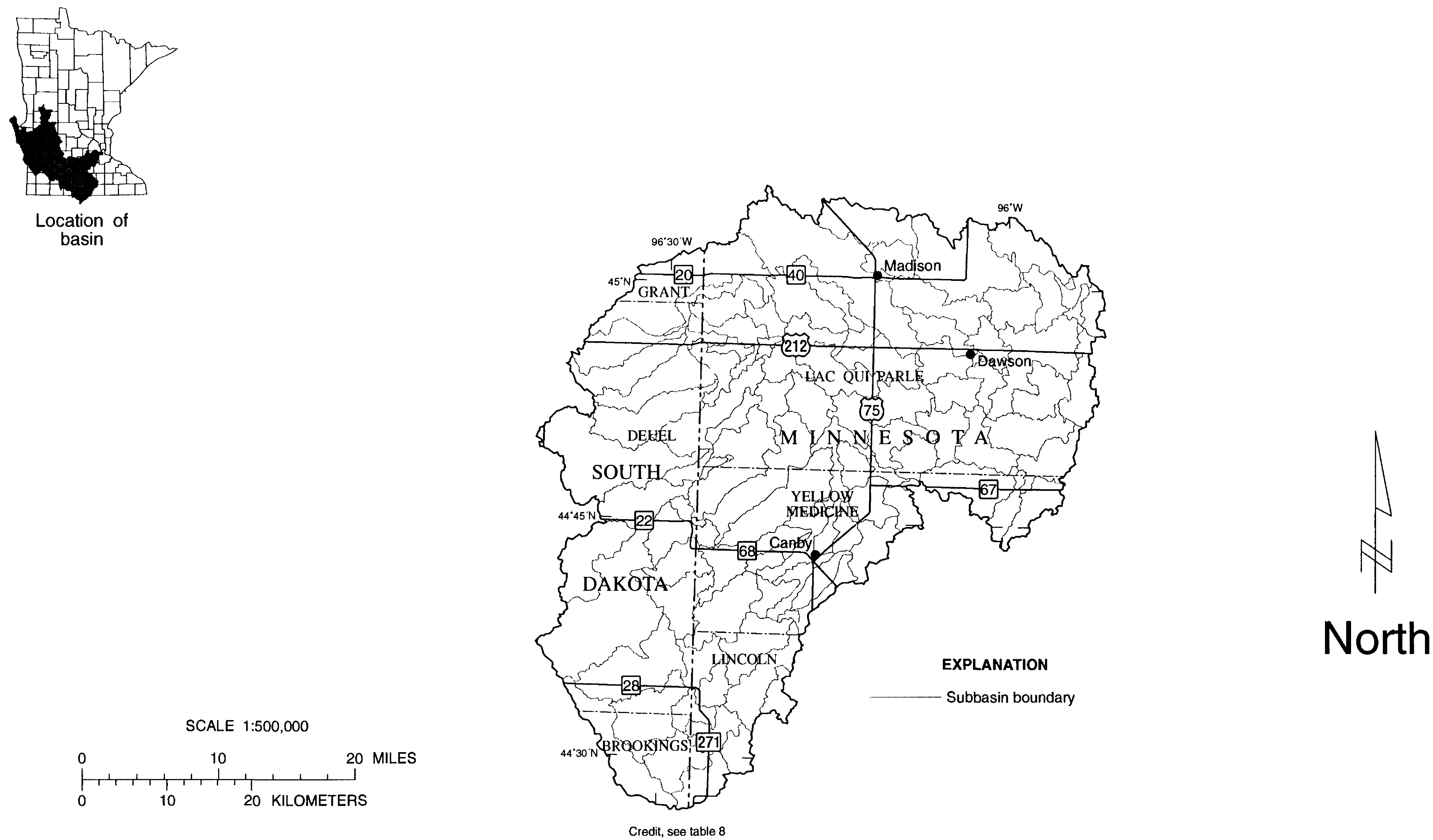
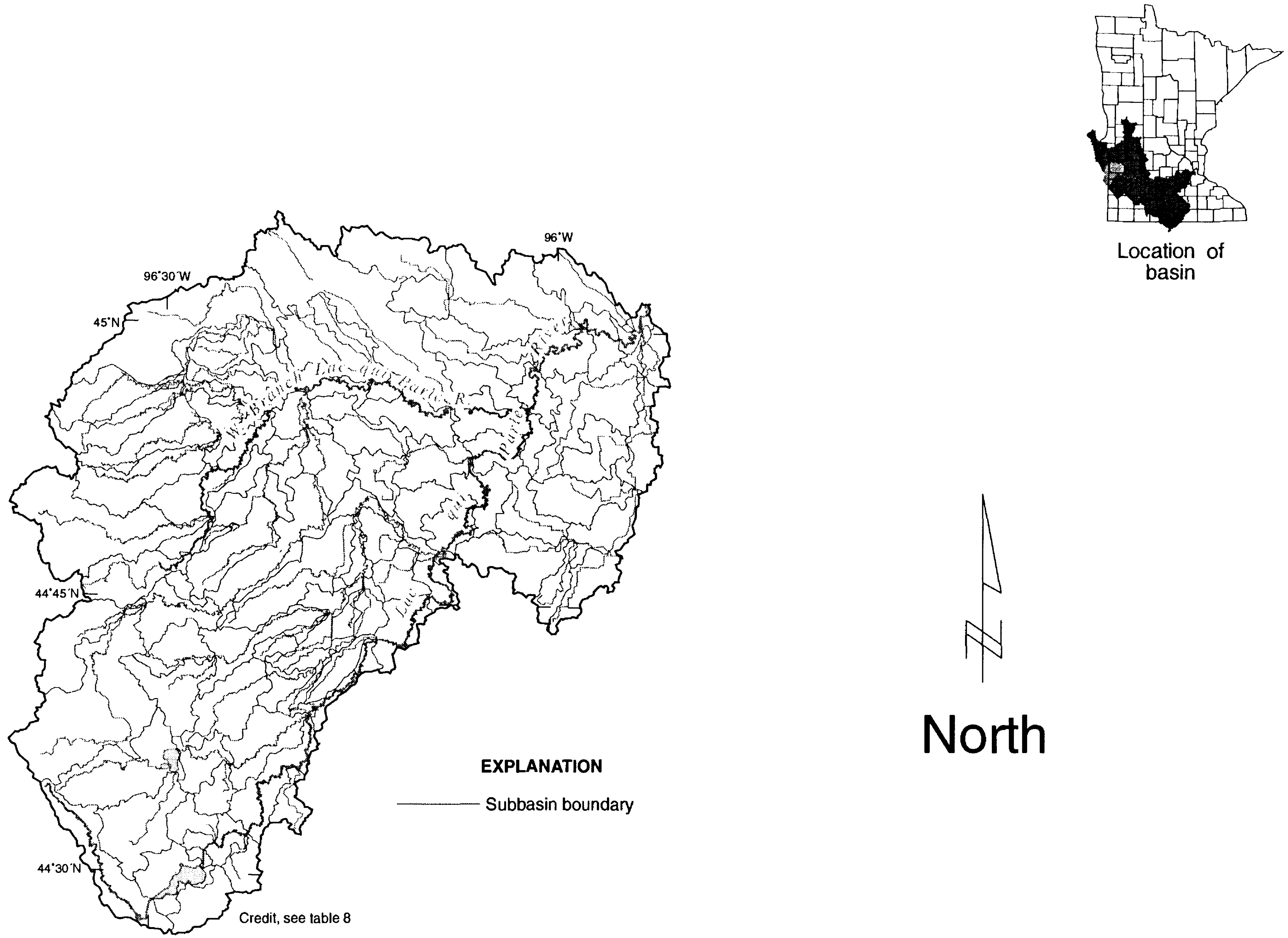


Figure 5A.--County boundaries, major roads, and cities in the Lac qui Parle River Basin.



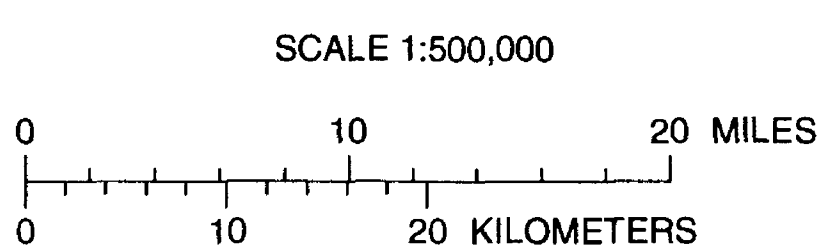


Figure 5B.--Subbasin boundaries and drainage patterns in the Lac qui Parle River Basin.

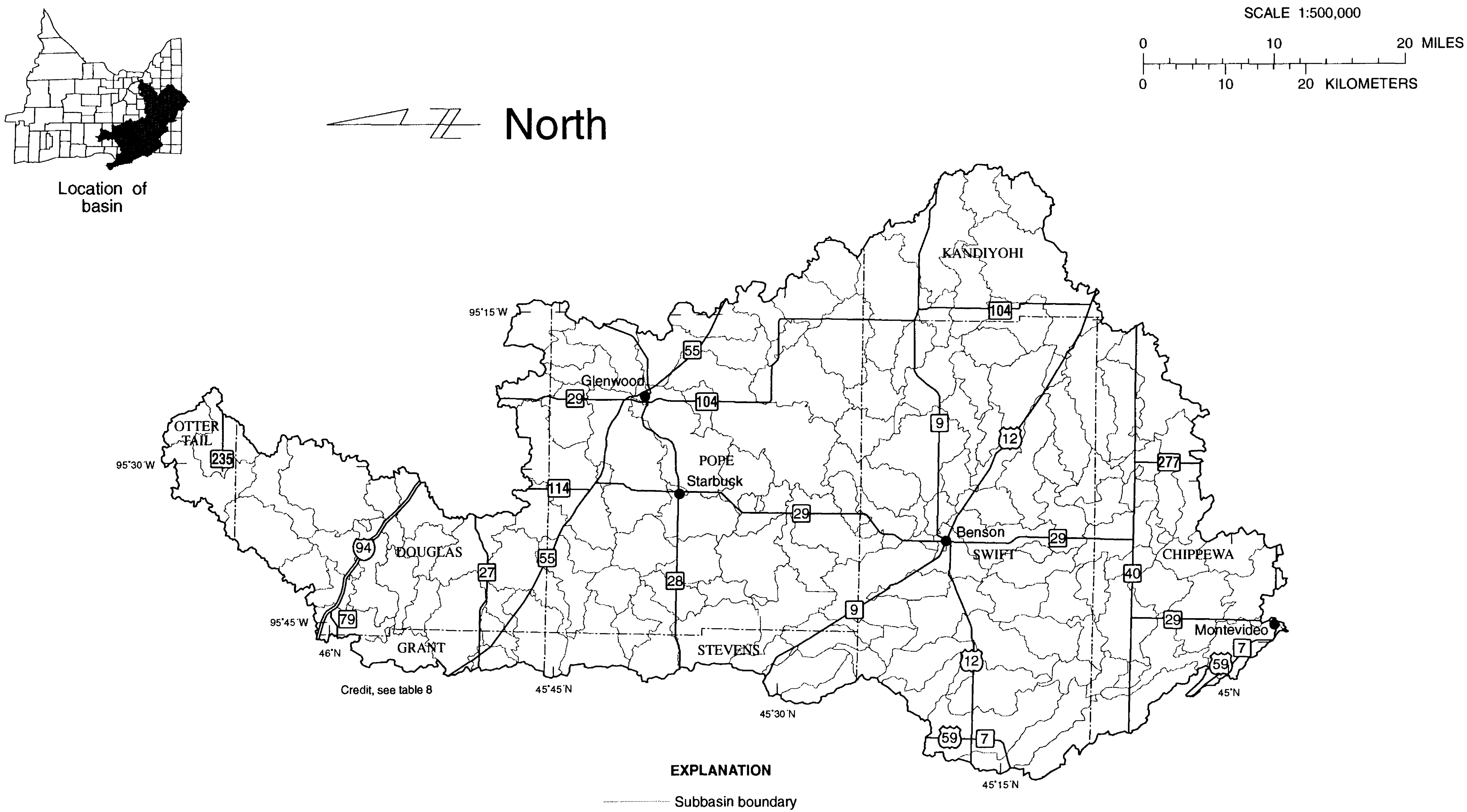


Figure 6A.--County boundaries, major roads, and cities in the Chippewa River Basin.

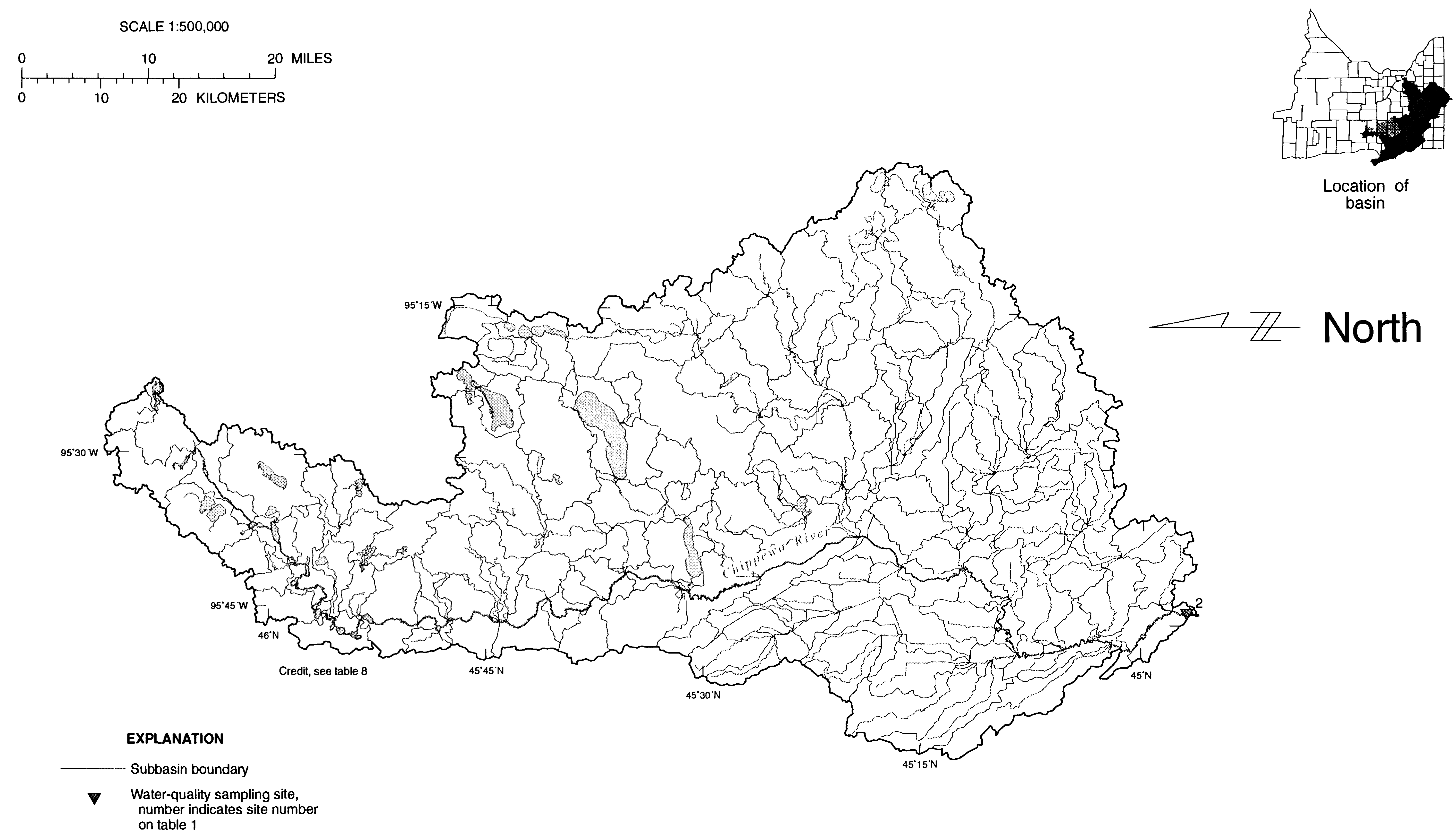


Figure 6B.--Subbasin boundaries and drainage patterns in the Chippewa River Basin.

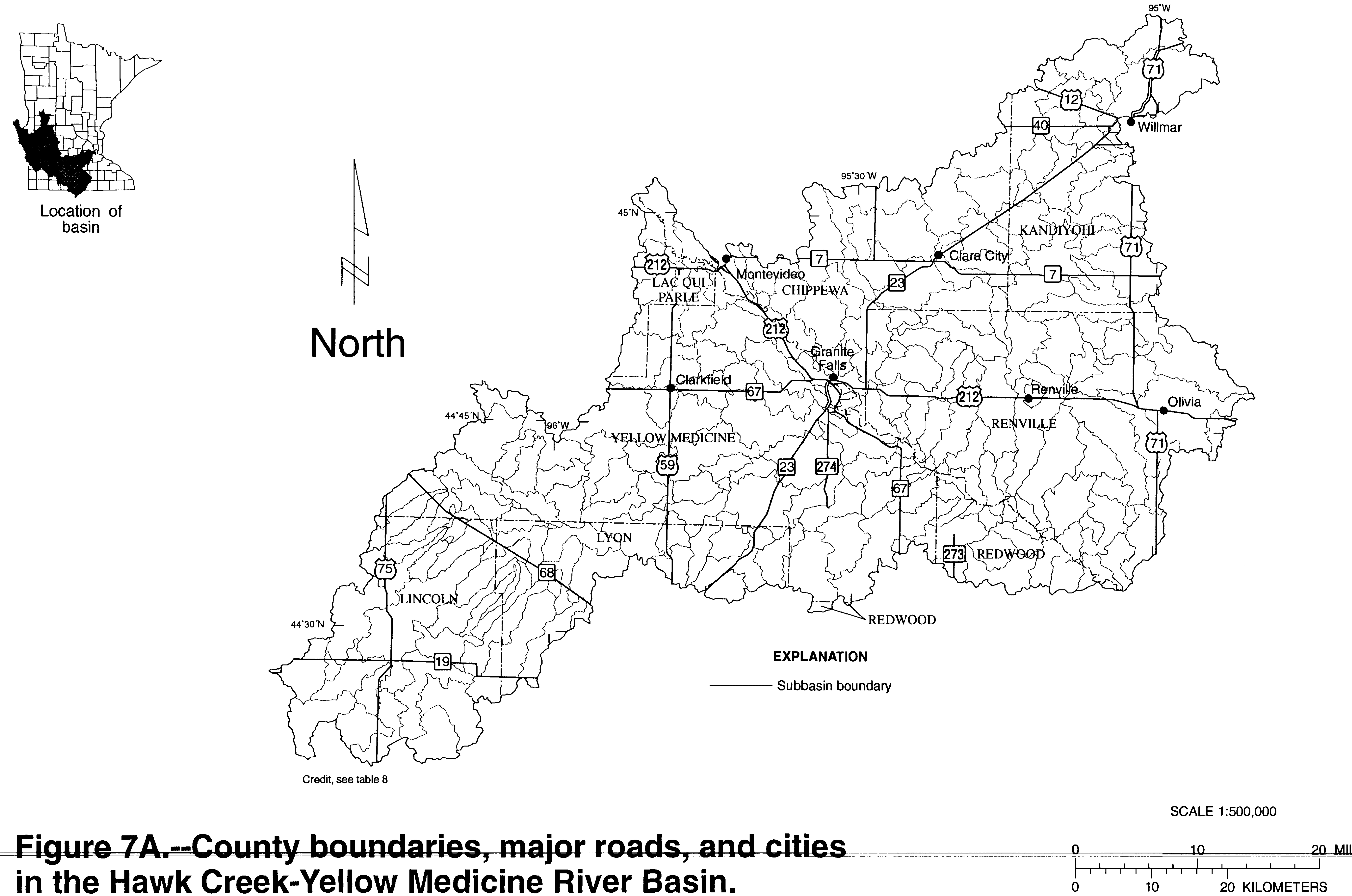


Figure 7A.--County boundaries, major roads, and cities in the Hawk Creek-Yellow Medicine River Basin.

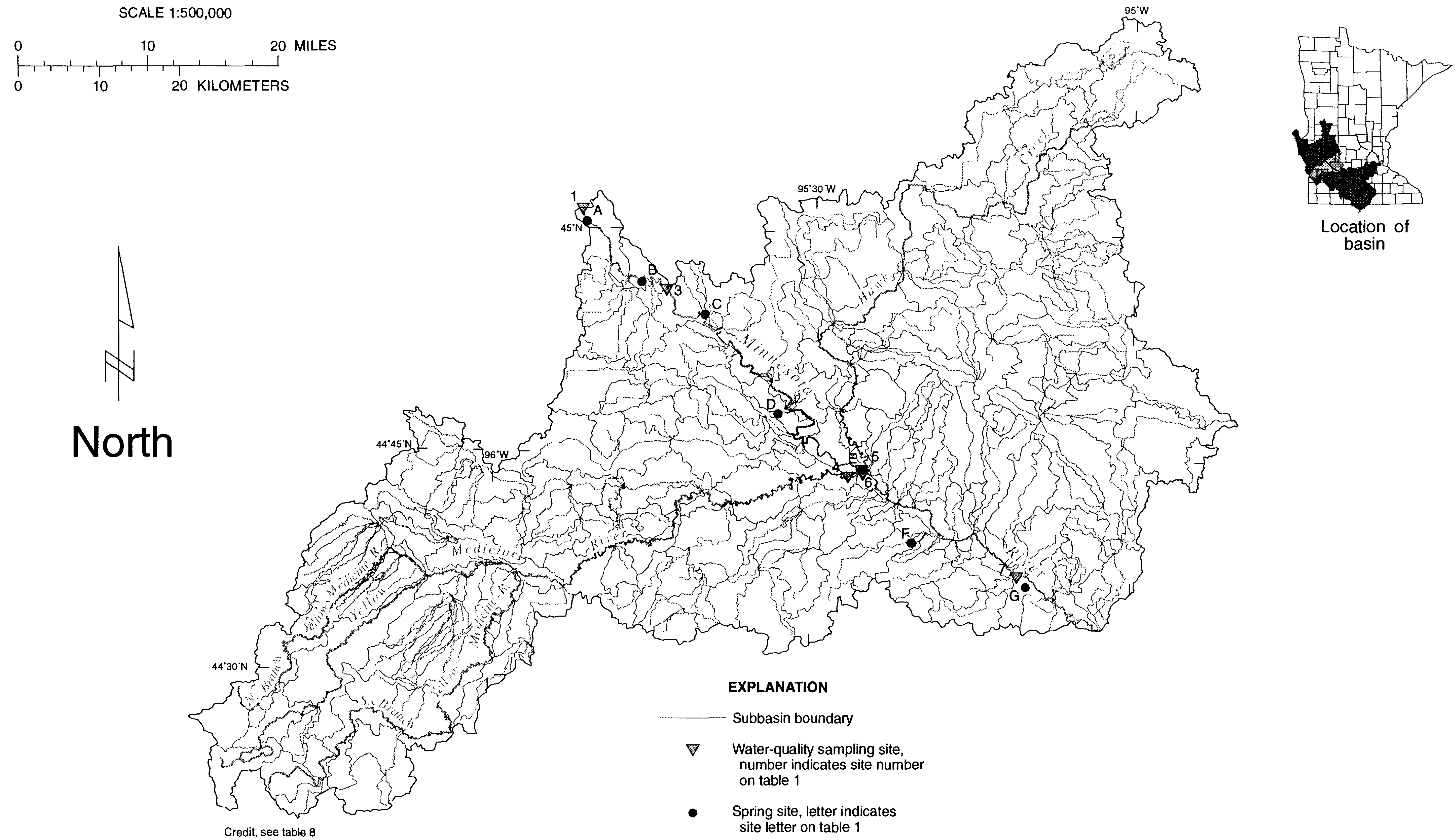


Figure 7B.--Subbasin boundaries and drainage patterns in the Hawk Creek--Yellow Medicine River Basin.

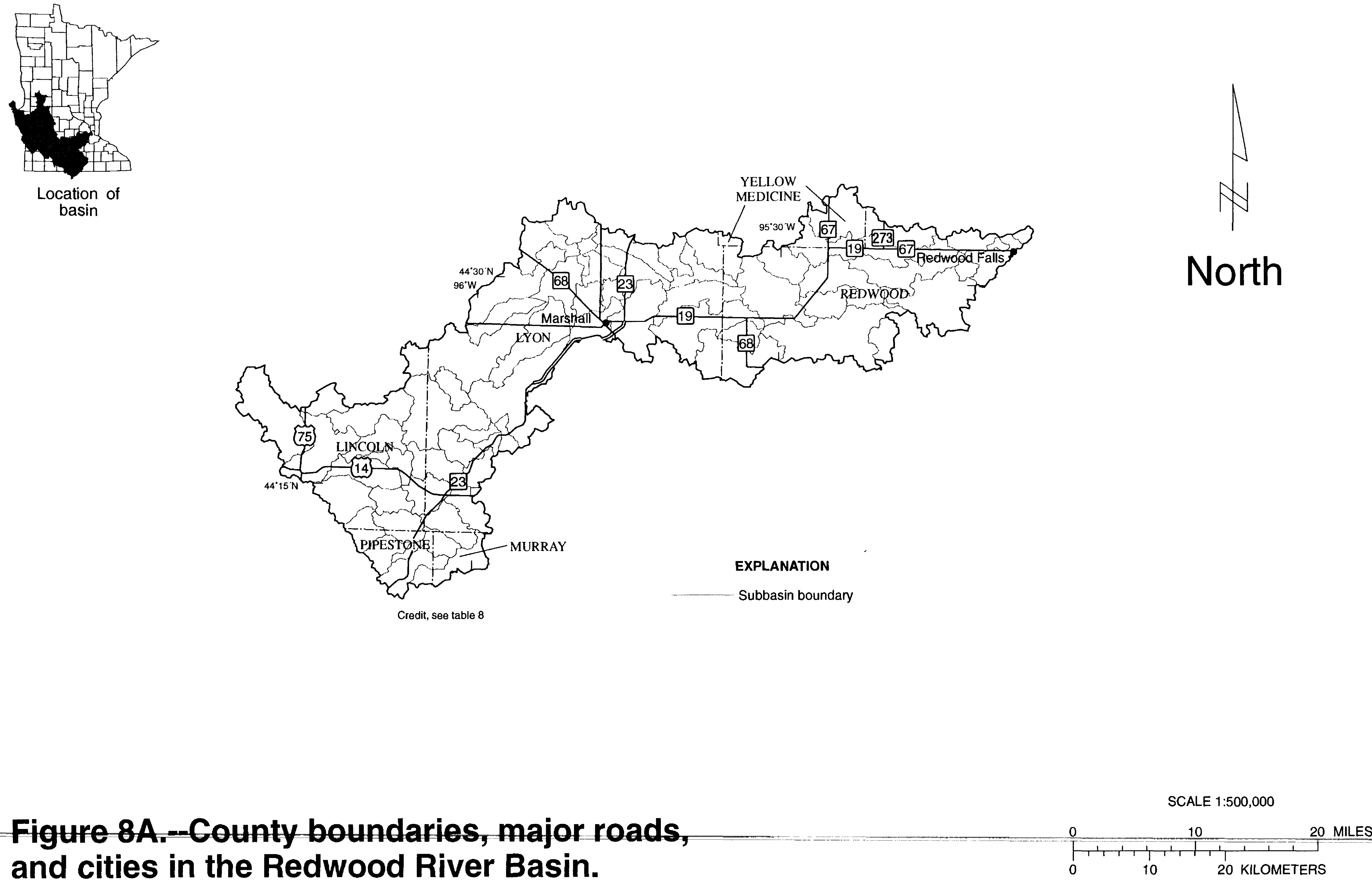


Figure 8A.--County boundaries, major roads, and cities in the Redwood River Basin.

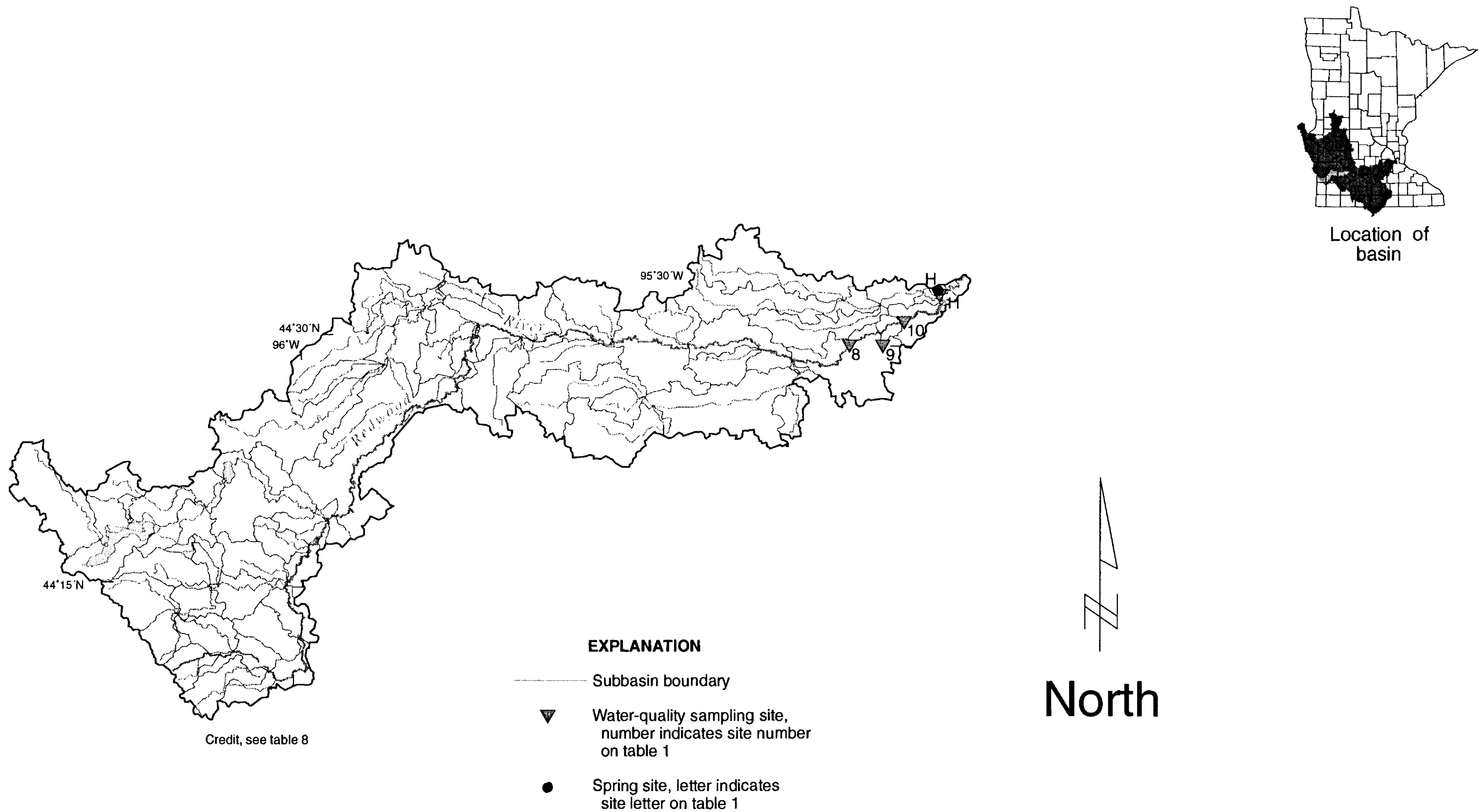


Figure 8B.--Subbasin boundaries and drainage patterns in the Redwood River Basin.

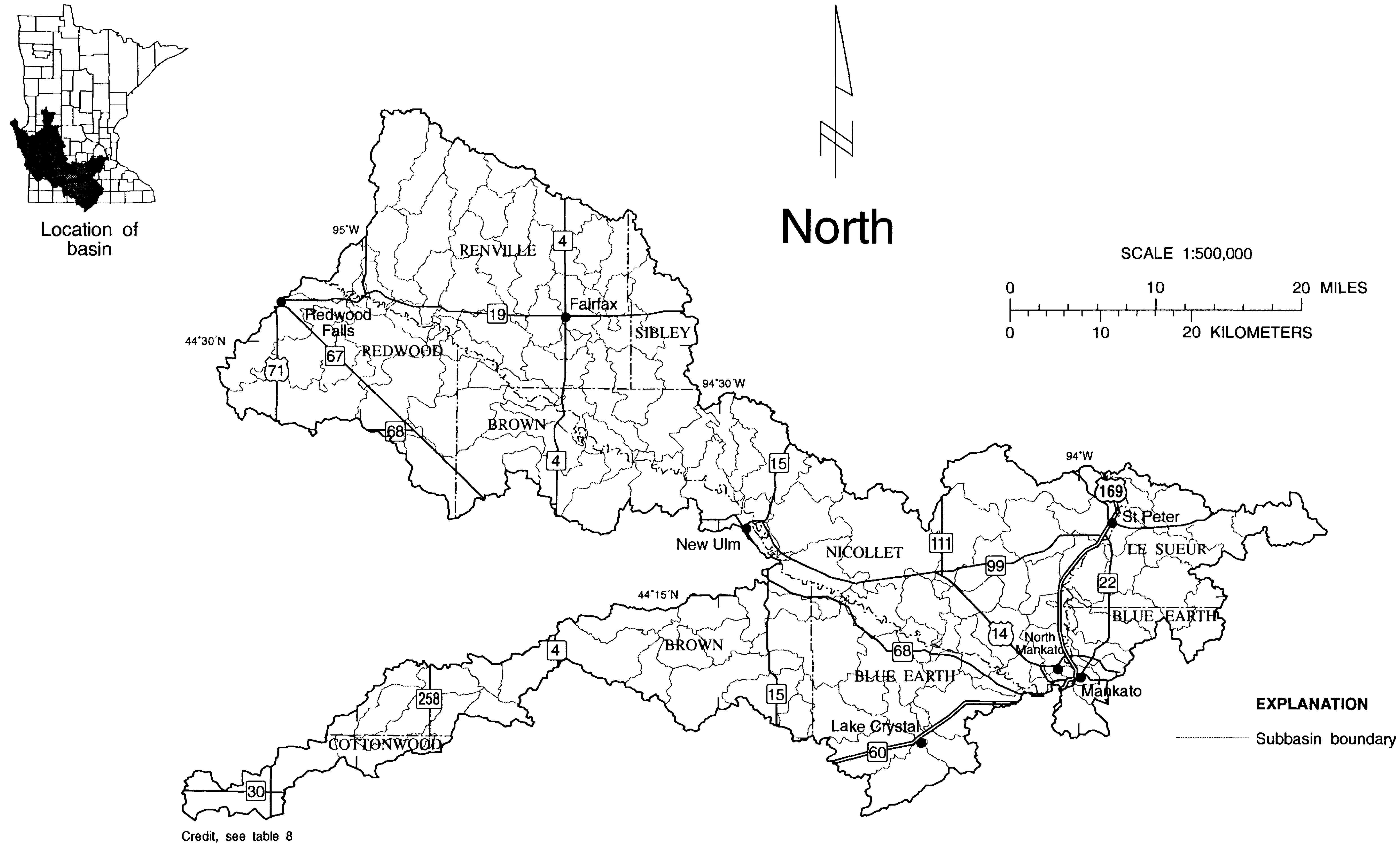


Figure 9A.--County boundaries, major roads, and cities in the Little Cottonwood-Middle Minnesota Rivers Basin.

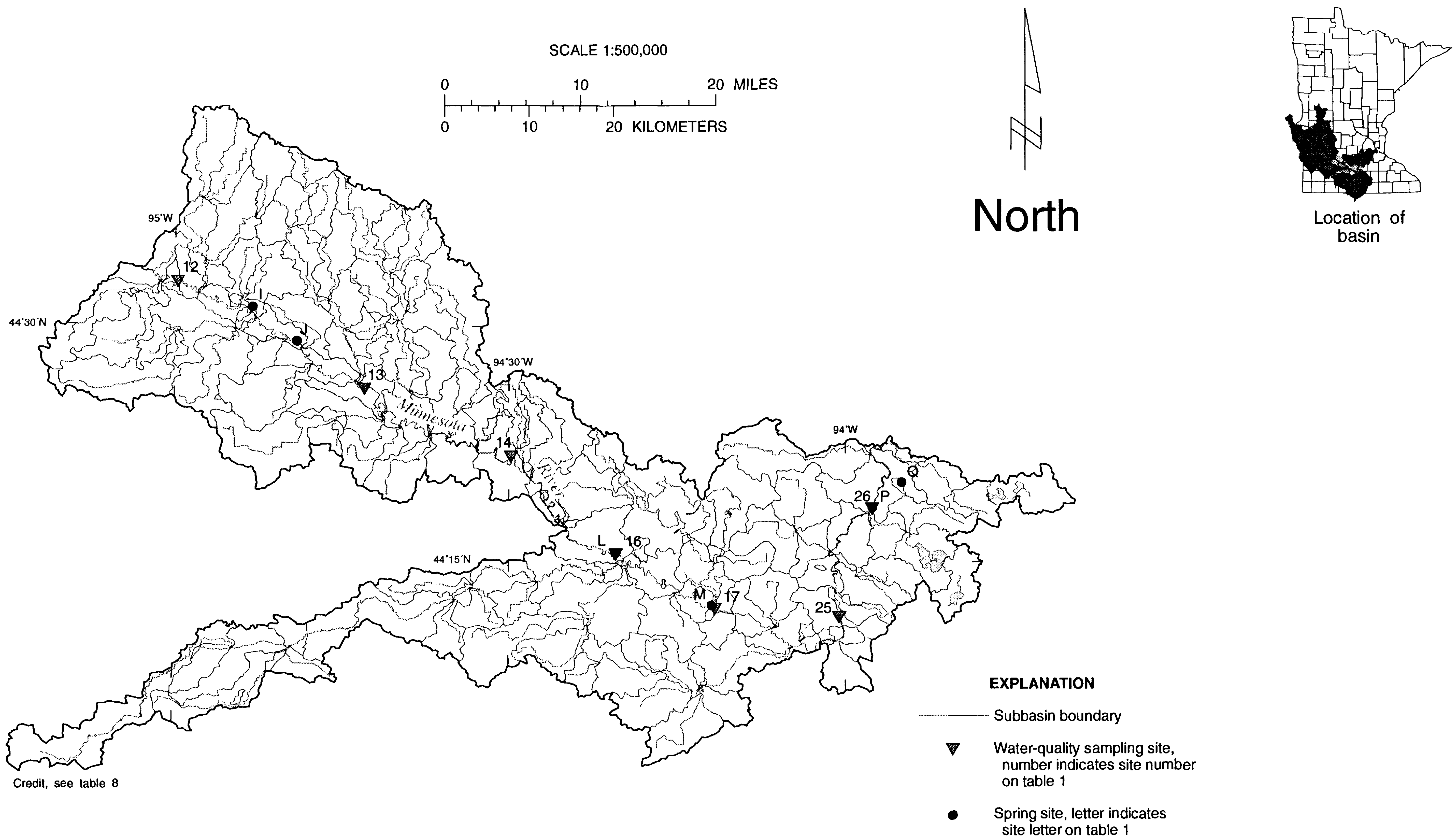


Figure 9B.--Subbasin boundaries and drainage patterns in the Little Cottonwood and Middle Minnesota River Basin.

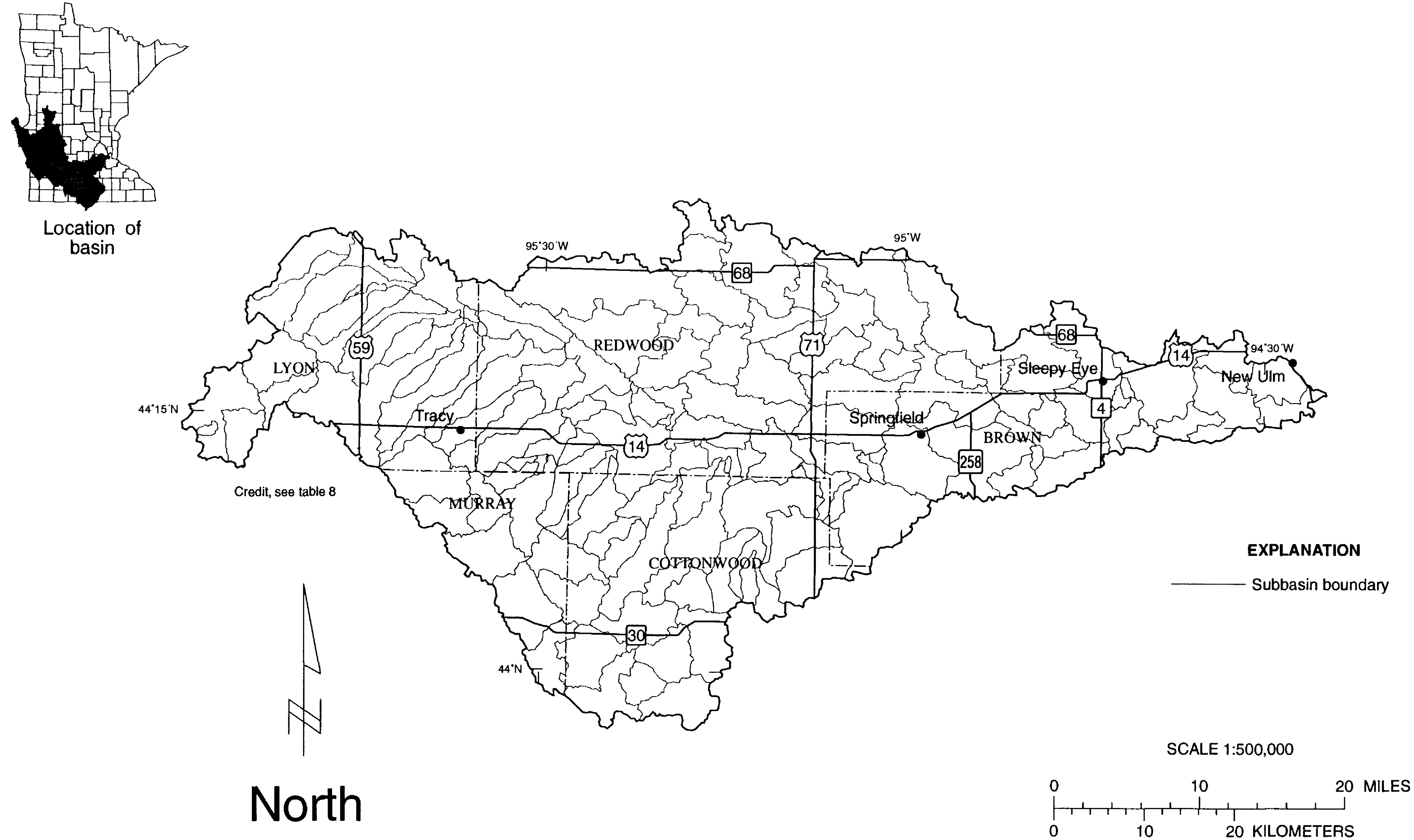


Figure 10A.--County boundaries, major roads, and cities in the Cottonwood River Basin.

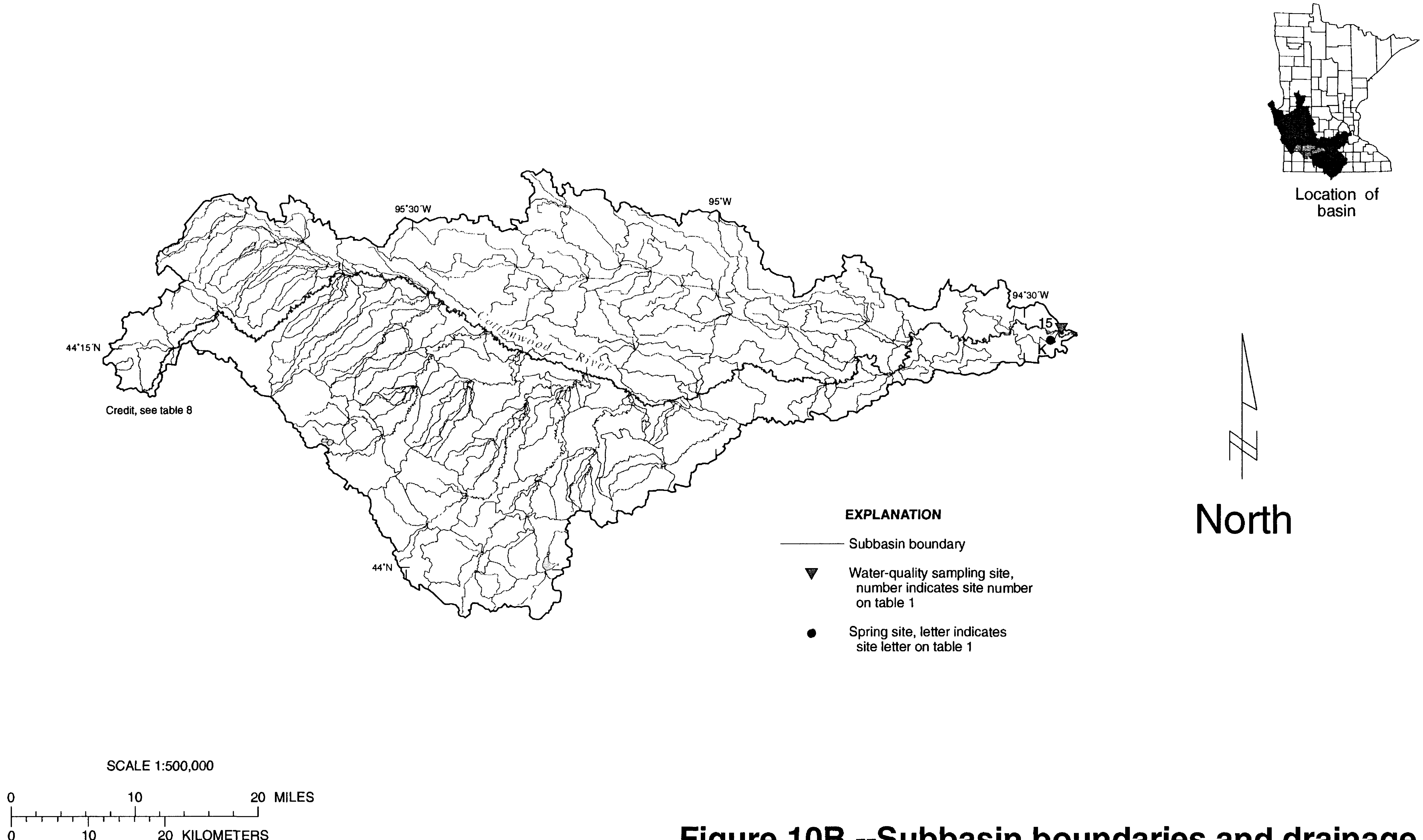


Figure 10B.--Subbasin boundaries and drainage patterns in the Cottonwood River Basin.

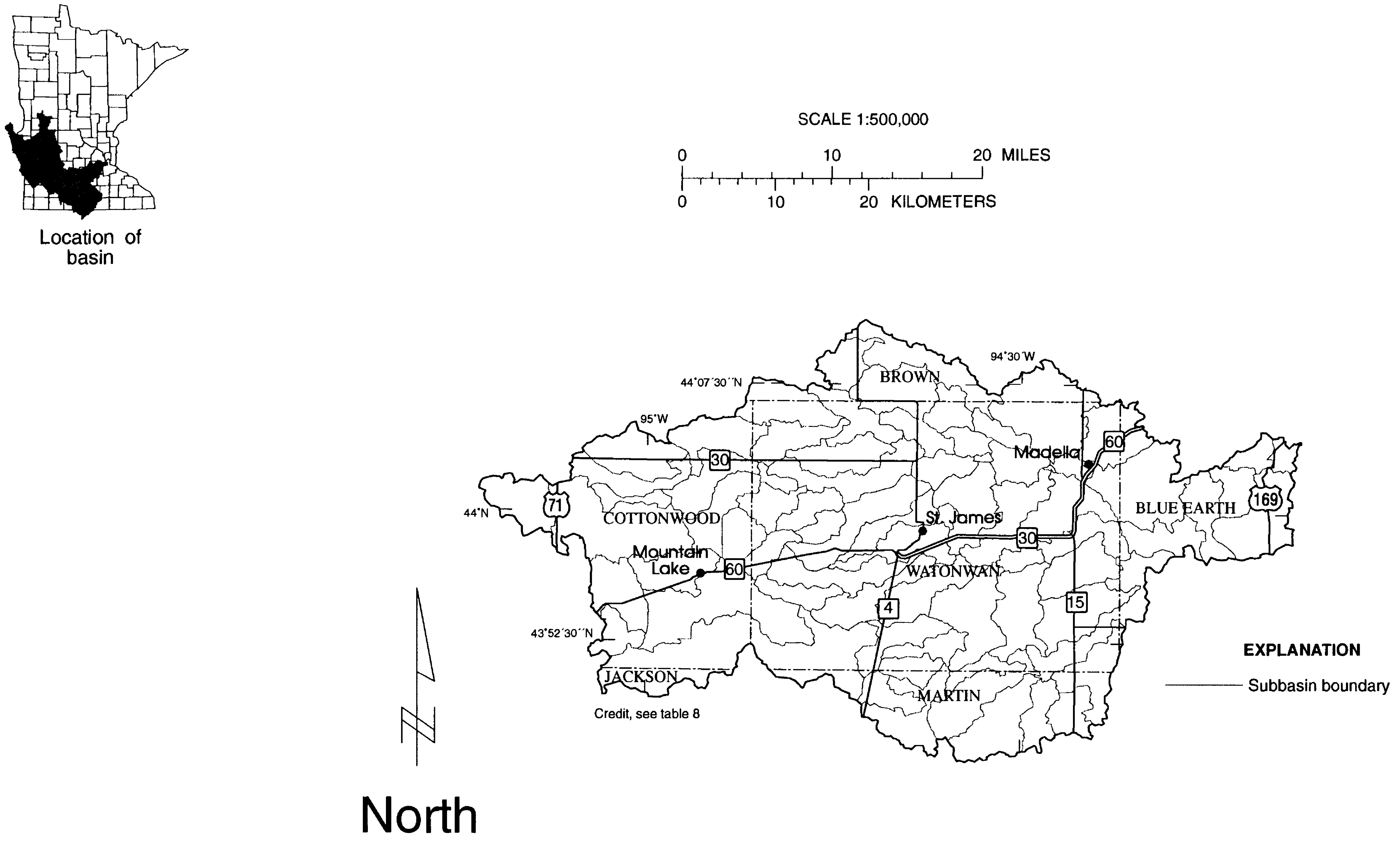


Figure 11A.--County boundaries, major roads, and cities in the Watonwan River Basin.

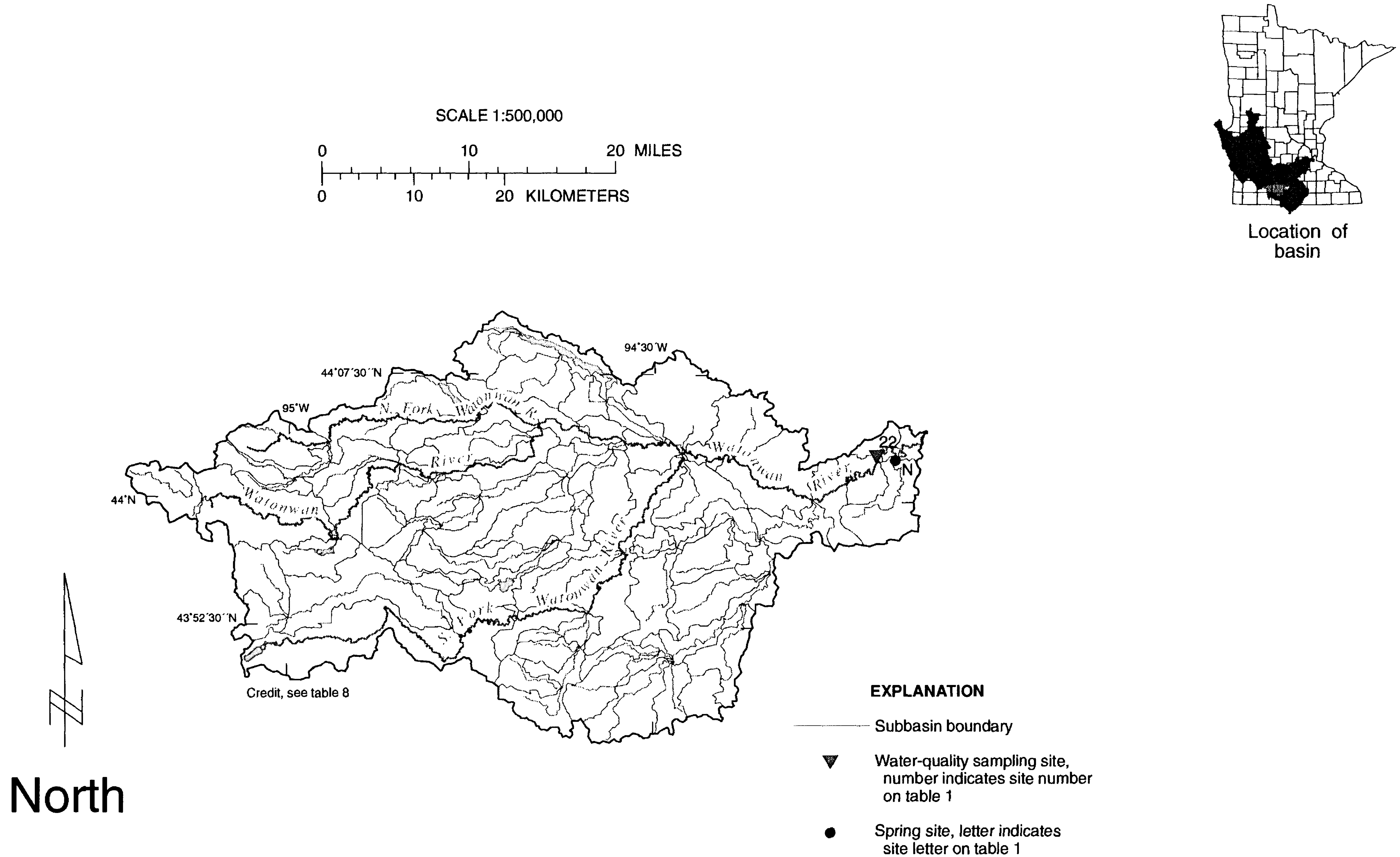


Figure 11B.--Subbasin boundaries and drainage patterns in the Watonwan River Basin.

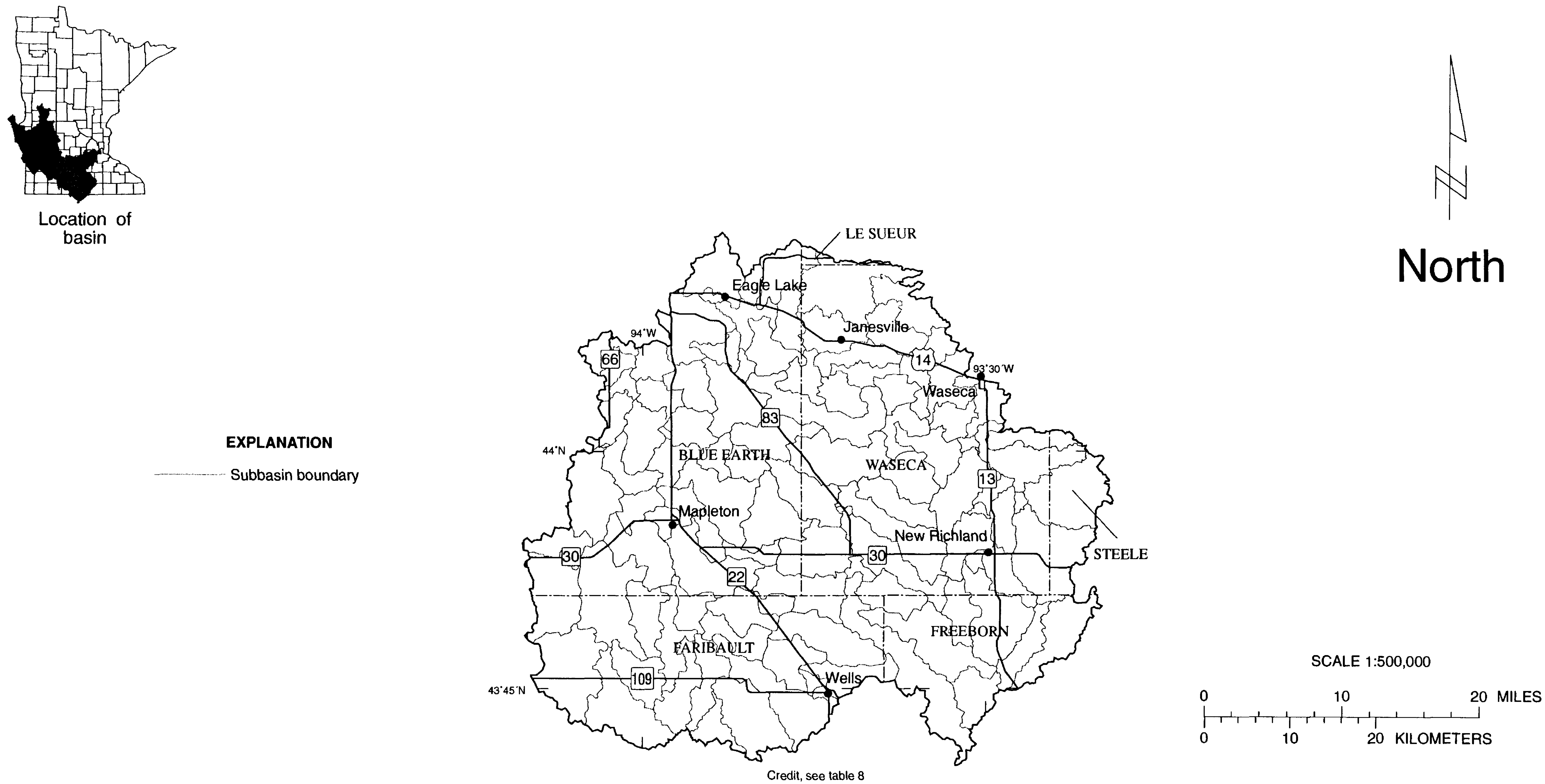


Figure 12A.--County boundaries, major roads, and cities in the Le Sueur River Basin.

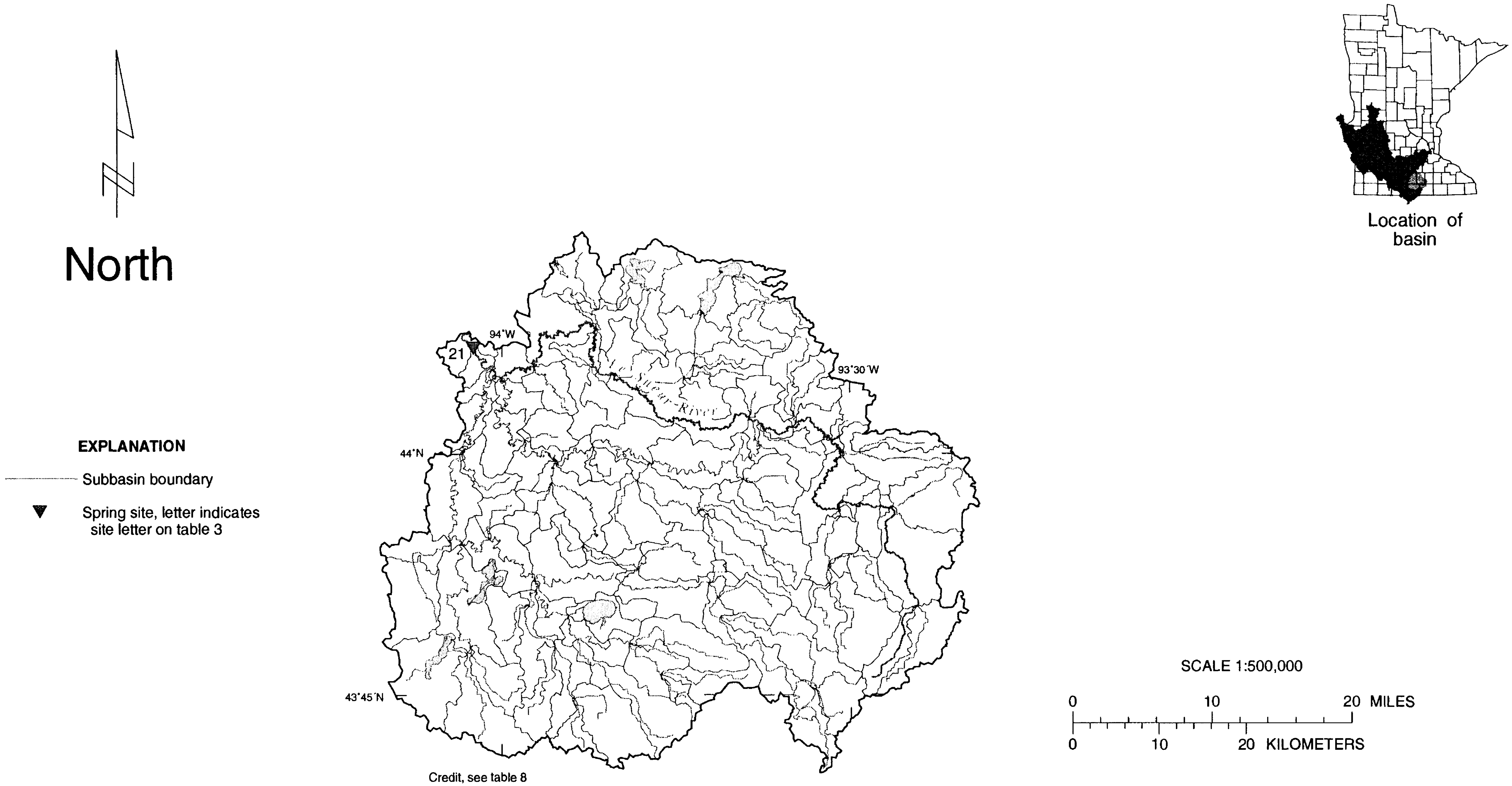


Figure 12B.--Subbasin boundaries and drainage patterns in the Le Sueur River Basin.

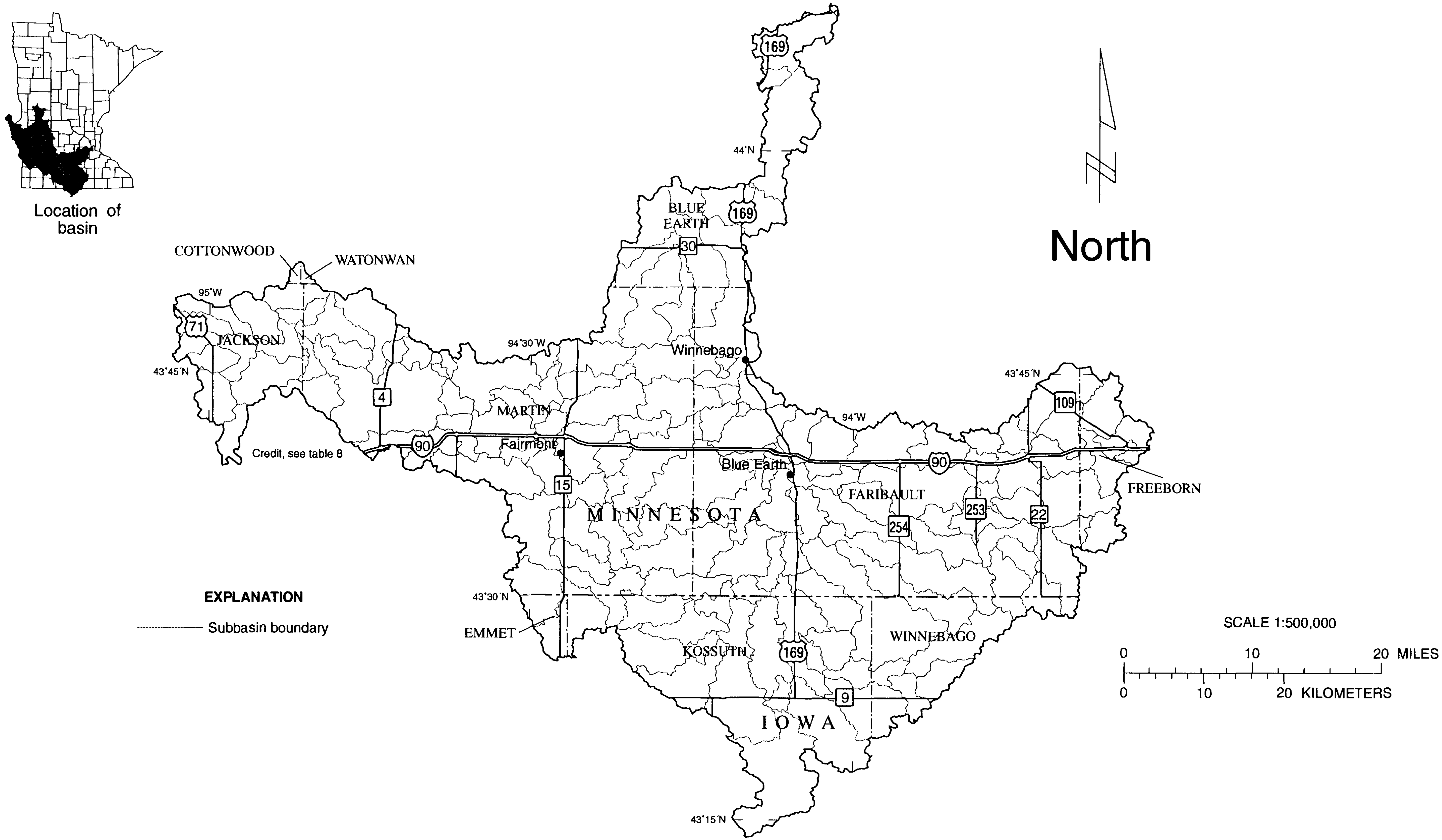
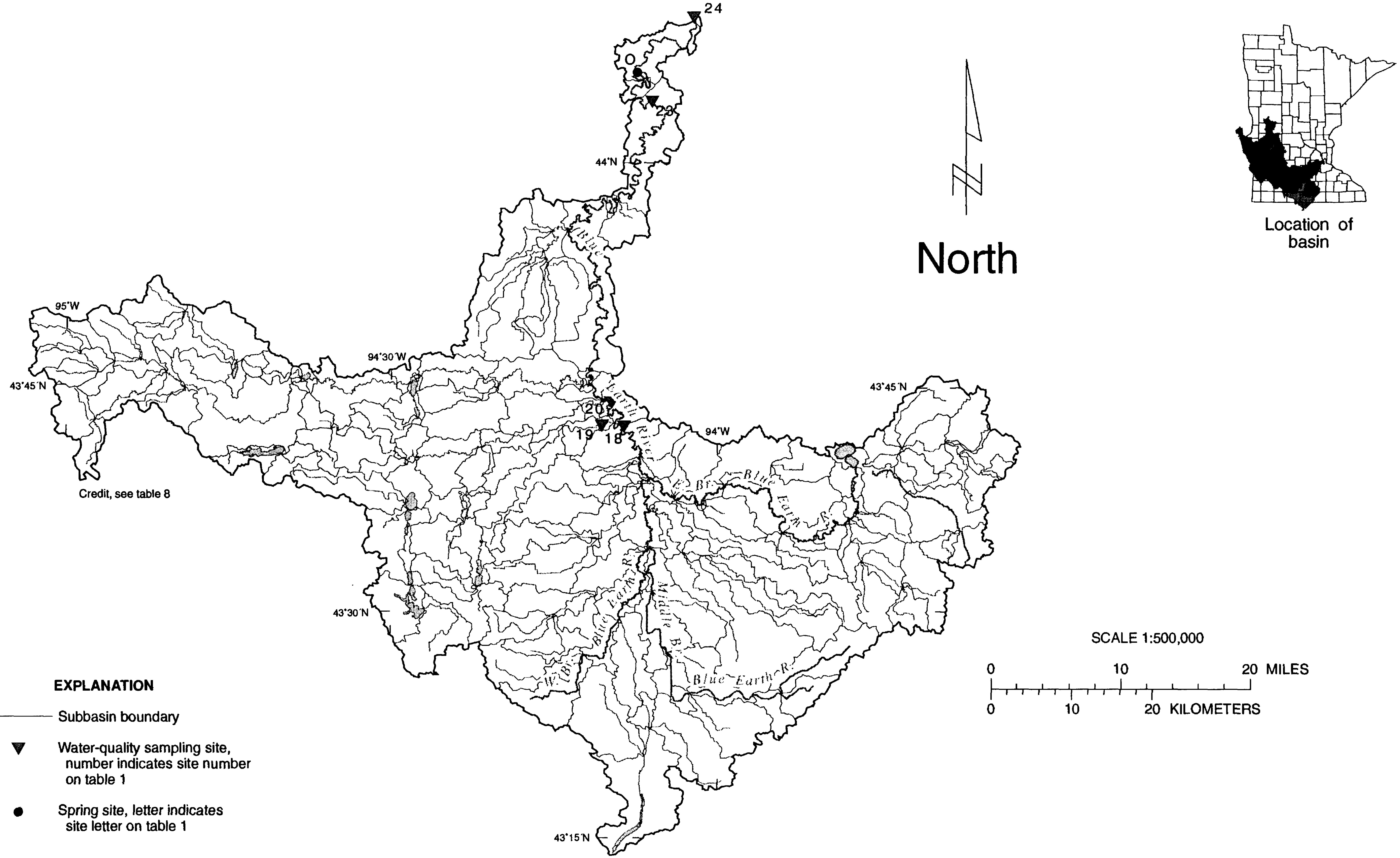


Figure 13A.--County boundaries, major roads, and cities in the Blue Earth River Basin.



EXPLANATION

——— Subbasin boundary

▼ Water-quality sampling site, number indicates site number on table 1

● Spring site, letter indicates site letter on table 1

Figure 13B.--Subbasin boundaries and major drainage patterns in the Blue Earth River Basin.

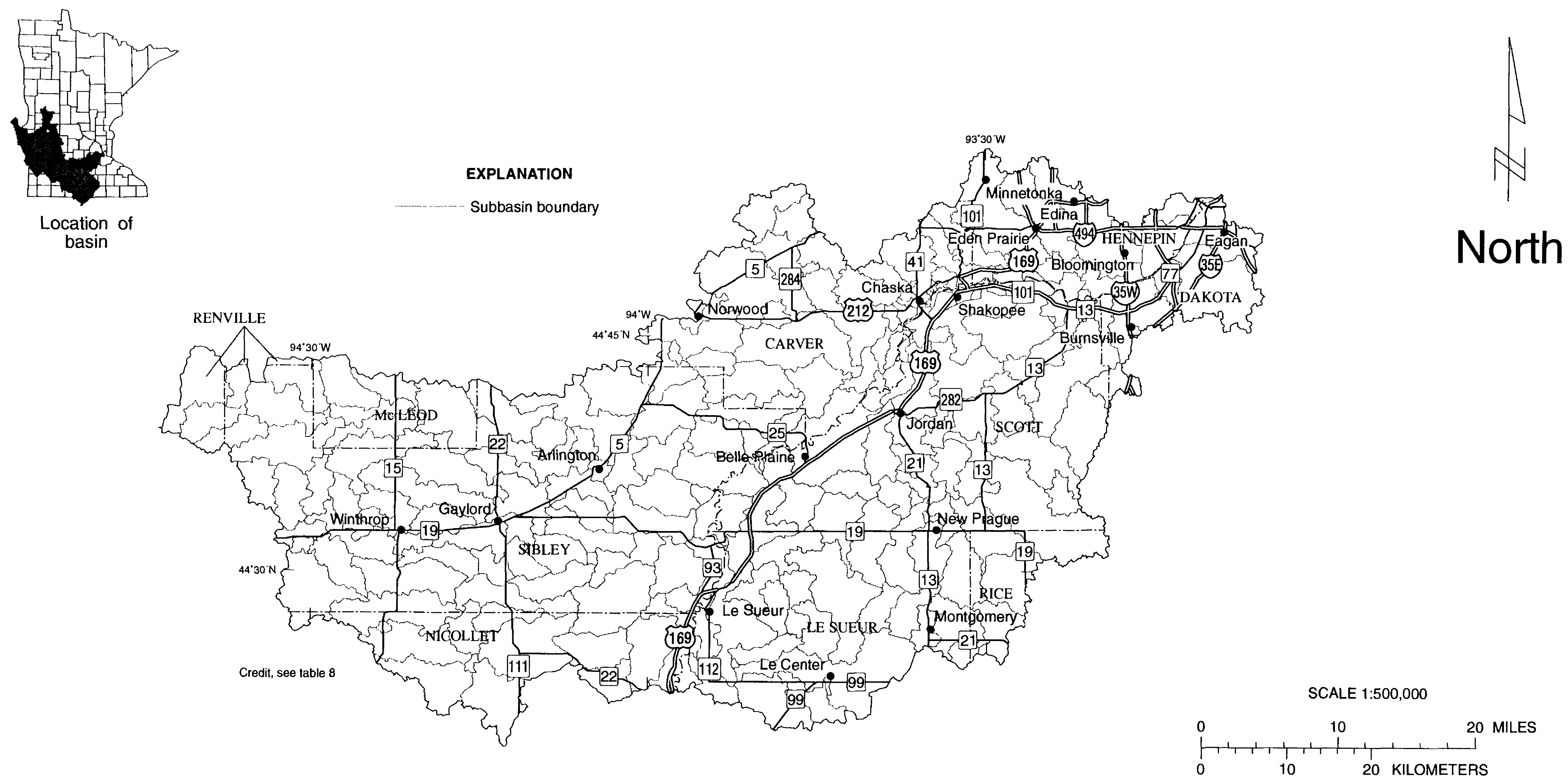


Figure 14A.--County boundaries, major roads, and cities in the Lower Minnesota River Basin.

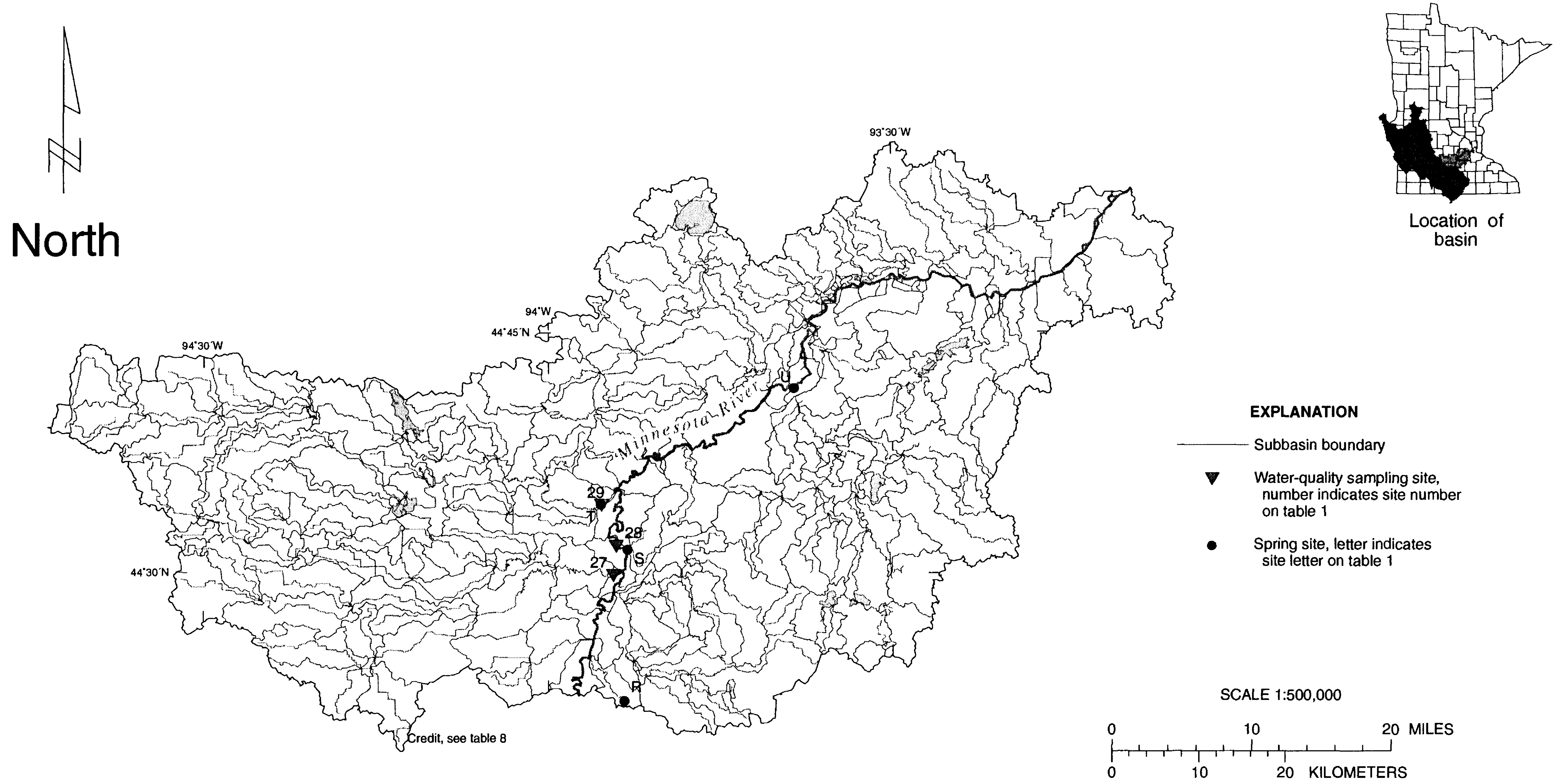


Figure 14B.--Subbasin boundaries and drainage patterns in the Lower Minnesota River Basin.

BEDROCK HYDROGEOLOGY

The Minnesota River Basin is underlain by rocks that range in age from Precambrian to Cretaceous (fig. 15). The Precambrian rocks are primarily igneous and metamorphic. The Paleozoic and Cretaceous rocks consist primarily of sandstone, shale, dolomite, and limestone. Geologic information on figure 15 is based on a map published by the Minnesota Geological Survey (Kanivetsky, 1979a). The GIS data base of bedrock hydrogeology is available from LMIC. A brief explanation of the lithology and age of each of the hydrogeologic units (Kanivetsky, 1979a) is shown on table 4.

QUATERNARY GEOLOGY

A thick sequence of glacial deposits of Quaternary age covers bedrock in most of the Minnesota River Basin; they were deposited by several glacial lobes during the Pleistocene Epoch, about 15,000 years ago. The glacial deposits range from clay-rich, poorly sorted till to well-sorted outwash consisting of sand and gravel. River bank stability and soil erodibility can be related to the texture and physical properties of the glacial deposits. Figure 16 is based on a map published by the Minnesota Geological Survey (Hobbs and Goebel, 1982). A GIS data base of Quaternary geology is available from the LMIC.

QUATERNARY HYDROGEOLOGY

The Quaternary hydrogeologic units shown in figure 17 describe the water-bearing characteristics of glacial drift and postglacial sediments which underlie the Minnesota River Basin. They are defined by geologic classification, material classification, and sustained yield rating. This figure is taken from a map prepared by the Minnesota Geological Survey (Kanivetsky, 1979b).

> The sustained yield rating is the hypothetical perpetual yield that could be obtained by continuous pumping from an isolated well penetrating the full thickness of a hydrogeologic unit, without irreversible depletion of the ground-water reservoir. The sustained yield rating is an index to the relative capacities of aquifers. It is not an estimate of the actual working yield to be expected from any given well. Working yields for practical periods of pumping may exceed sustained yield ratings. The sustained yield rating is derived from estimates of the porosity, permeability and thickness of an aquifer and the rate of ground-water recharge. Thus, the highest sustained yield rating is for alluvium in major river valleys where recharge from streamflow is possible. The sustained yield ratings shown in this map are approximations within wide limits for broad areas. For some large areas of Minnesota, hydrogeologic data are limited, and many local variations beyond estimated limits are to be expected (Kanivetsky, 1979b).

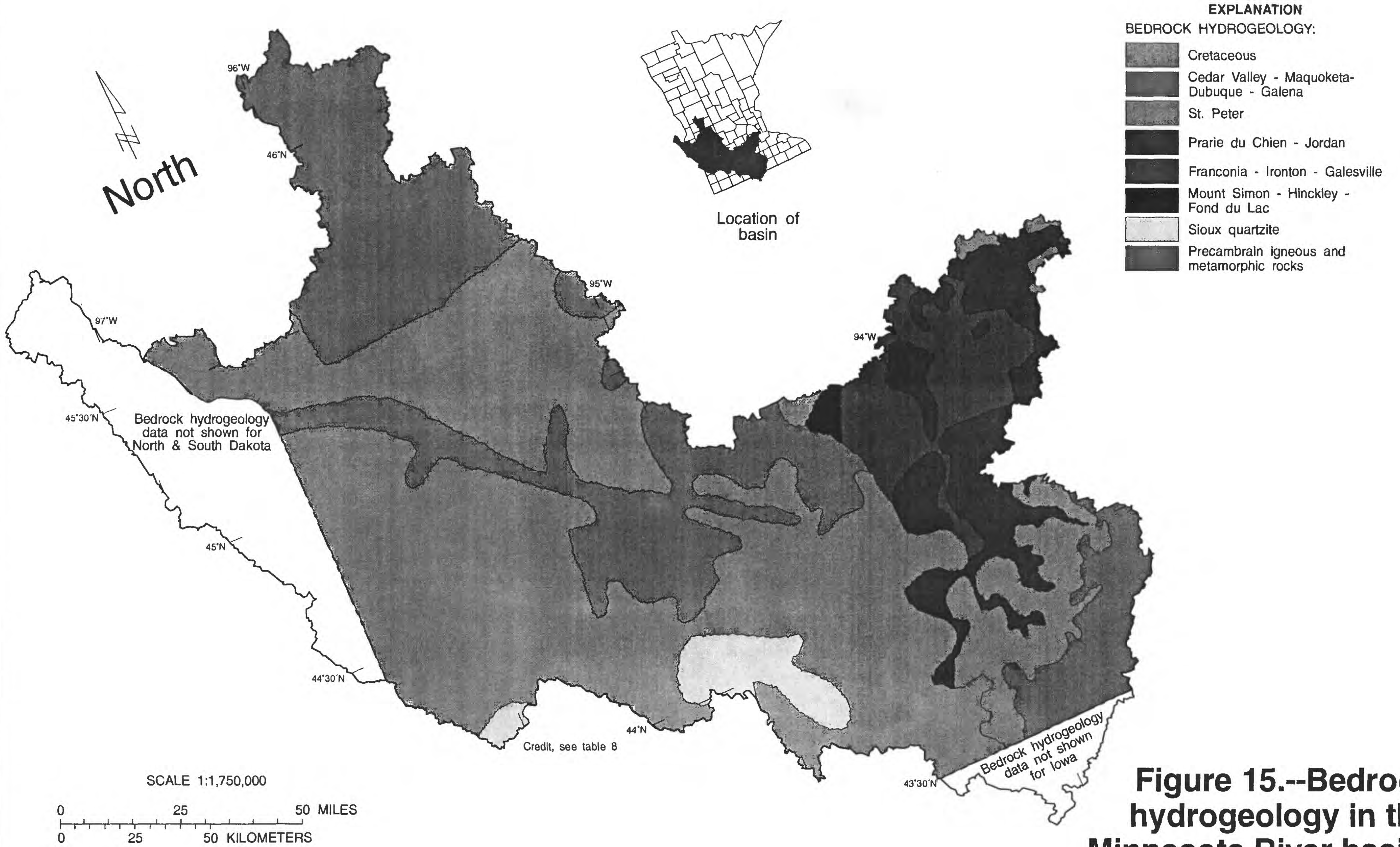


Figure 15.--Bedrock hydrogeology in the Minnesota River basin.

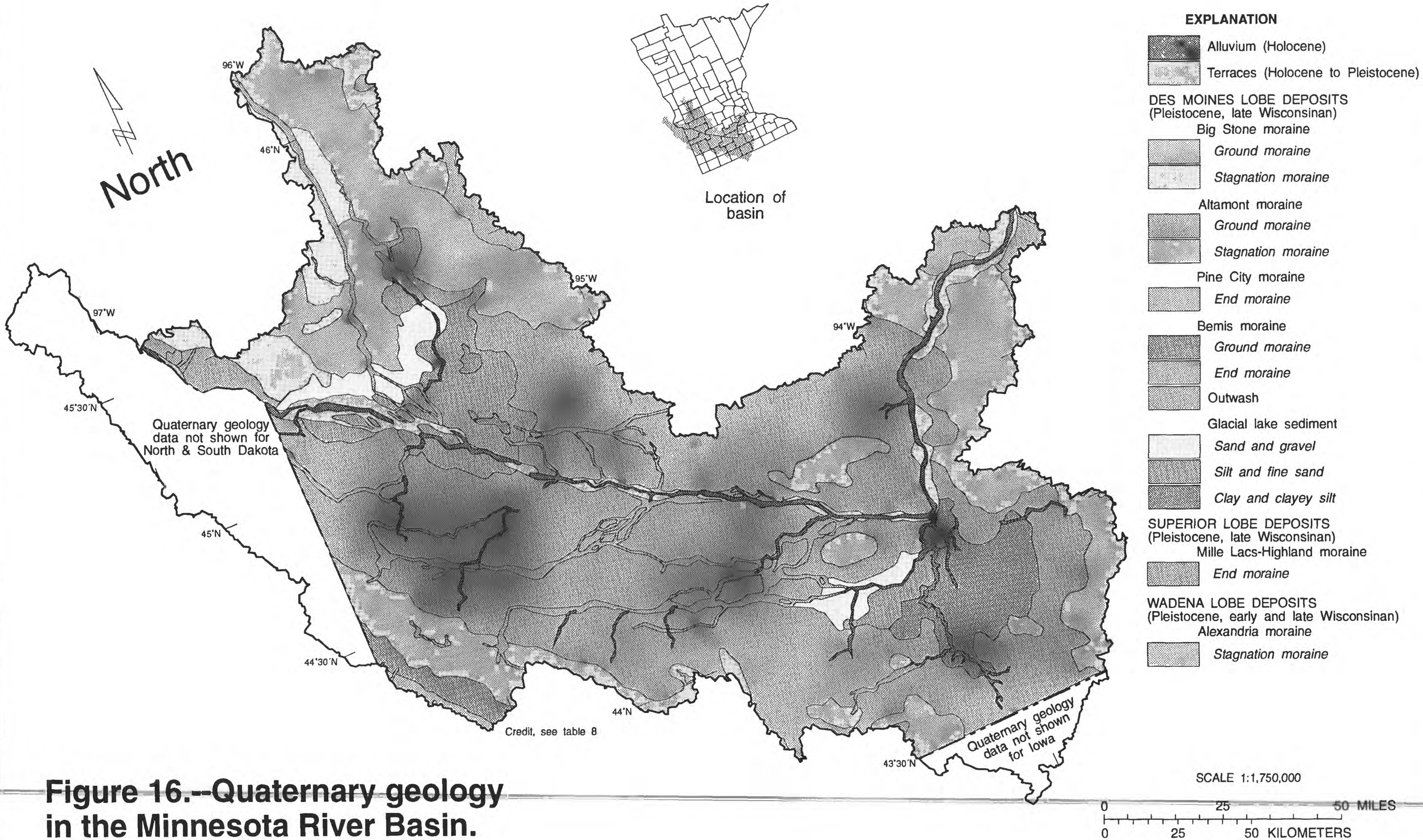


Figure 16.--Quaternary geology in the Minnesota River Basin.

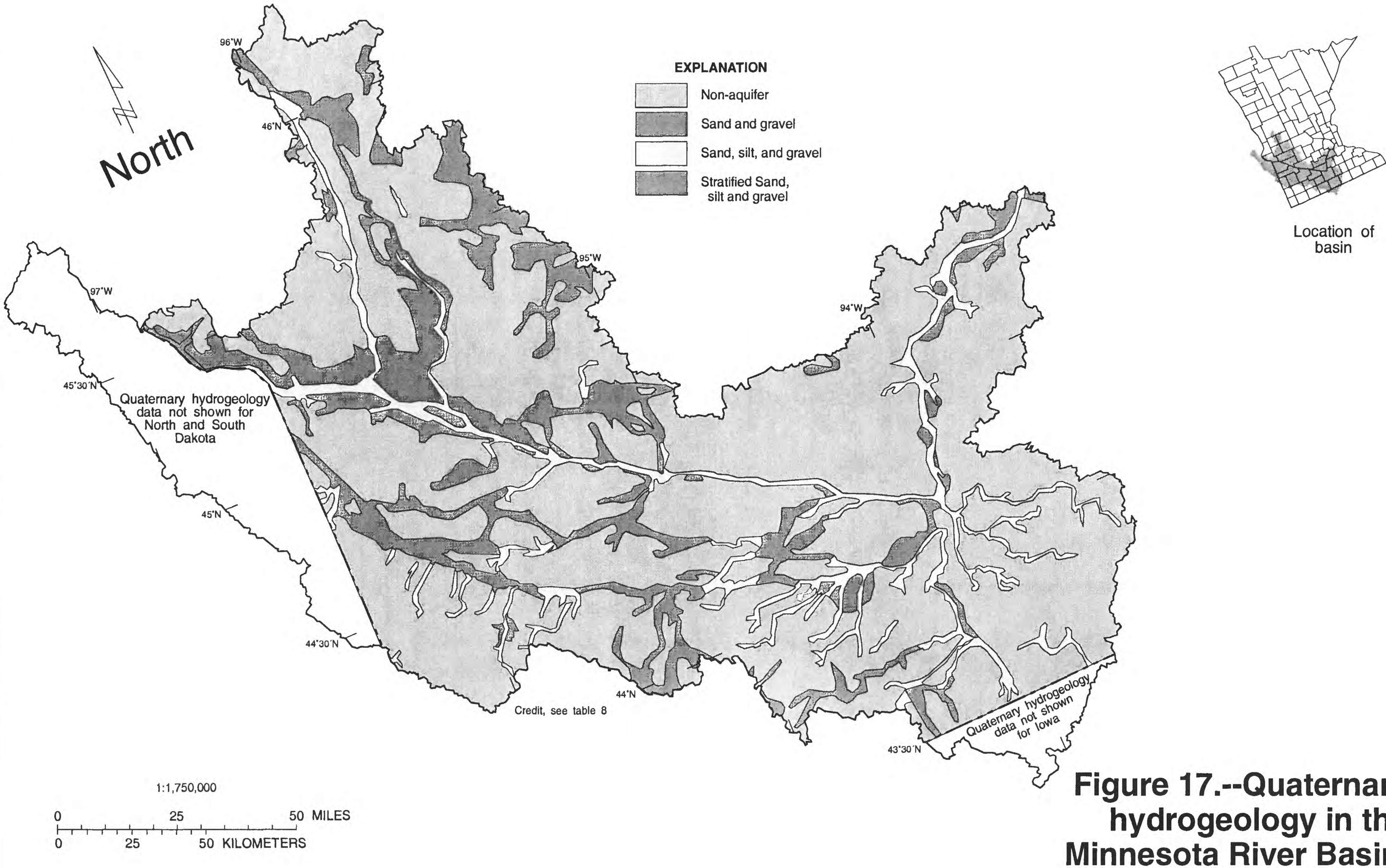


Figure 17.--Quaternary hydrogeology in the Minnesota River Basin.

GEOMORPHIC REGIONS

Geomorphic regions (fig. 18) are defined by topographic relief and soil material. The GIS data base containing the geomorphic region data consists of 40-acre grid-cell data. This data base was prepared by the LMIC using 1:125,000 preliminary Minnesota Soil Atlas sheets (Land Management Information Center, 1989, p. 22). These maps are published at a scale of 1:250,000 in the Minnesota Soil Atlas series by the Agricultural Experiment Station, University of Minnesota (Agricultural Experiment Station, 1973, 1979, 1981). The GIS data are available from the LMIC.

SOIL LANDSCAPE UNITS

The physical properties of soils are significant because they affect the ability of a soil to resist erosion and transport by wind and water, and affect the ability of a soil to retard or to transmit chemicals to streams and to ground water. Soil landscape units (figs. 19-30) are groups of soils generalized into homogeneous units based on sub-surface soil texture, surface soil texture, drainage characteristics, and surface color. Combinations of these four characteristics describe unique soil types.

The GIS data base containing soil landscape unit data consists of 40-acre grid-cell data. This data base was prepared by the LMIC using 1:250,000 preliminary Minnesota Soil Atlas sheets (Land Management Information Center, 1989). These maps are published at a scale of 1:250,000 in the Minnesota Soil Atlas series by the Agricultural Experiment Station, University of Minnesota (Agricultural Experiment Station, 1973, 1979, 1981). The GIS data are available from the LMIC.

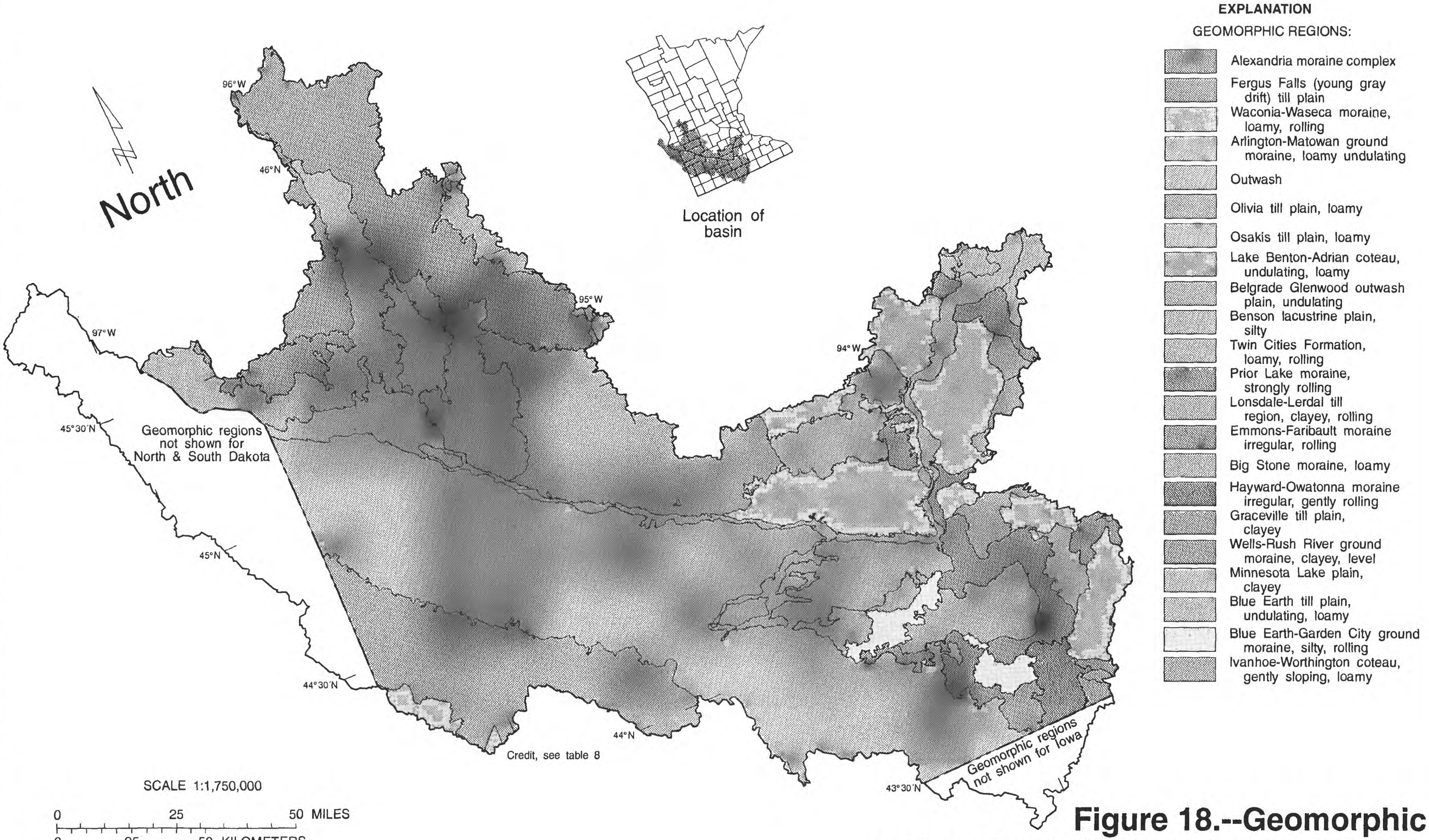


Figure 18.--Geomorphic regions in the Minnesota River Basin.

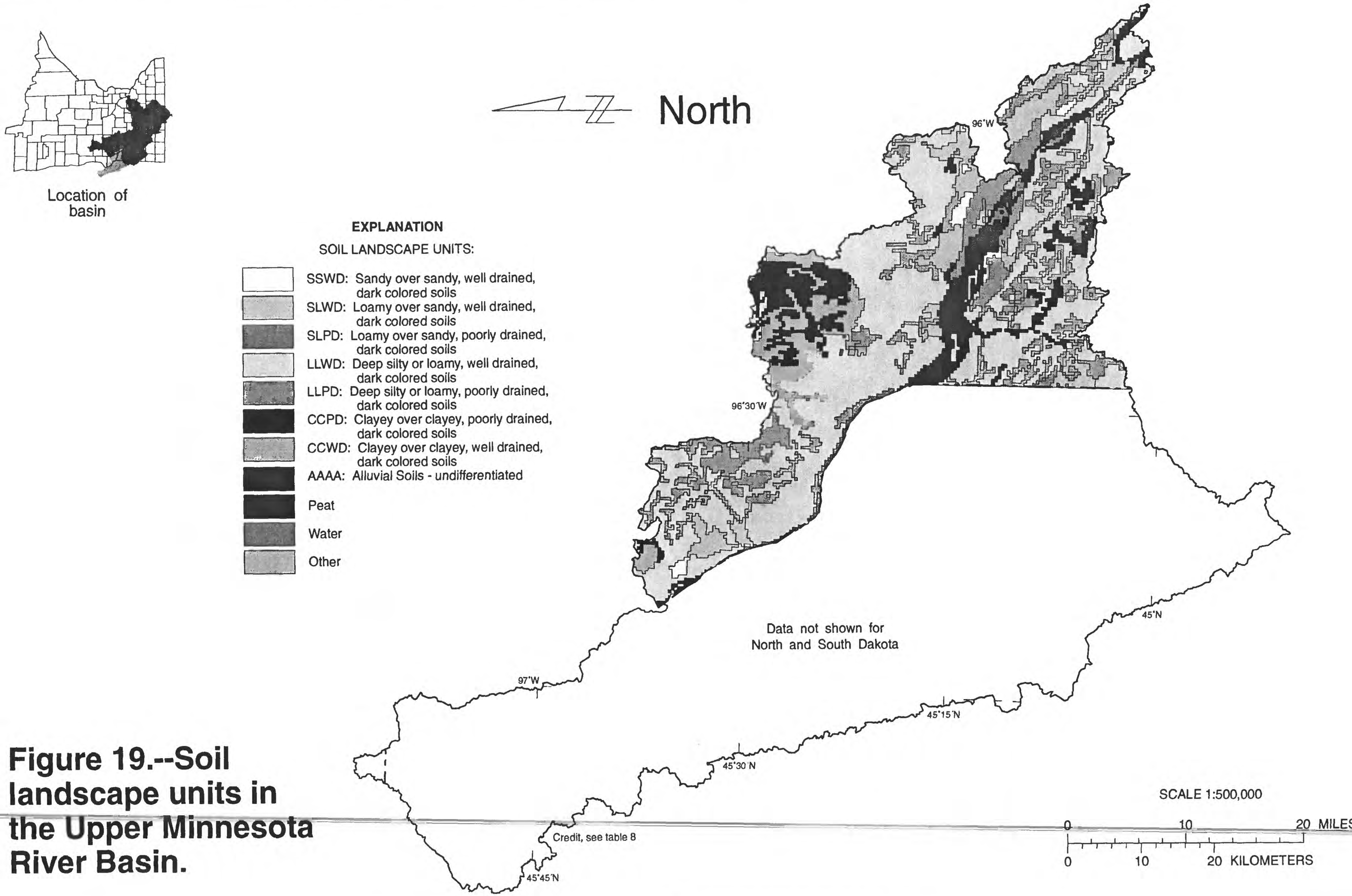


Figure 19.--Soil landscape units in the Upper Minnesota River Basin.

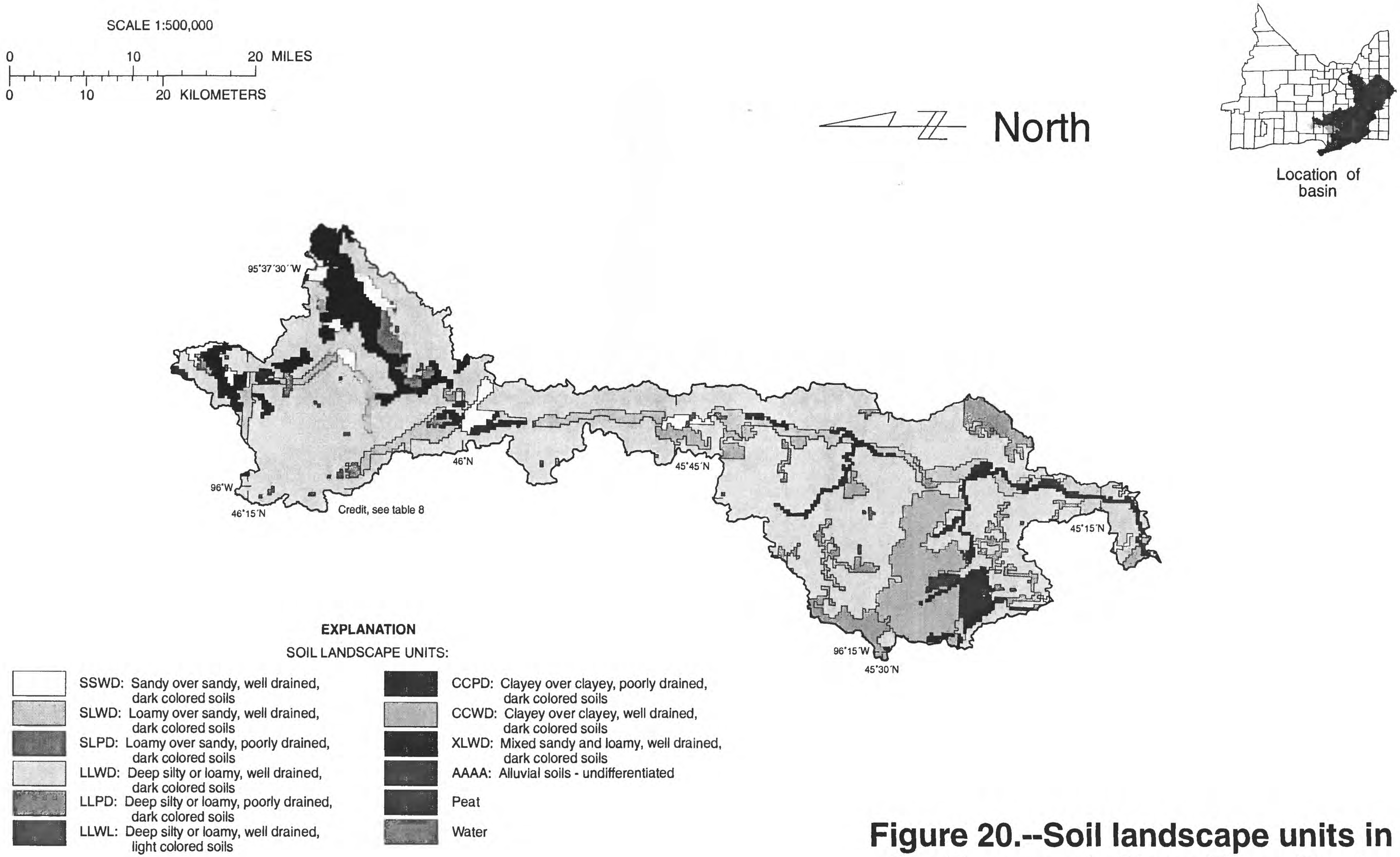


Figure 20.--Soil landscape units in the Pomme de Terre River Basin.

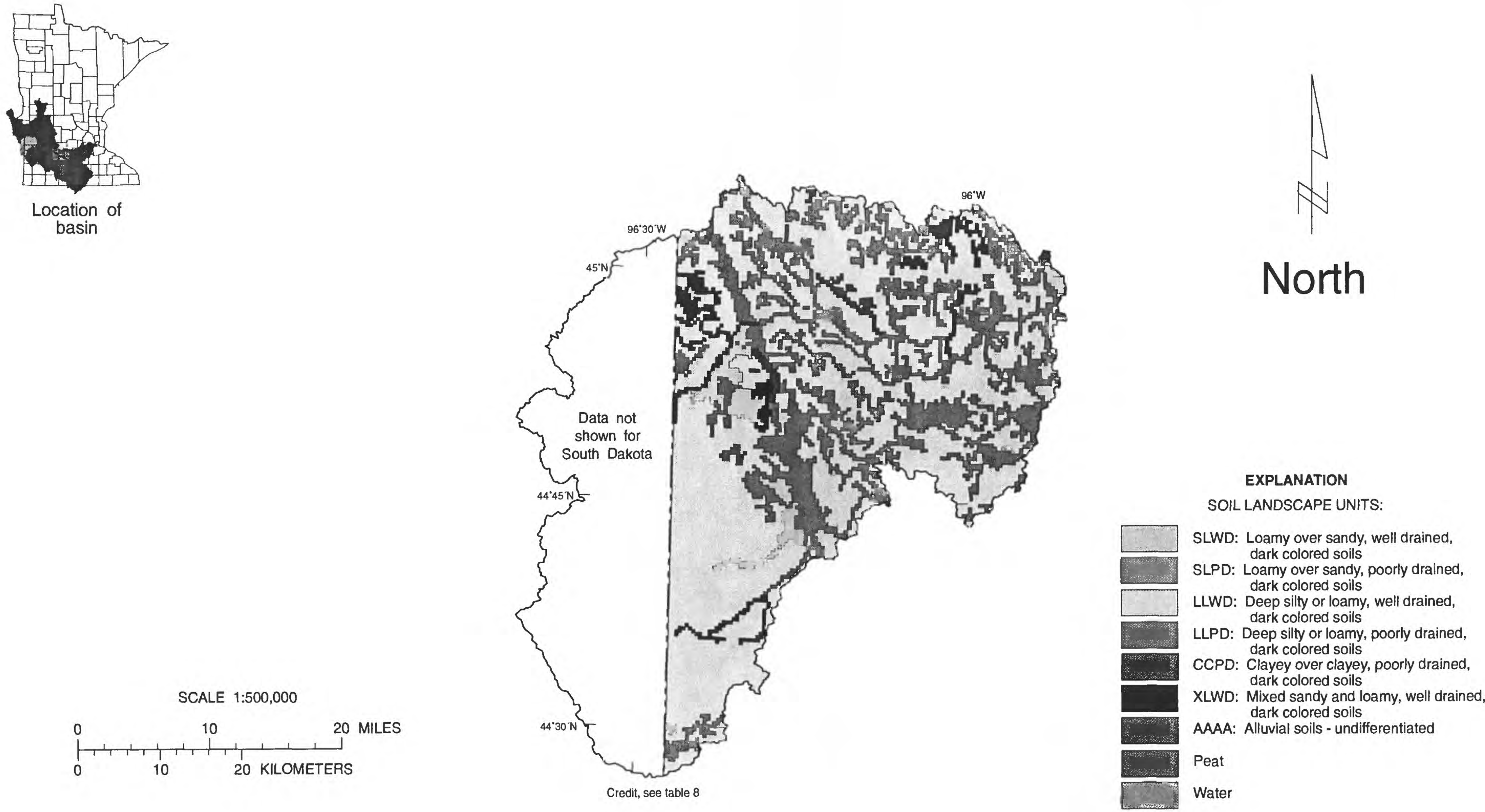


Figure 21.--Soil landscape units in the Lac qui Parle River Basin.

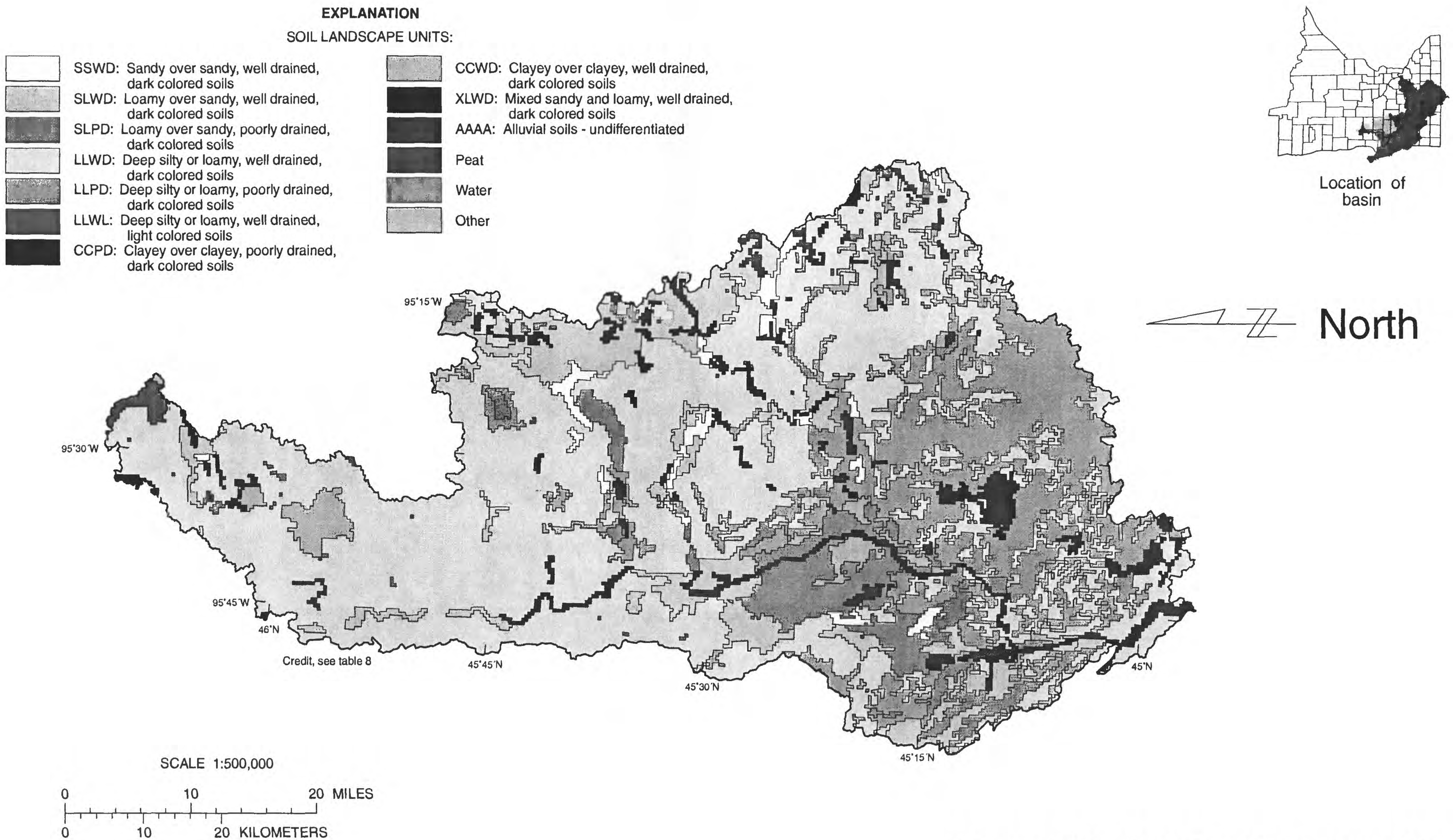


Figure 22.--Soil landscape units in the Chippewa River Basin.

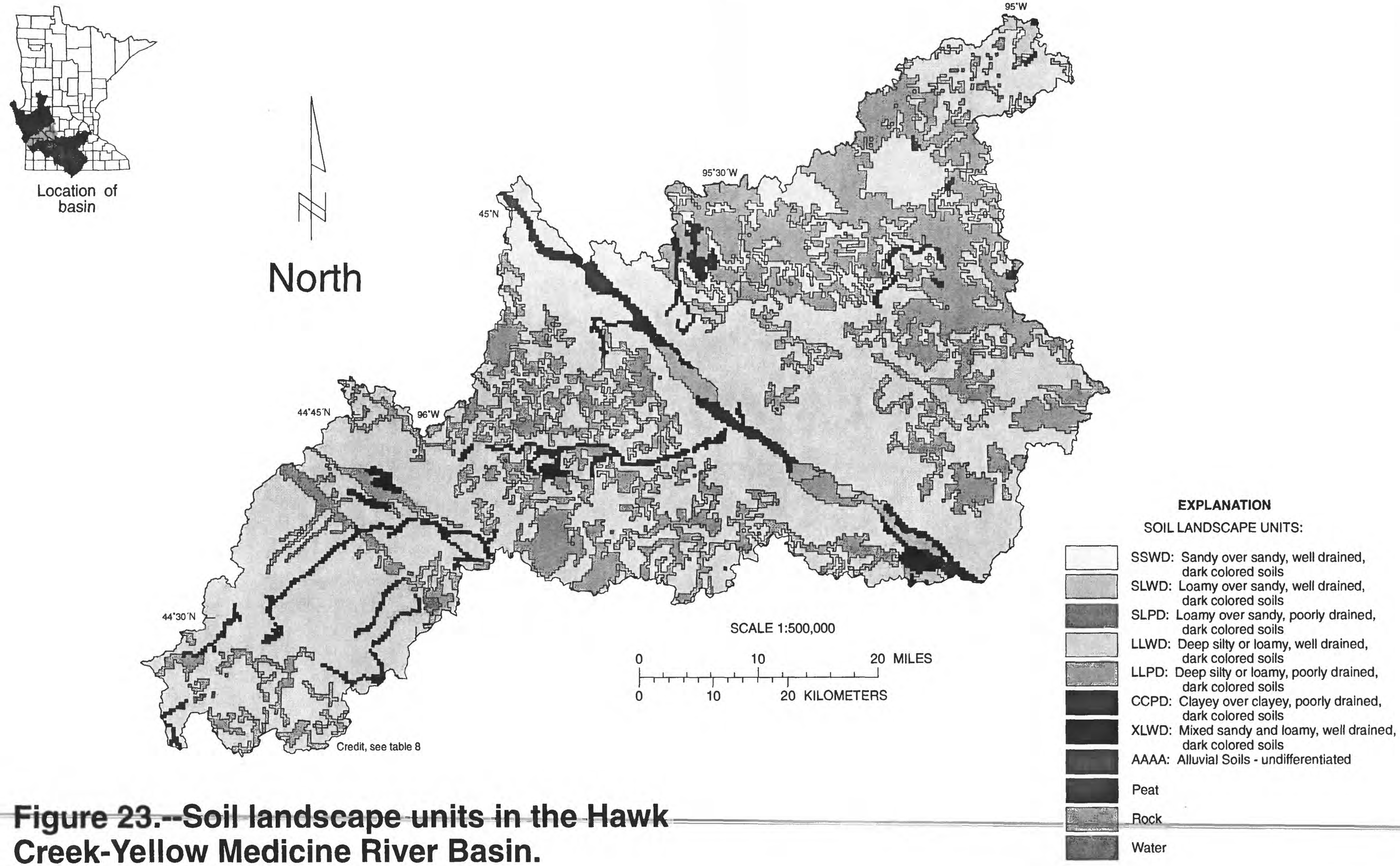


Figure 23.--Soil landscape units in the Hawk Creek-Yellow Medicine River Basin.

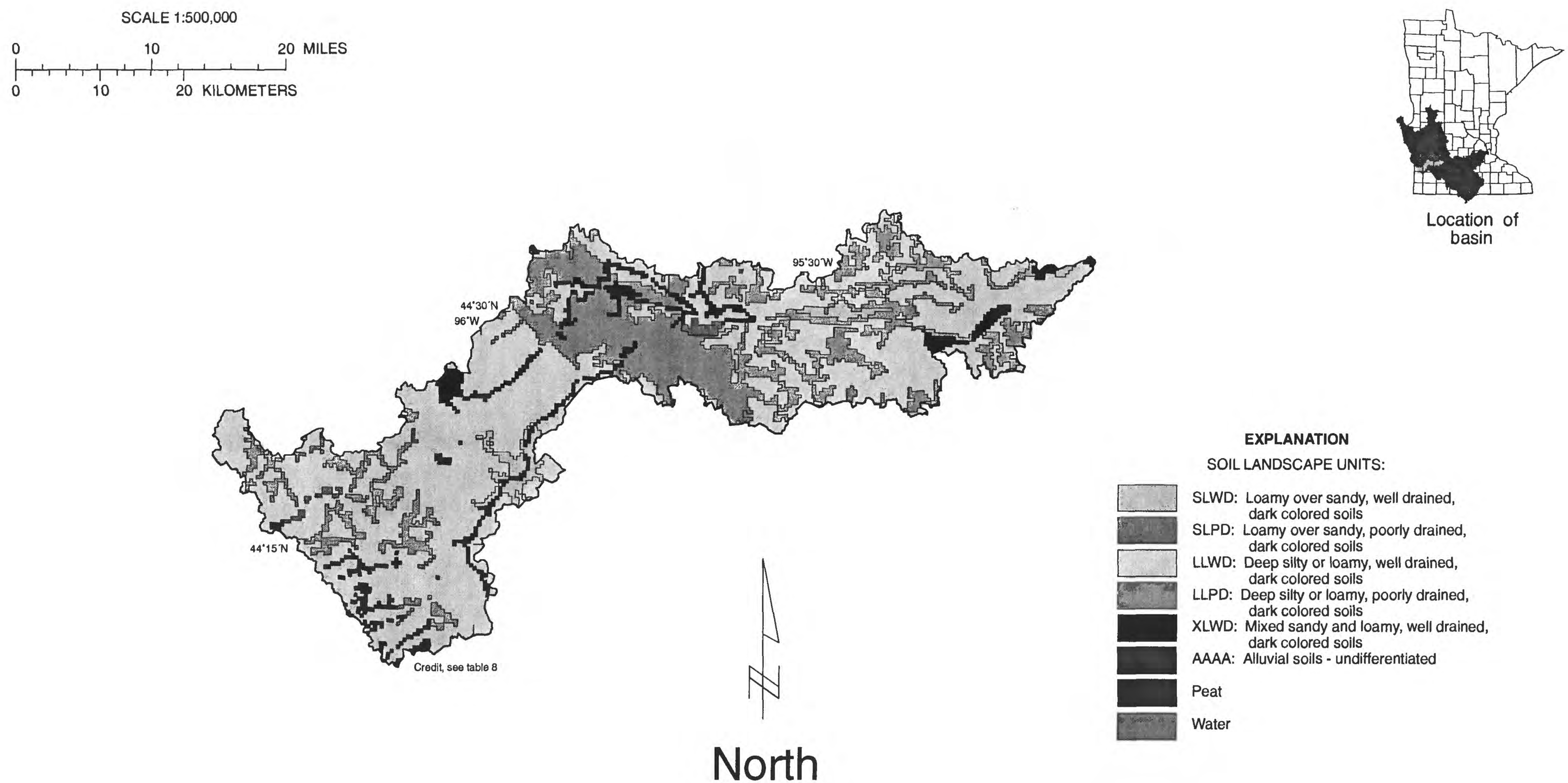


Figure 24.--Soil landscape units in the Redwood River Basin.

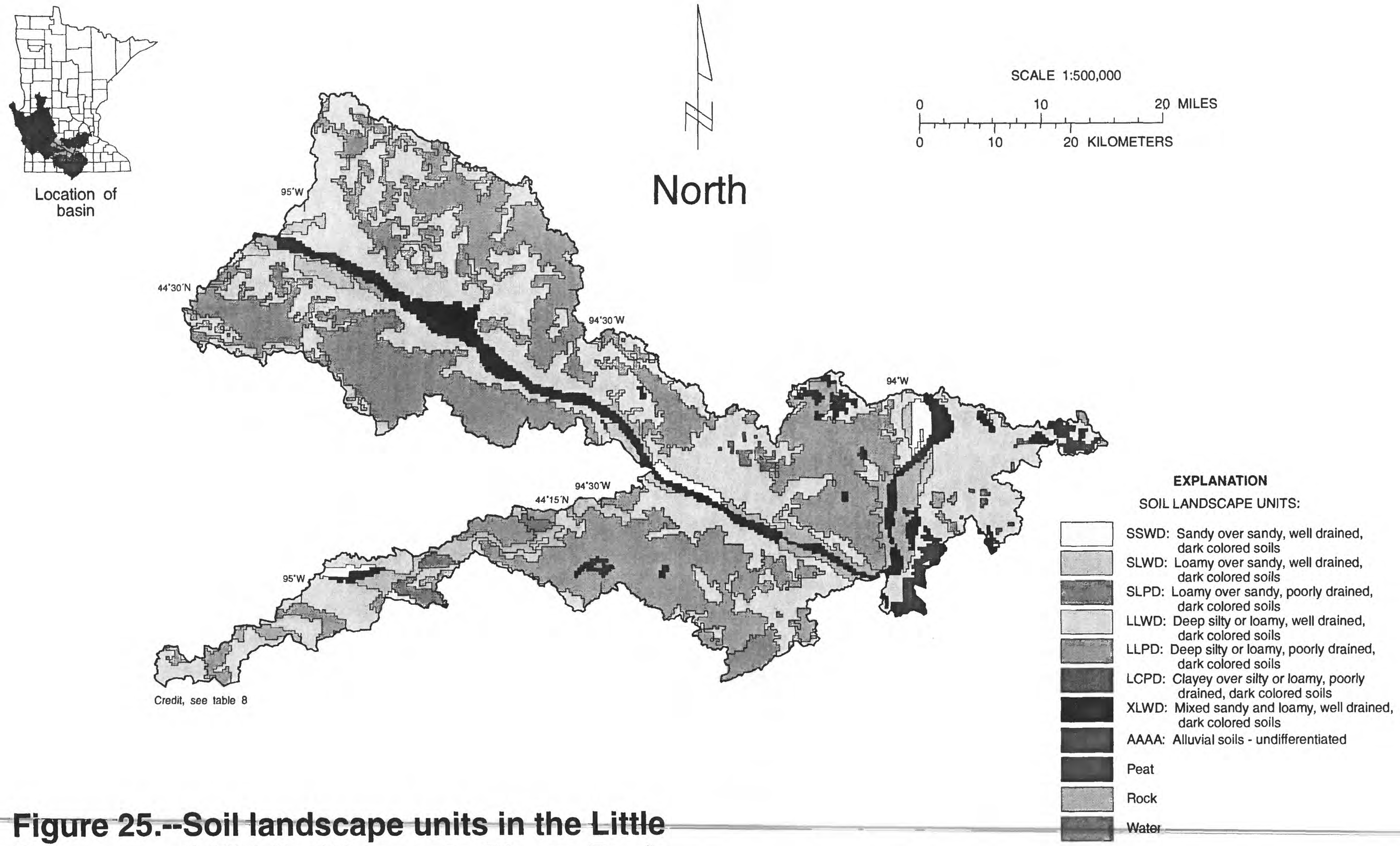


Figure 25.--Soil landscape units in the Little Cottonwood-Middle Minnesota Rivers Basin.

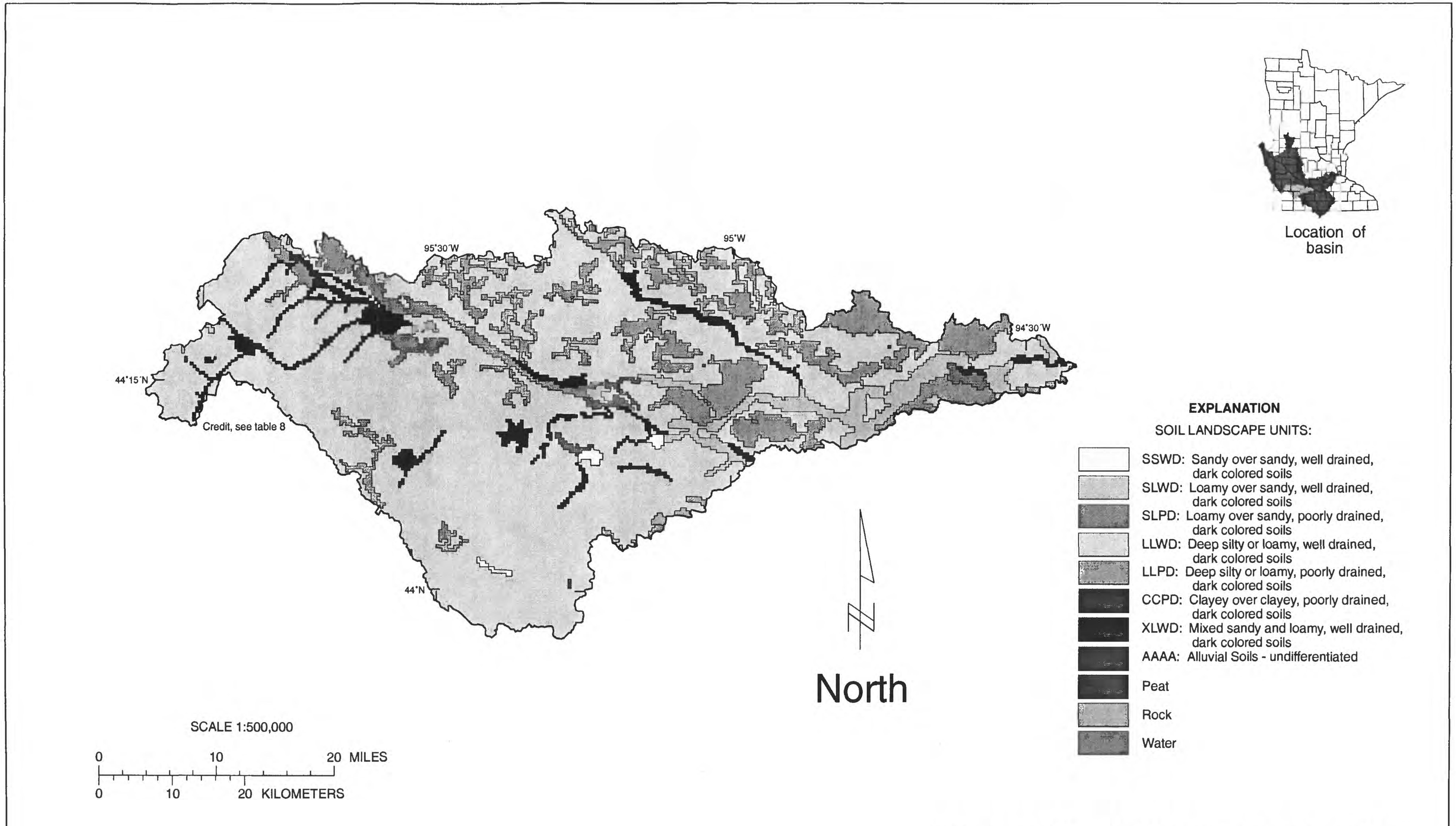


Figure 26.--Soil landscape units in the Cottonwood River Basin.

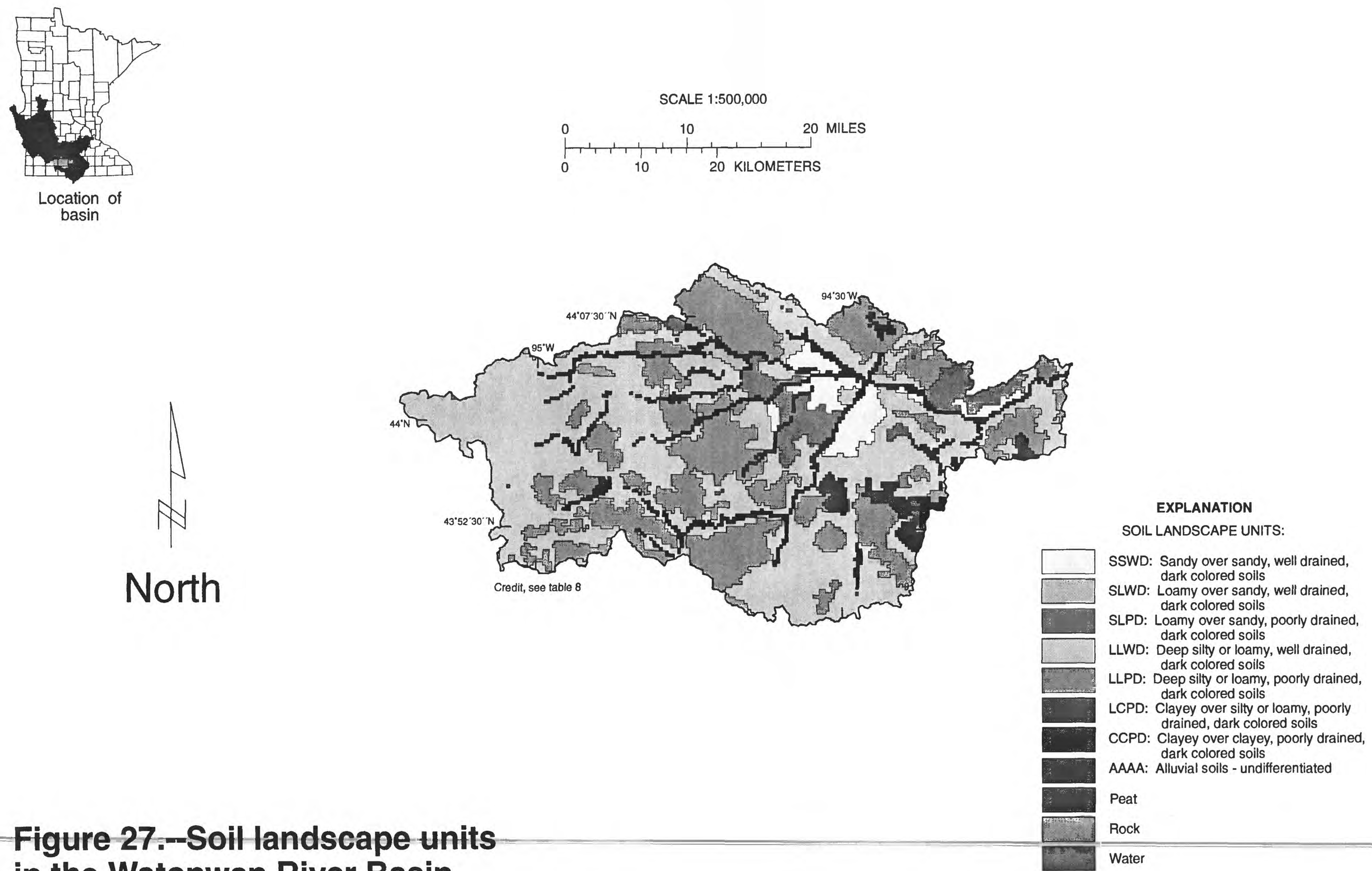


Figure 27.--Soil landscape units in the Watonwan River Basin.

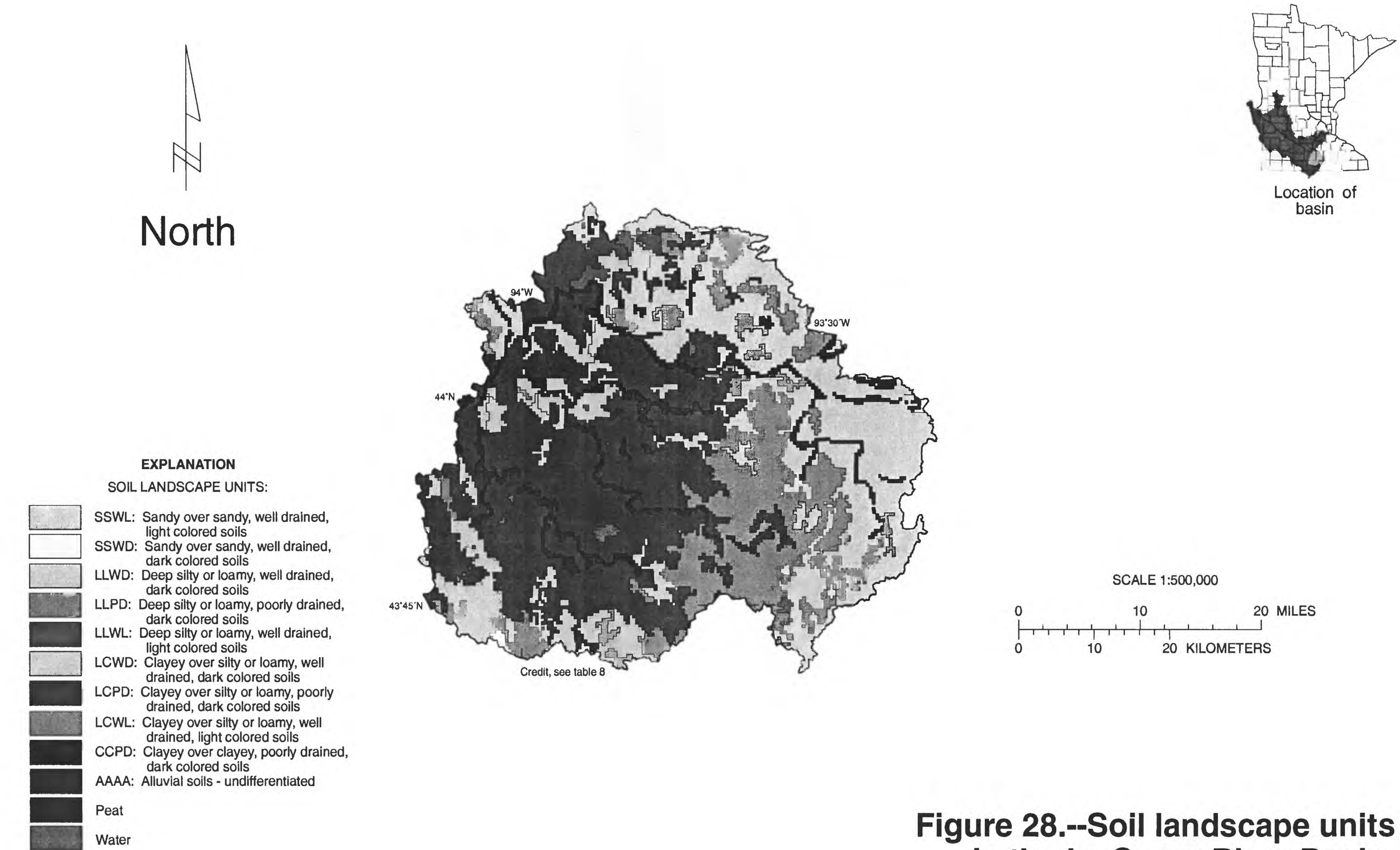


Figure 28.--Soil landscape units in the Le Sueur River Basin.

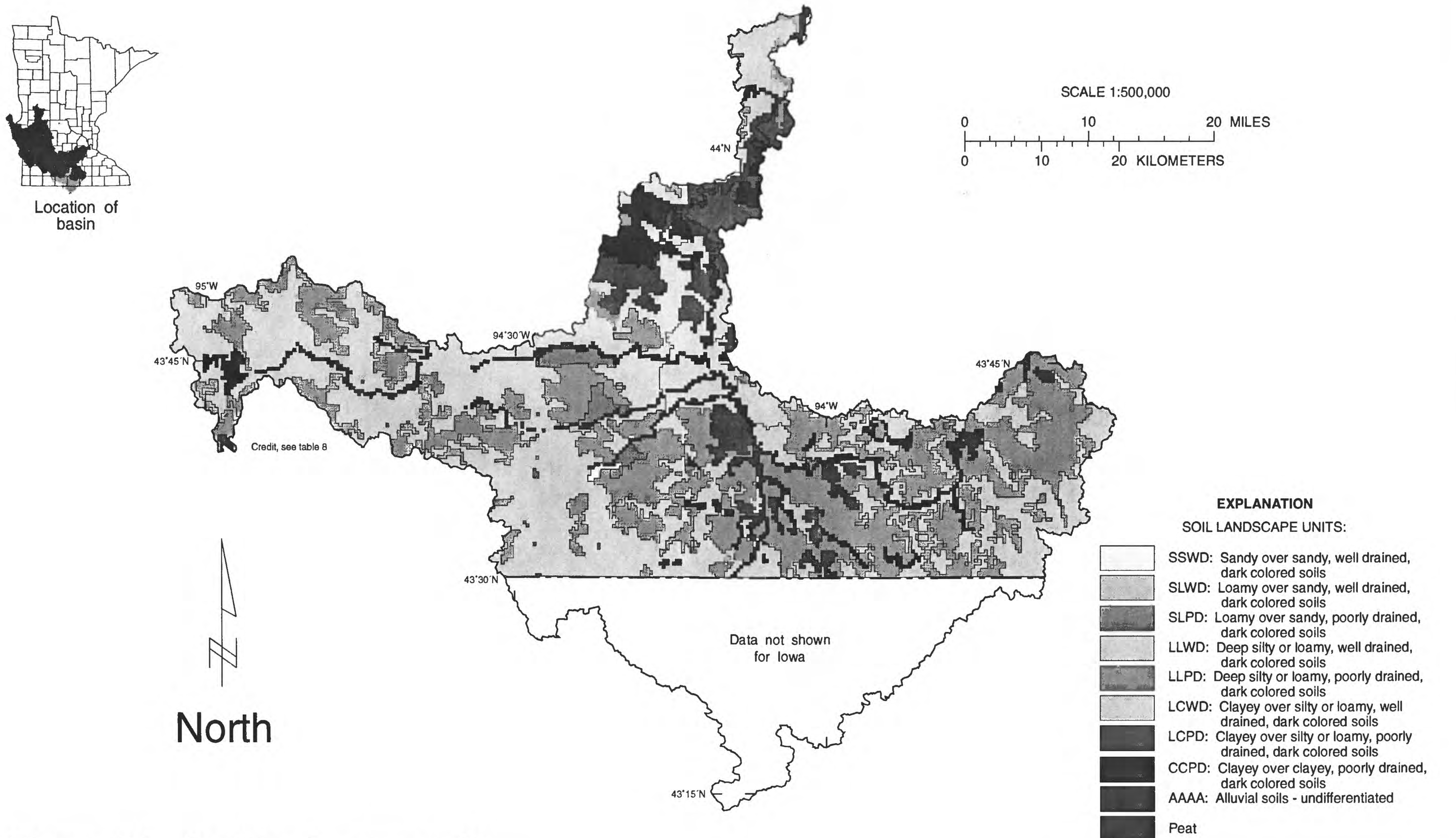


Figure 29.--Soil landscape units in the Blue Earth River Basin.

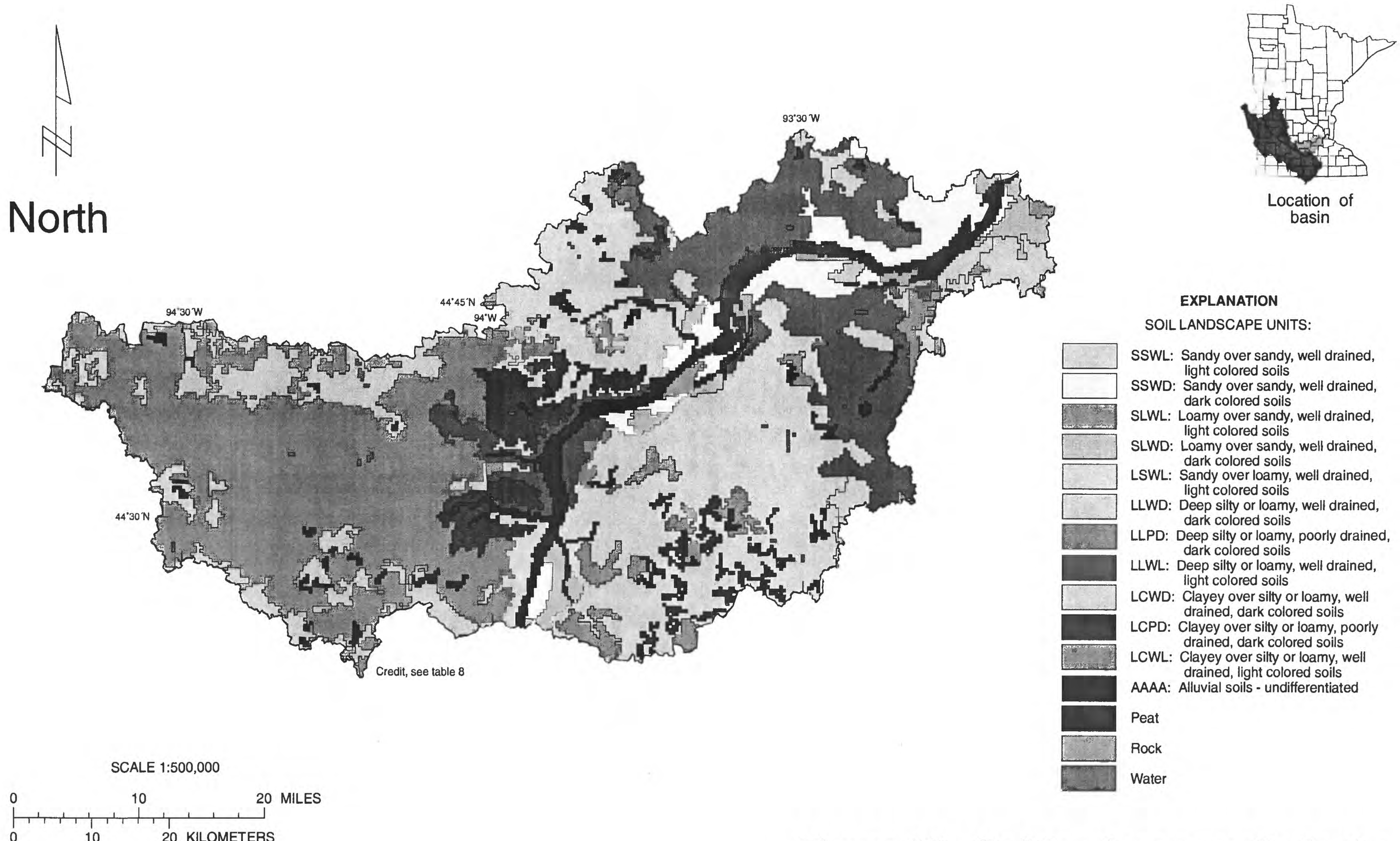
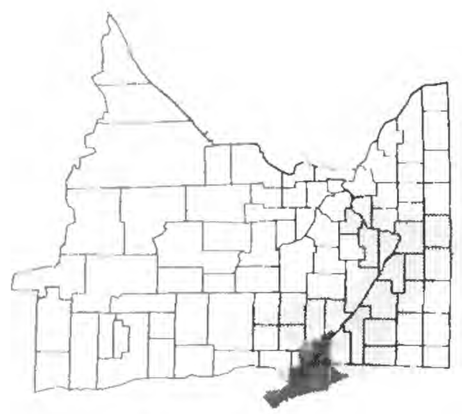


Figure 30.--Soil landscape units in the Lower Minnesota River Basin.



Location of
basin

EXPLANATION

——— Wetland

The wetlands in each of the basins of the Minnesota River Basin are shown in figures 31-42. The GIS data base of wetlands was prepared by the MDNR from wetland maps constructed by the U.S. Fish and Wildlife Service (USFWS) at a scale of 1:24,000. These maps were prepared as part of the National Wetlands Inventory from high-altitude photographs. Wetlands were identified based on vegetation, visible hydrology, and geography in accordance with Cowardin and others, 1979 (U.S. Fish and Wildlife Service, 1991). GIS data bases of the National Wetlands Inventory area avaibable from LMIC.

The Minnesota River Basin once had abundant wetlands. Many of these wetlands have now been drained for agricultural purposes and urban development. Wetlands are important because they affect streamflow and water quality. They reduce peak runoff and sustain ground-water recharge and streamflow during low-flow periods and act as traps for nutrients, sediment, and other chemicals transported with runoff (Carter and others, 1979).

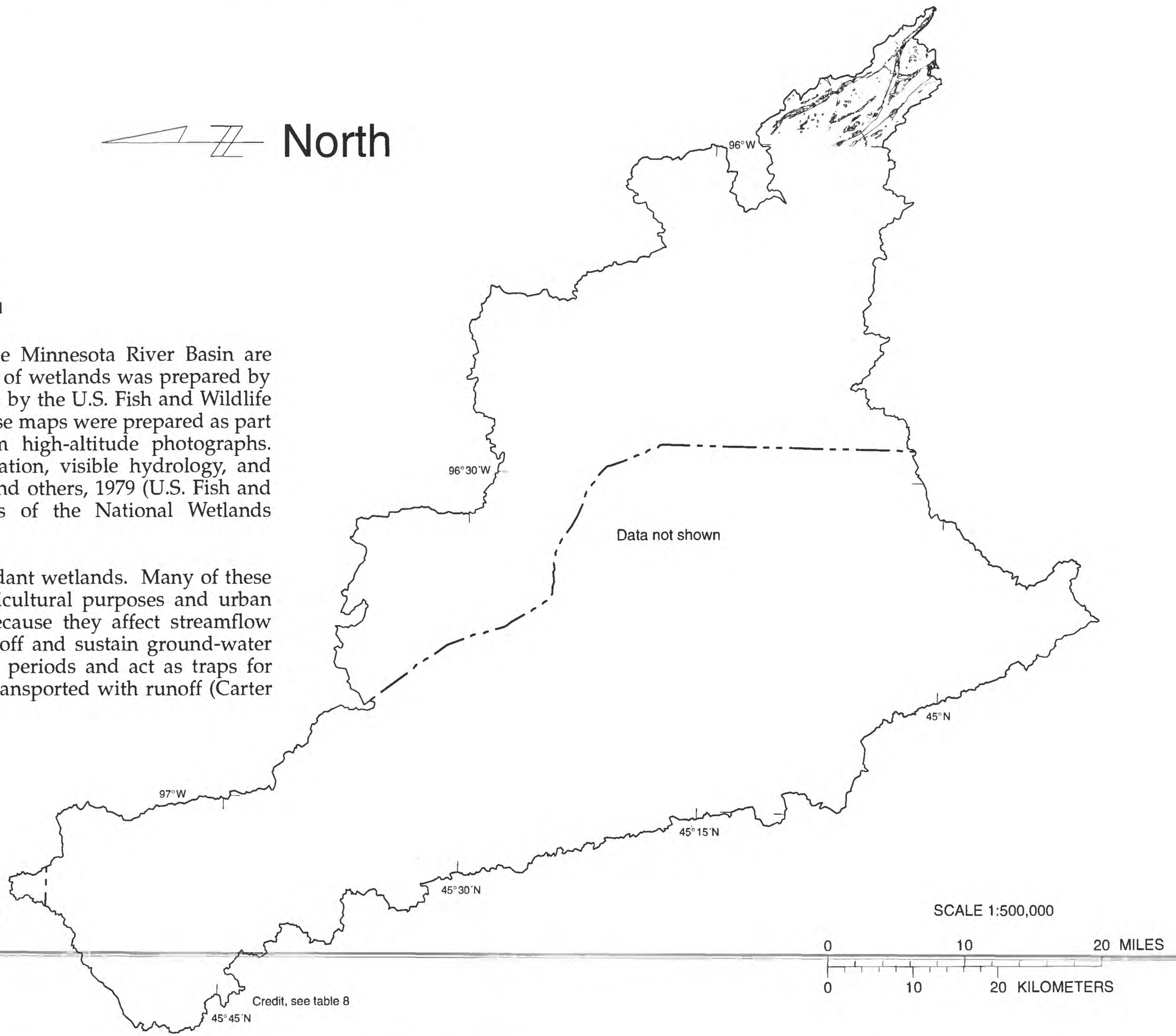


Figure 31.--Wetlands in the Upper Minnesota River Basin.

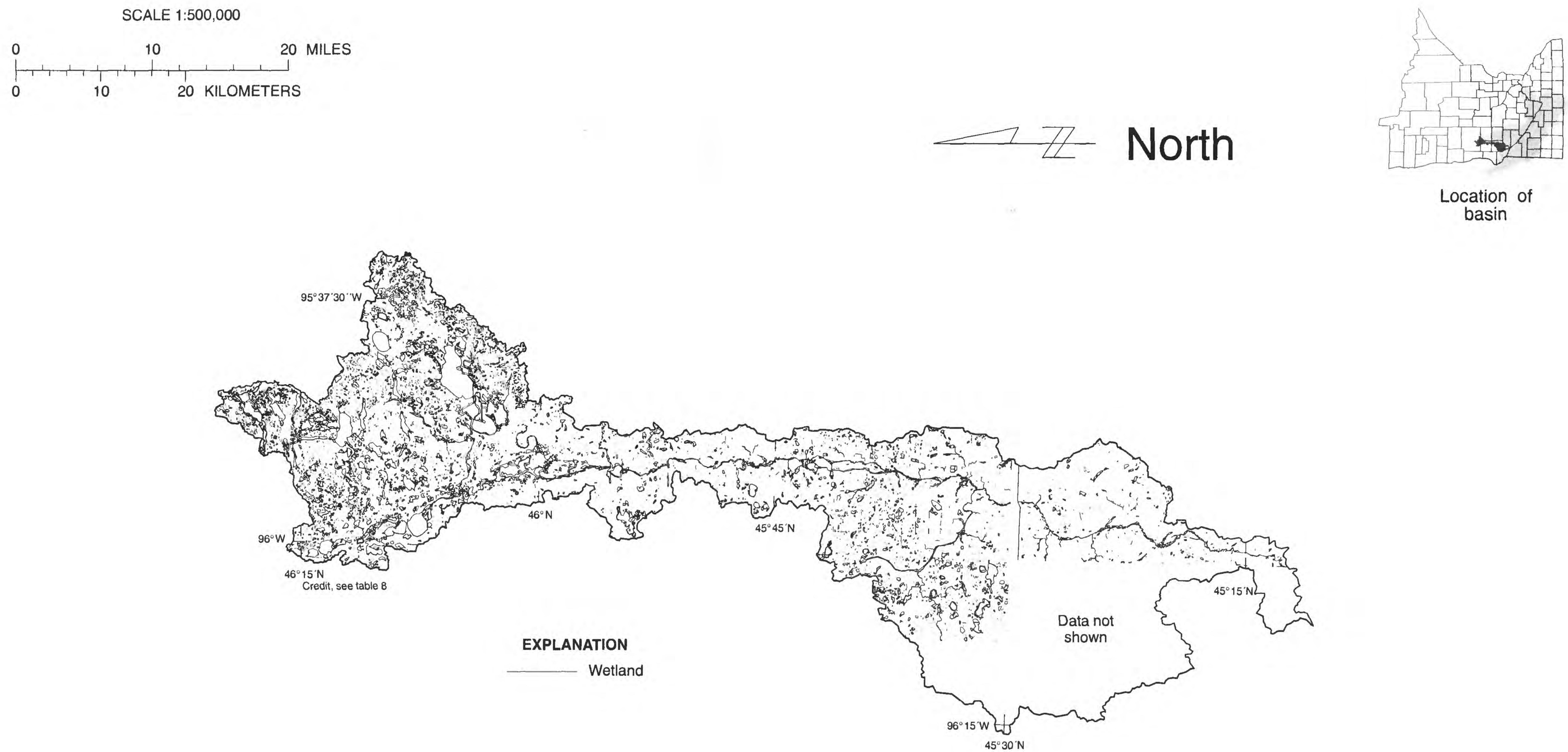
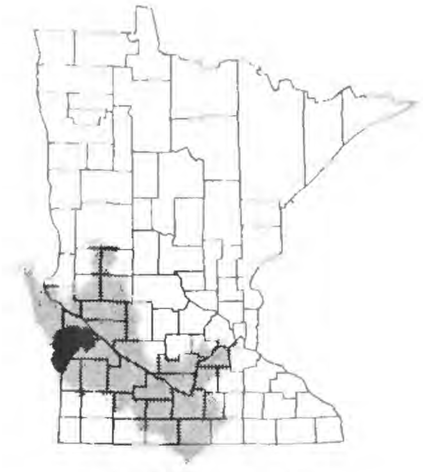
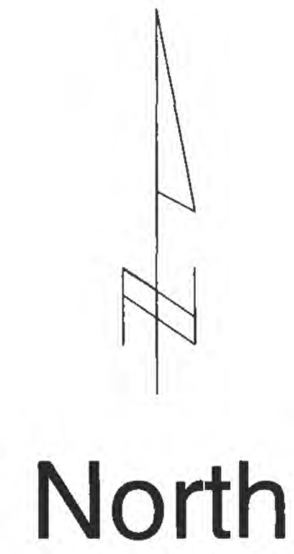


Figure 32.--Wetlands in the Pomme de Terre River Basin.





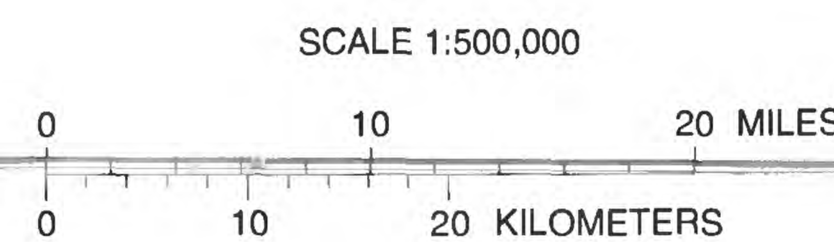


Figure 33.--Wetlands in the Lac qui Parle River Basin.

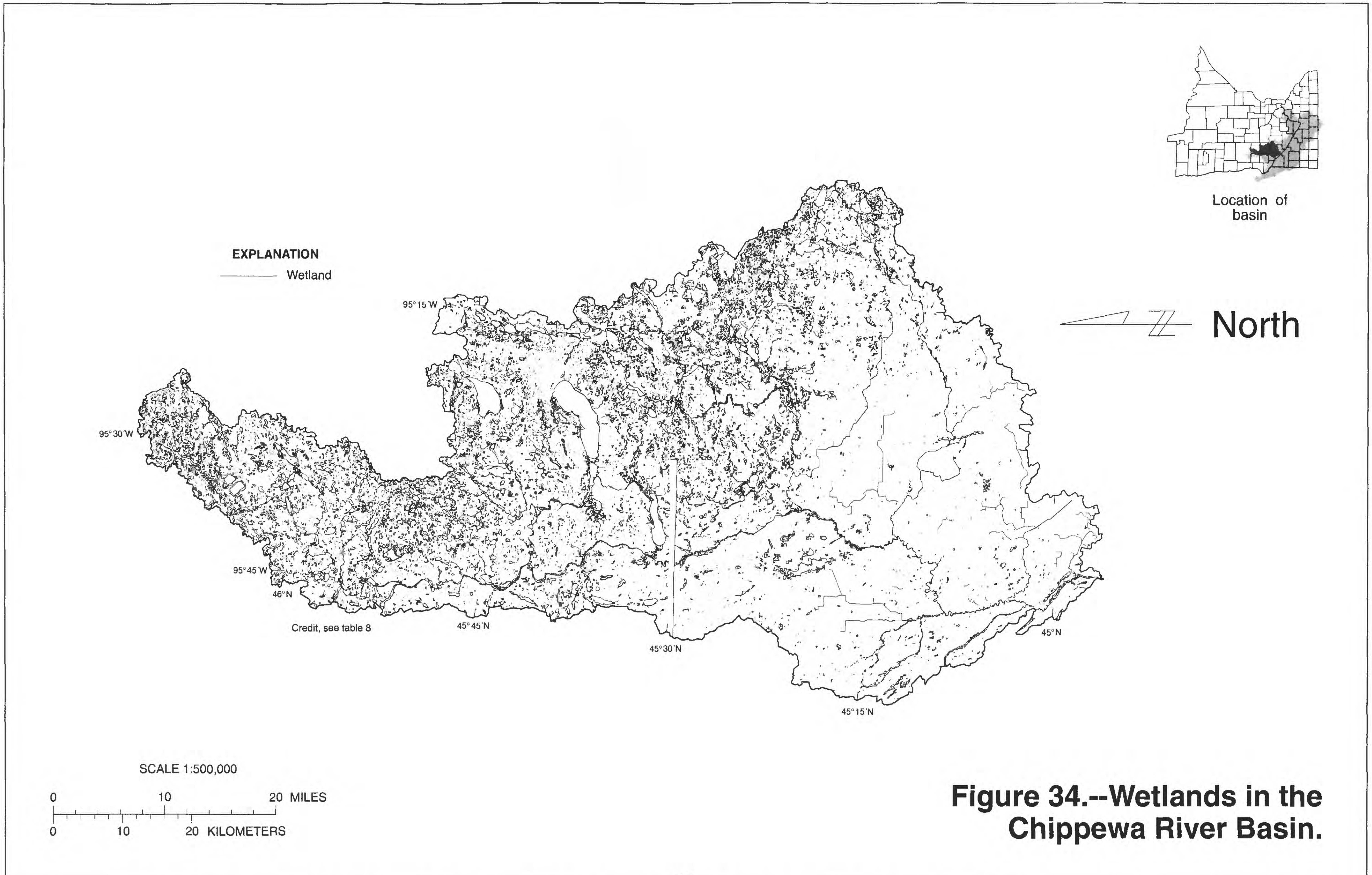


Figure 34.--Wetlands in the Chippewa River Basin.

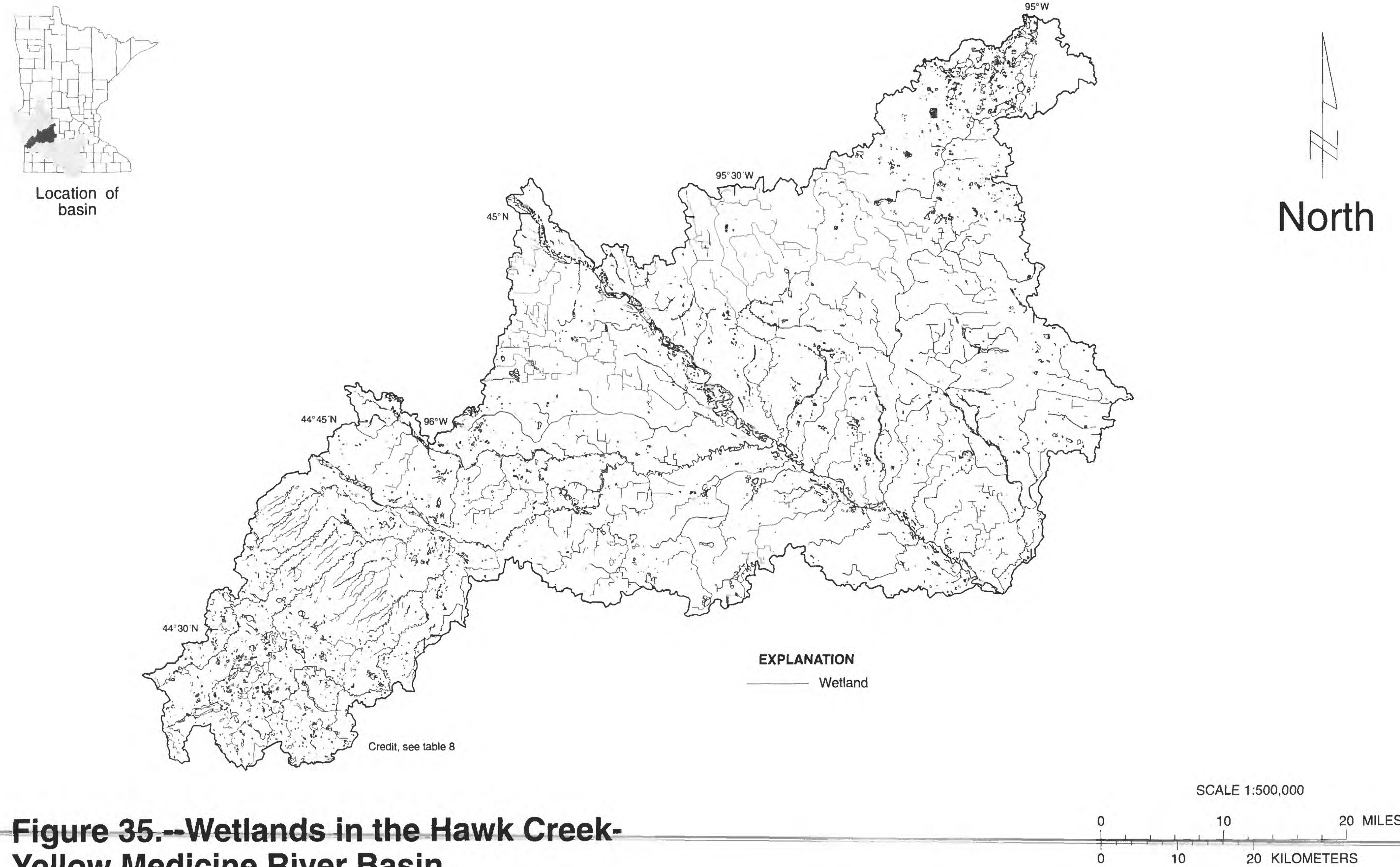


Figure 35.--Wetlands in the Hawk Creek-Yellow Medicine River Basin.

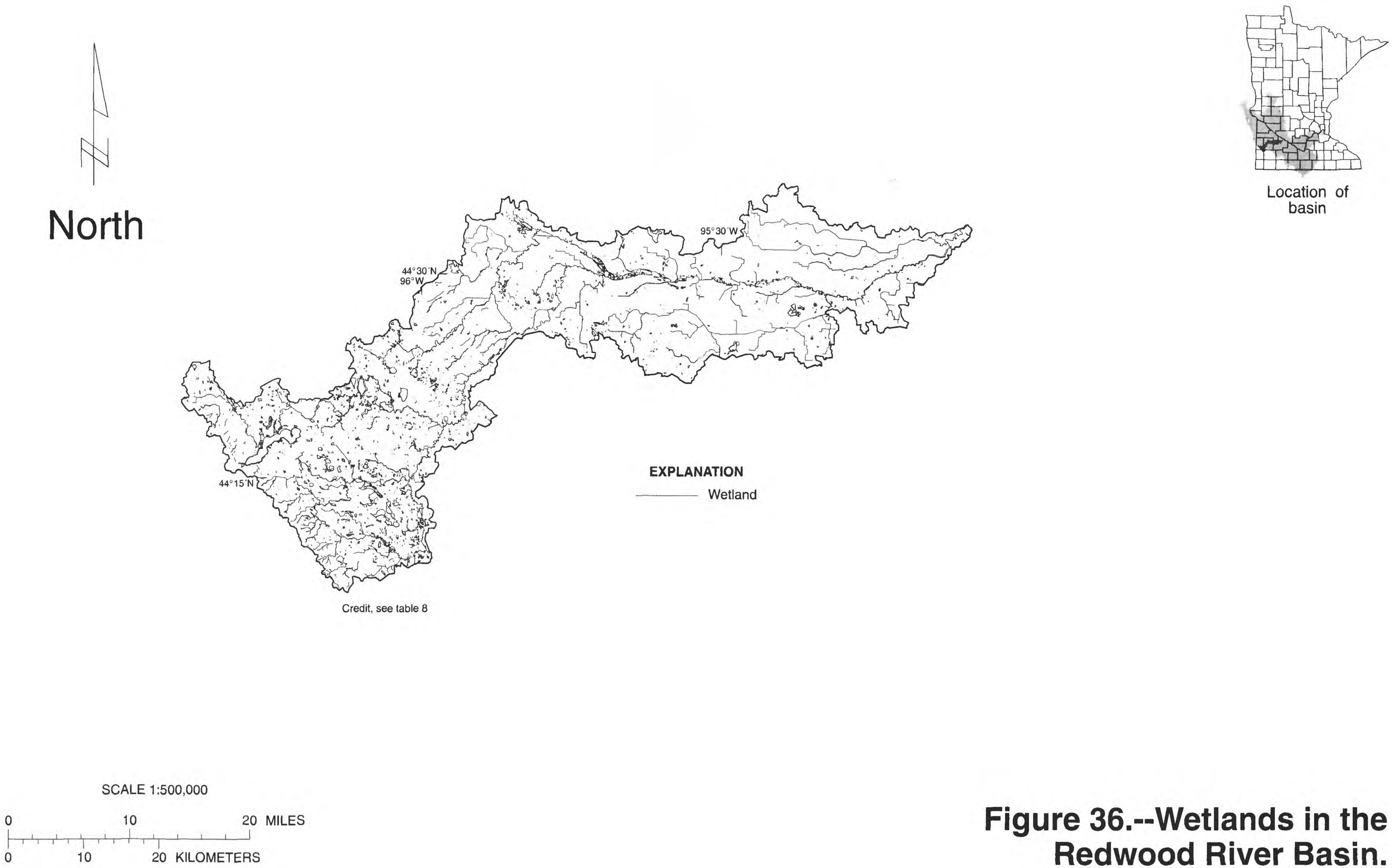


Figure 36.--Wetlands in the Redwood River Basin.

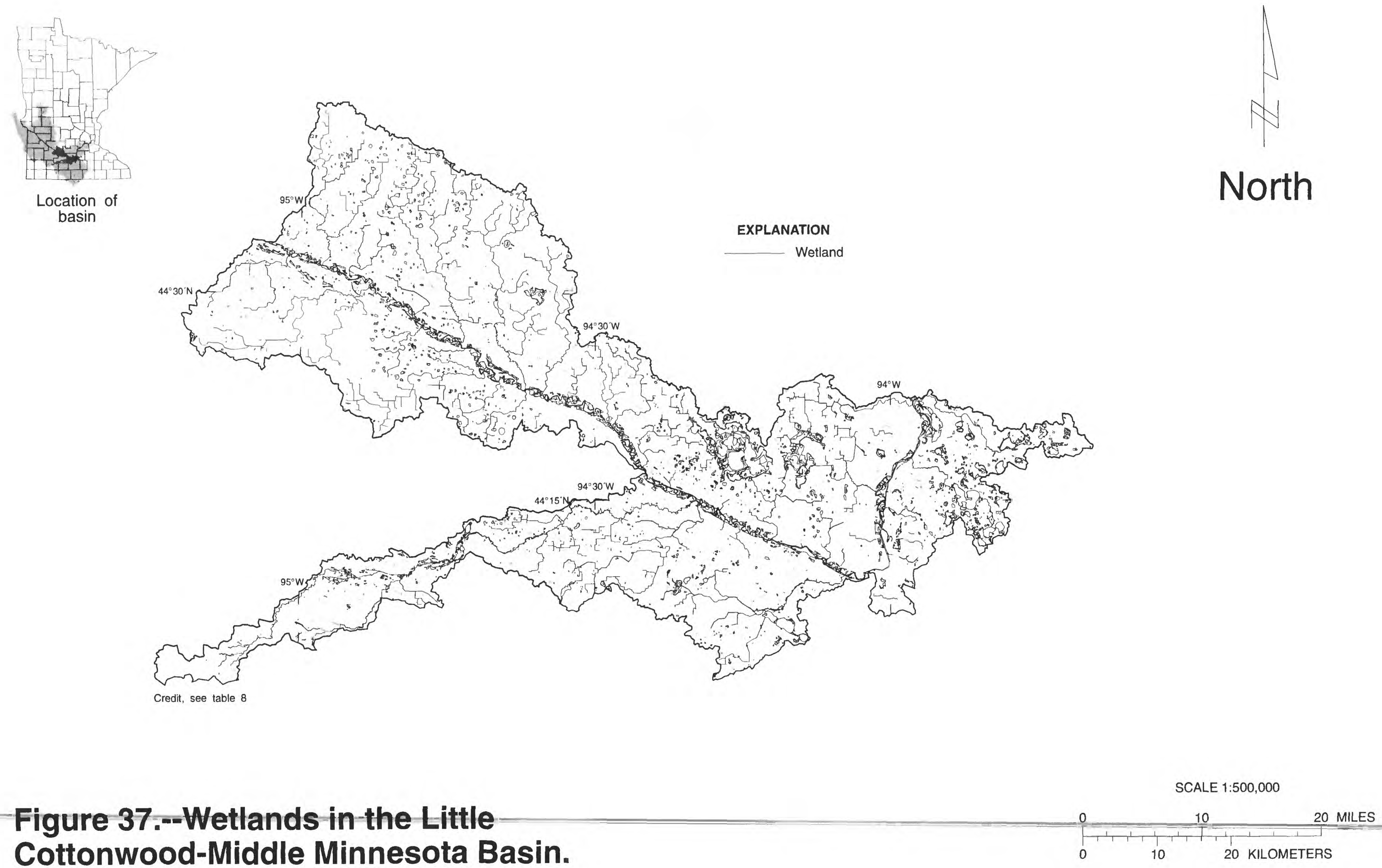


Figure 37.--Wetlands in the Little Cottonwood-Middle Minnesota Basin.

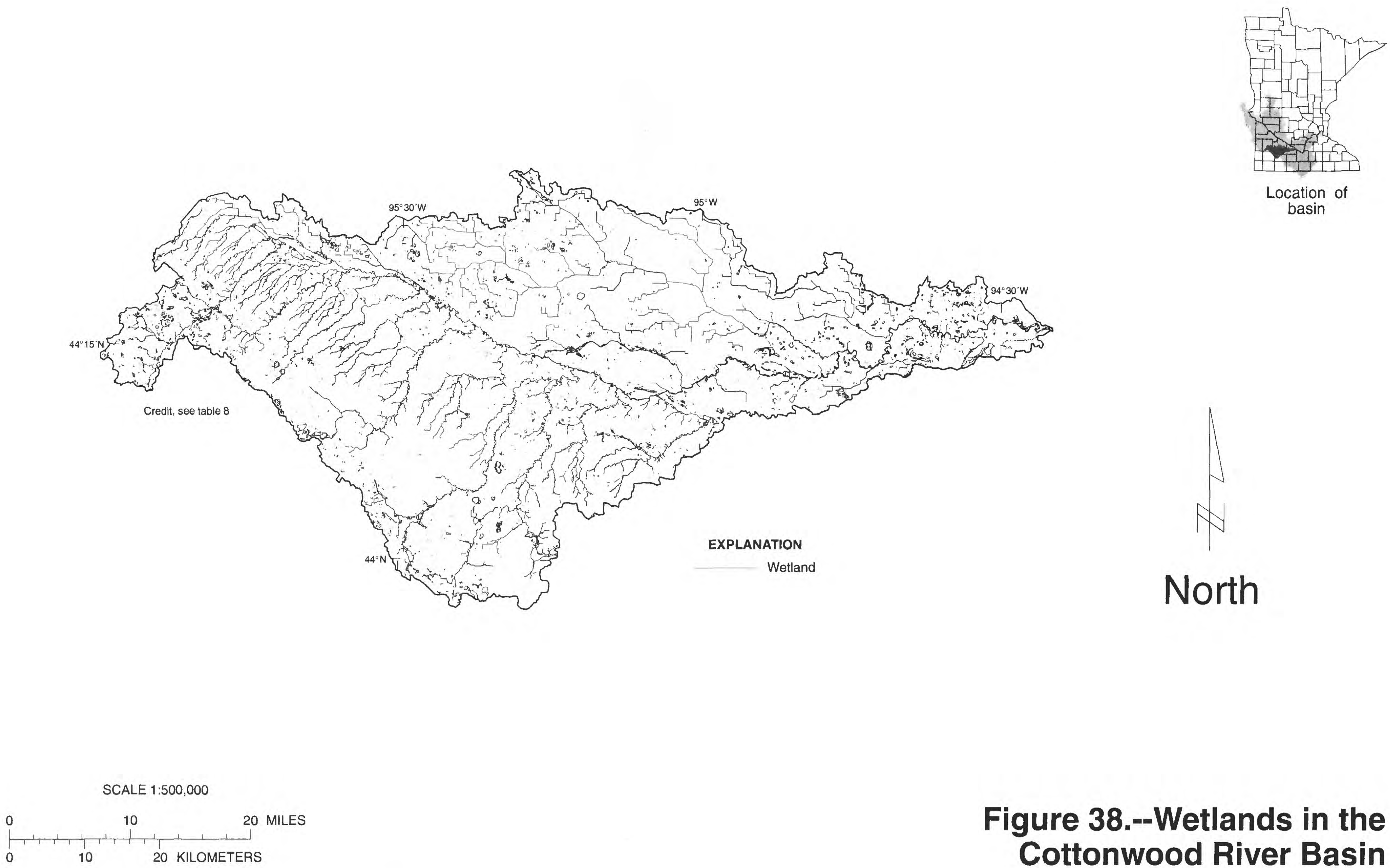


Figure 38.--Wetlands in the Cottonwood River Basin

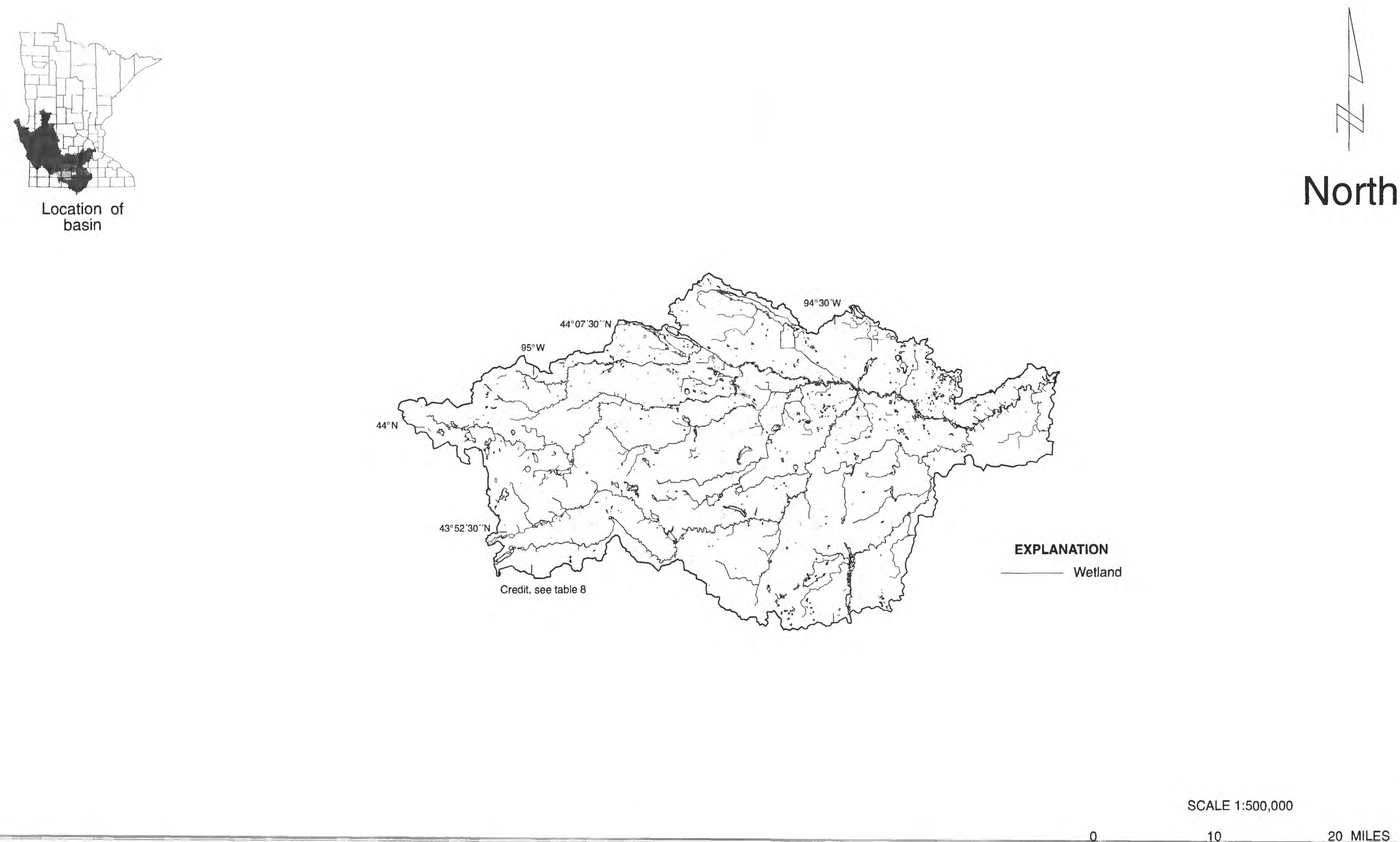
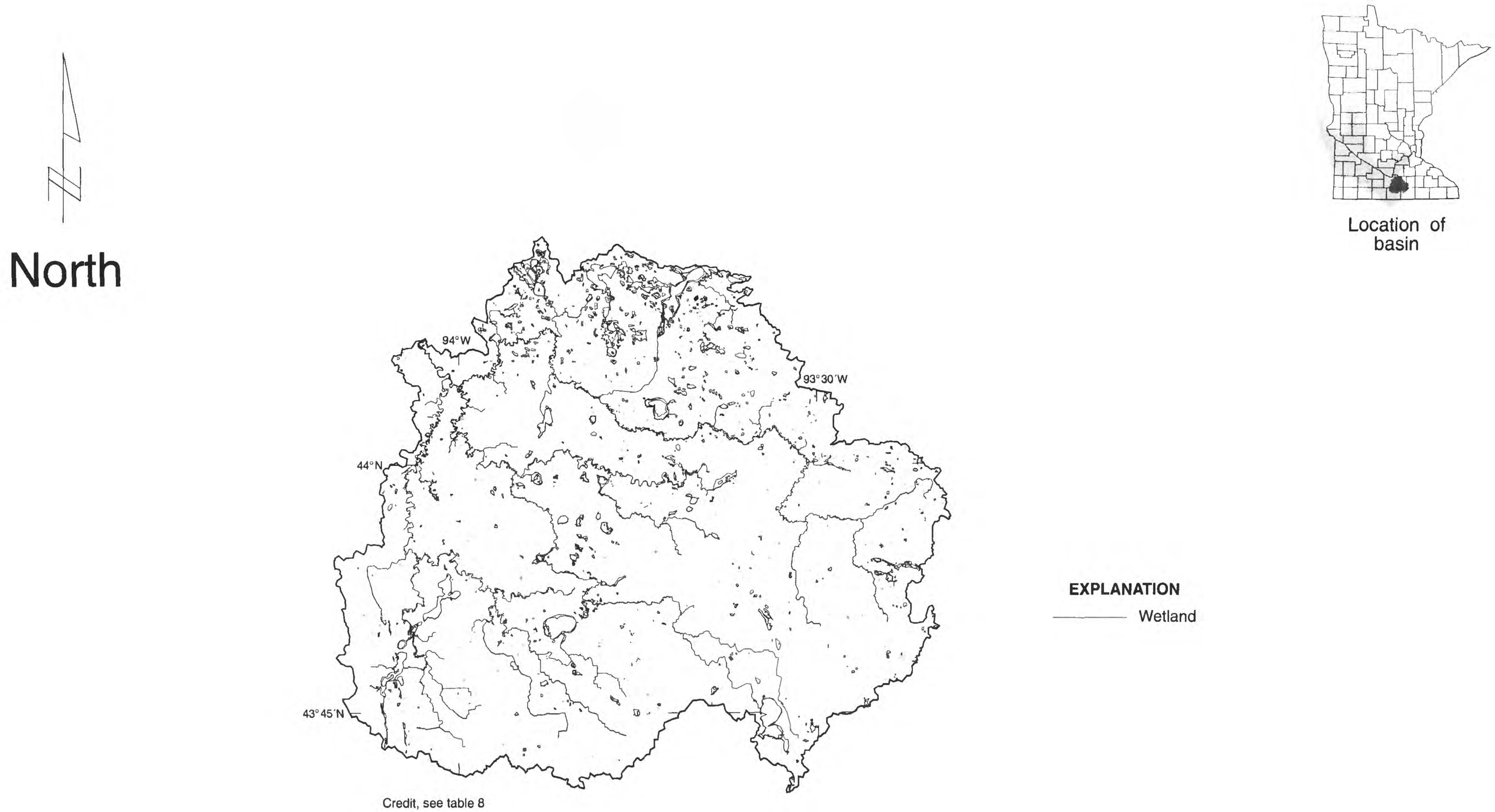


Figure 39.--Wetlands in the Watonwan River Basin.



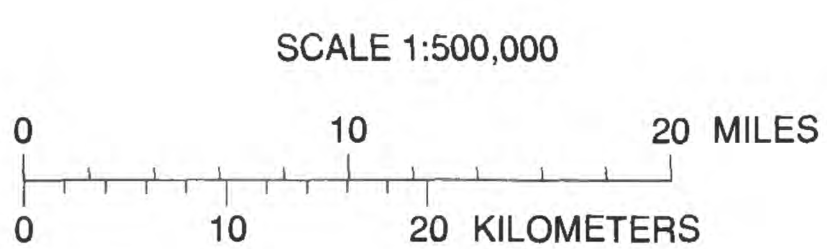


Figure 40.--Wetlands in the Le Sueur River Basin.

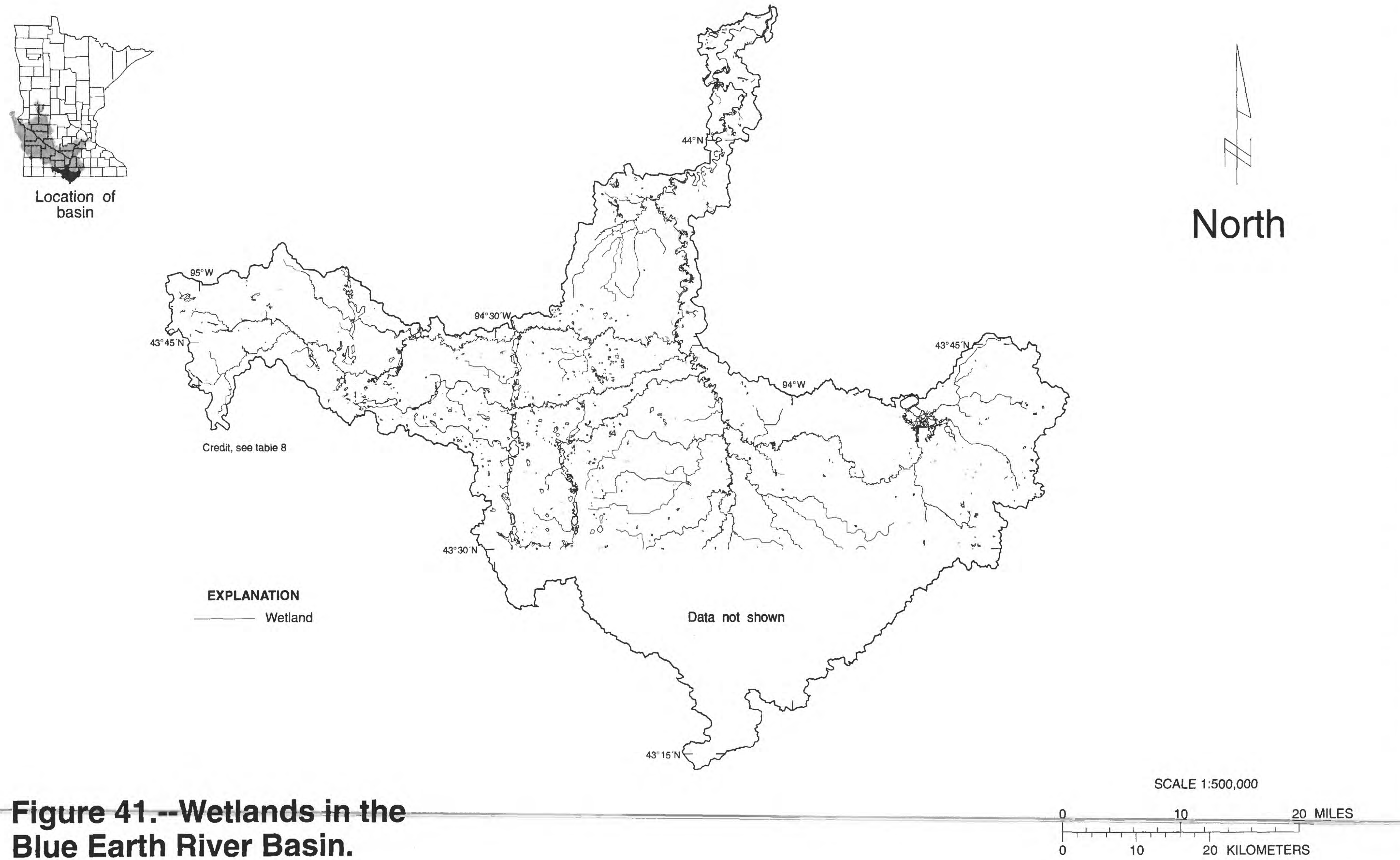


Figure 41.--Wetlands in the Blue Earth River Basin.

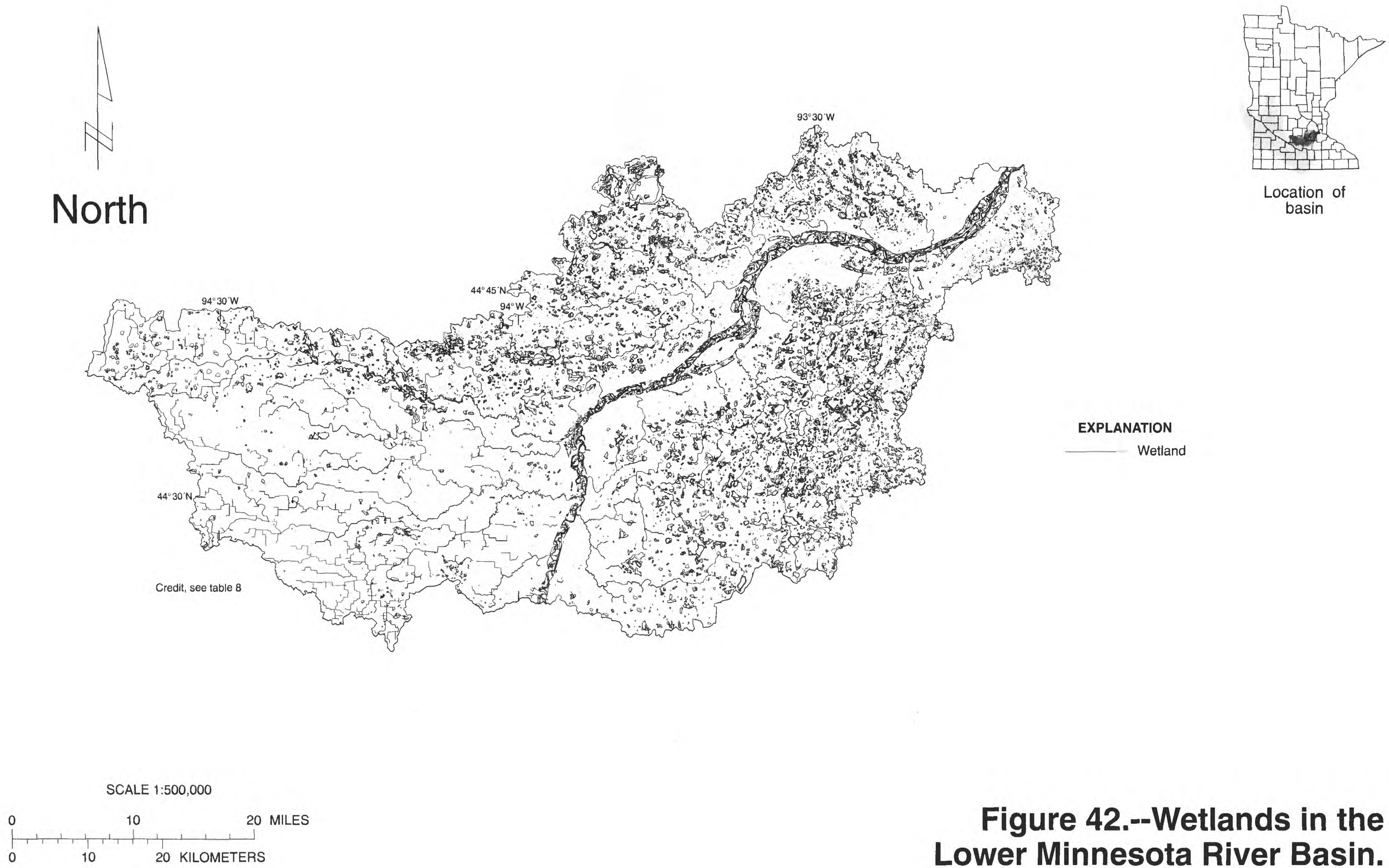


Figure 42.--Wetlands in the Lower Minnesota River Basin.

AVERAGE ANNUAL PRECIPITATION

Average annual precipitation in the Minnesota River Basin generally increases from west to east. Variability of annual precipitation influences the delivery of runoff, sediment, and nutrients to the Minnesota River. Data shown on figure 43 is based on a map published by the MDNR (Greg Spoden, Minnesota Department of Natural Resources, written commun., 1993).

AVERAGE ANNUAL RUNOFF

Average annual runoff in the Minnesota River Basin ranges from less than two inches in the western part of the basin to more than six inches in the eastern part of the basin (fig. 44). The increase from west to east is related to an increase in precipitation and a decrease in potential evapotranspiration. Runoff is a significant control on the ability of a basin to deliver sediment and nutrients to a river. Figure 44 is based on information from a map of average annual runoff of tributary streams in Minnesota for the period 1951-80 (U.S. Geological Survey, 1986, p. 285-294; for additional information see Gebert and others, 1987). A GIS data base of average annual runoff is available from the USGS.

ECOREGIONS

Various classification systems have been used to describe land with the goal of identifying homogeneous areas. Omernik and Gallant (1988) classified ecoregions (ecological regions) (fig. 45) for the north-central United States based on landscape features such as potential natural vegetation, mineral availability from the soils and geologic materials, physiography, land use, and land cover (including types of wetlands and crops). Ecoregions generally are considered to be regions of homogeneity in ecological systems or in relations between organisms and their environment (Omernik and Gallant, 1988). Ecoregions in figure 45 are from a GIS data base of ecoregions in the United States based upon the ecoregions defined by Omernik (1987). The data base is available from the USGS.

LAND USE

Land use in the Minnesota River Basin primarily is agricultural. In eastern parts of the basin urbanization within the Twin Cities Metropolitan Area has changed land use. Land use in the basins of the Minnesota River Basin is shown in figures 46-57 and is listed in table 5.

Land use data is from the MLMIS100 data base. The primary information source was 1:90,000 scale air photos from black and white film. Areal photographs of the part of the state south of St. Cloud were taken in April 1968. Areal photographs of the remaining part of the state were taken in April 1969. County highway maps published in 1968 were used as a secondary source of data. The MLMIS100 classification scheme uses two criteria: dominant economic activity and dominant spatial area. Spatial dominance was confined to the undeveloped (in terms of structure) land classes and generally refers to plant cover type. The developed classes are determined by dominant economic activity (Land Management Information Center, 1989, p. 12).

Cultivated land includes areas where the land has been recently tilled or crops harvested. Pasture and open land is non-forested land that is not used for any identifiable purpose. Examples include grazing land or abandoned farm land. Forested land includes land where the dominant land cover is trees. To be considered forested, an area must contain trees whose crowns cover 10 percent of the area. Marsh consists of areas where the dominant land cover is non-forested, permanently wet, and vegetated. Water includes areas where the dominant land cover is open and permanent water. Urban residential areas contain 5 or more residential dwellings and commercial buildings in a forty-acre parcel. Urban non-residential or mixed residential development land contains at least one commercial, industrial, or institutional facility in a forty-acre parcel. Transportation includes areas where the dominant land use consists of facilities for the conveyance of people or materials. Extractive land is primarily used for the extraction of minerals. Examples are mines, tailing piles, and gravel pits.

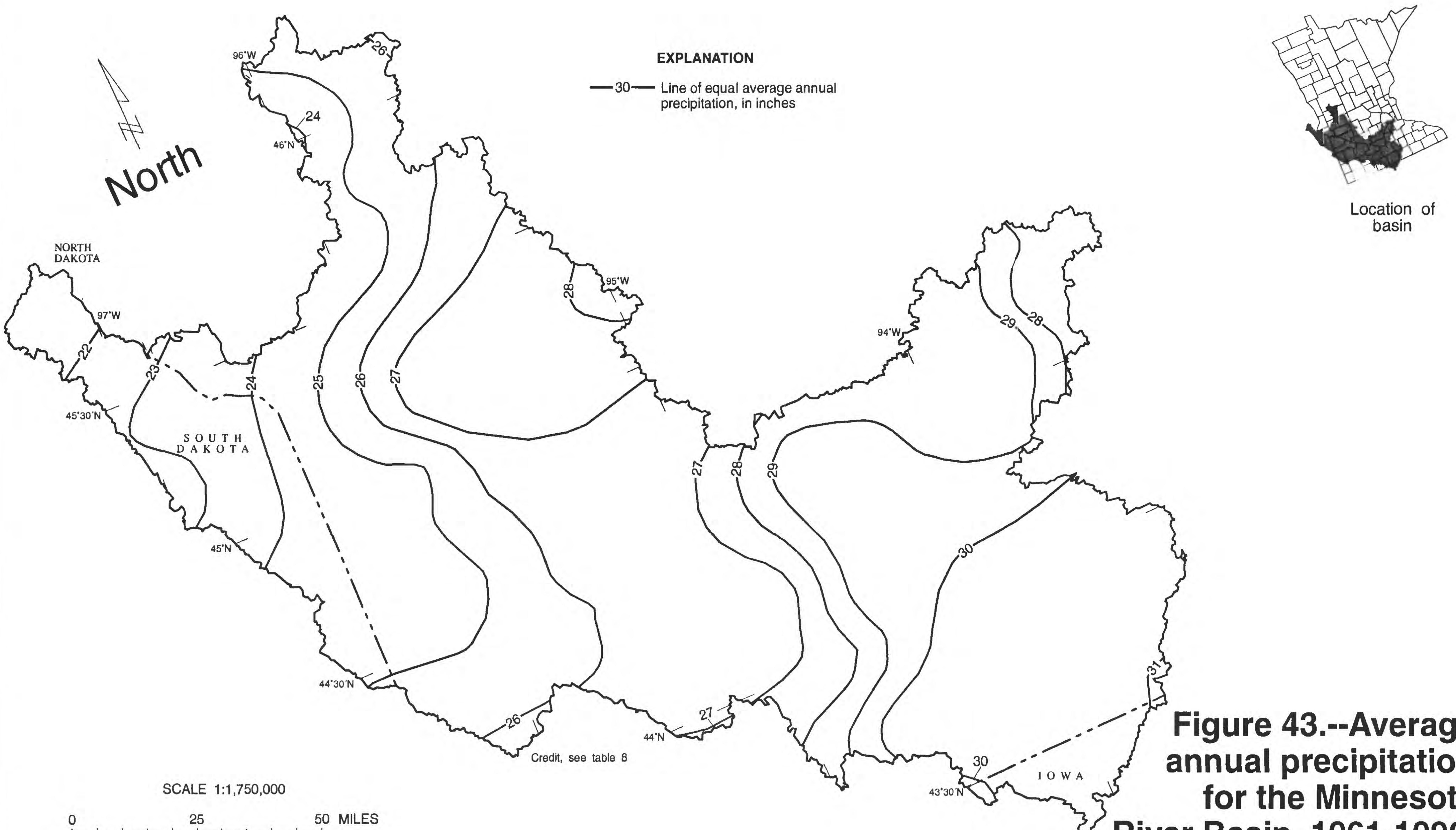


Figure 43.--Average annual precipitation for the Minnesota River Basin, 1961-1990.
(Copyright 1990 to Minn. Dept. of Natl. Resources, 1990.)

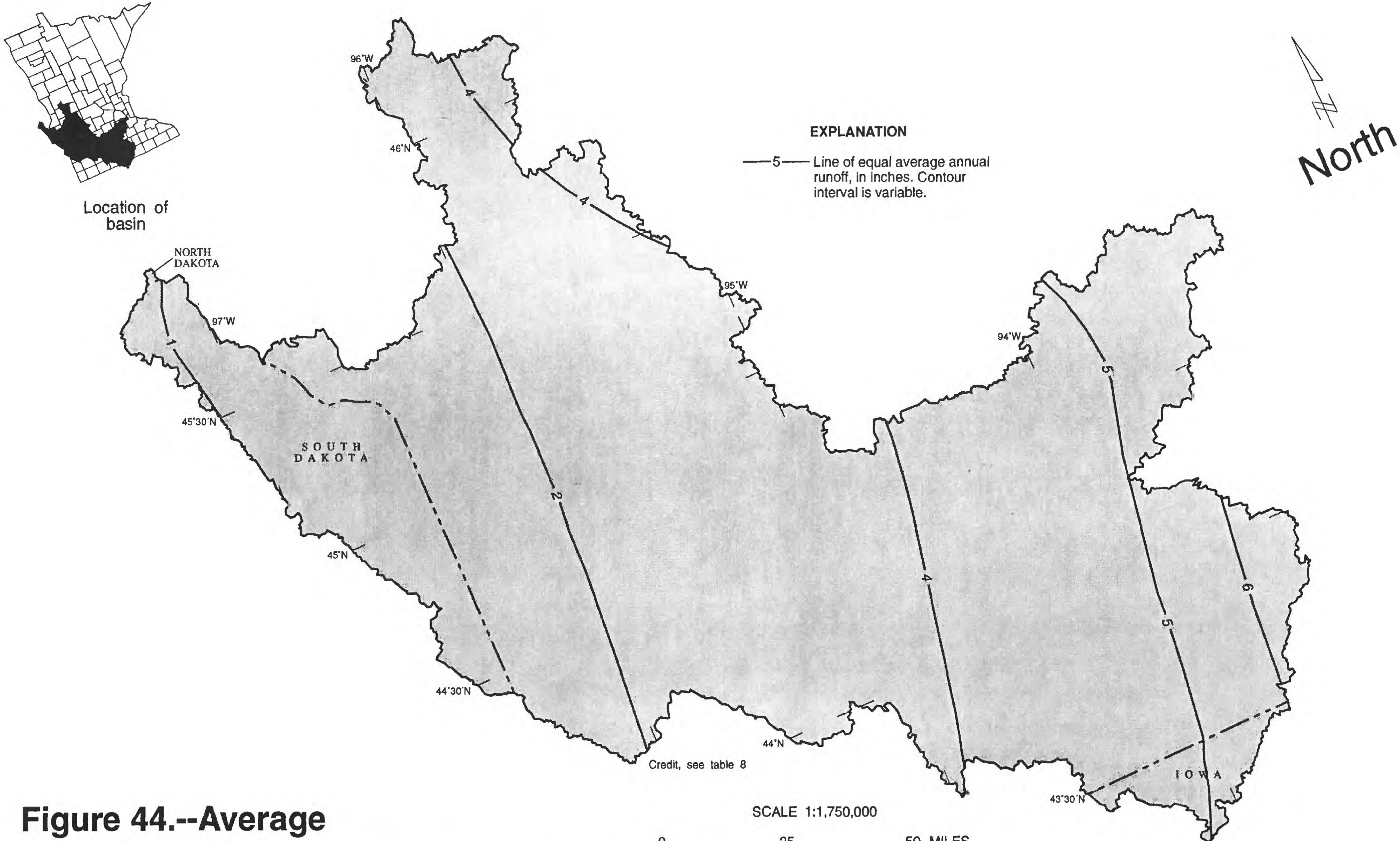


Figure 44.--Average annual runoff in the Minnesota River Basin, 1951-80.

Figure 45.--Ecoregions in the Minnesota River Basin.

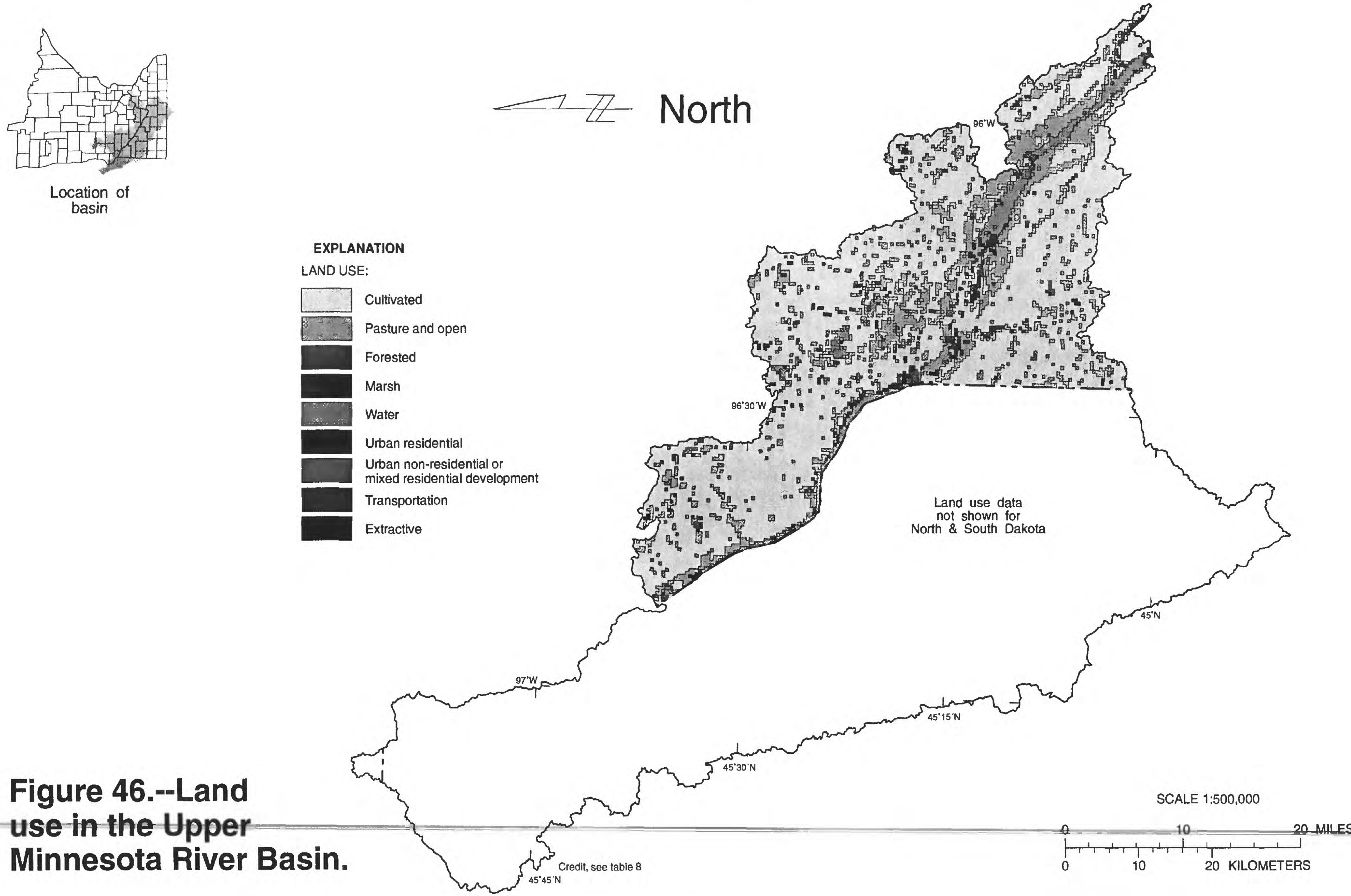


Figure 46.--Land use in the Upper Minnesota River Basin.

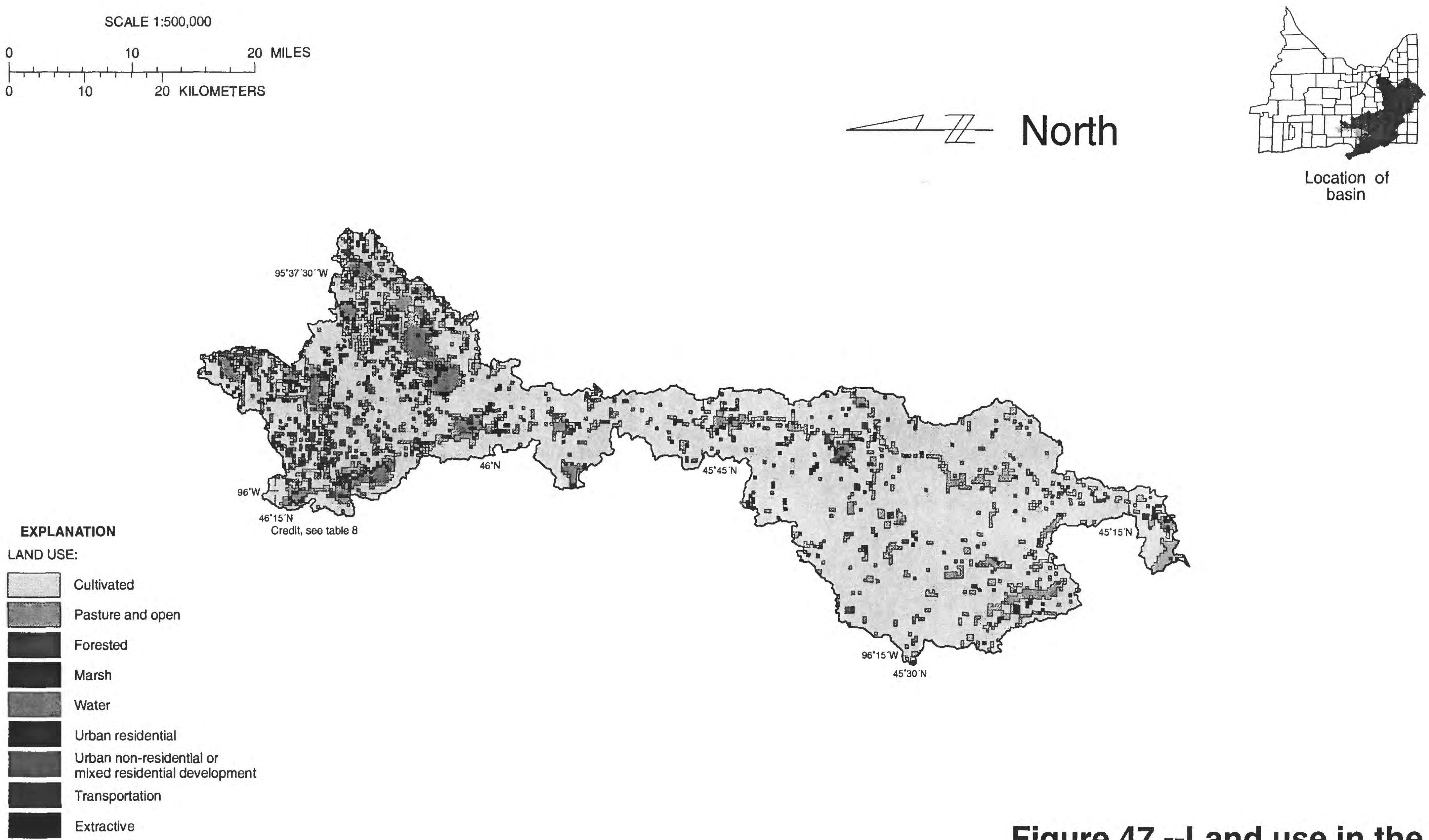


Figure 47.--Land use in the Pomme de Terre River Basin.

Figure 48.--Land use in the Lac qui Parle River Basin.

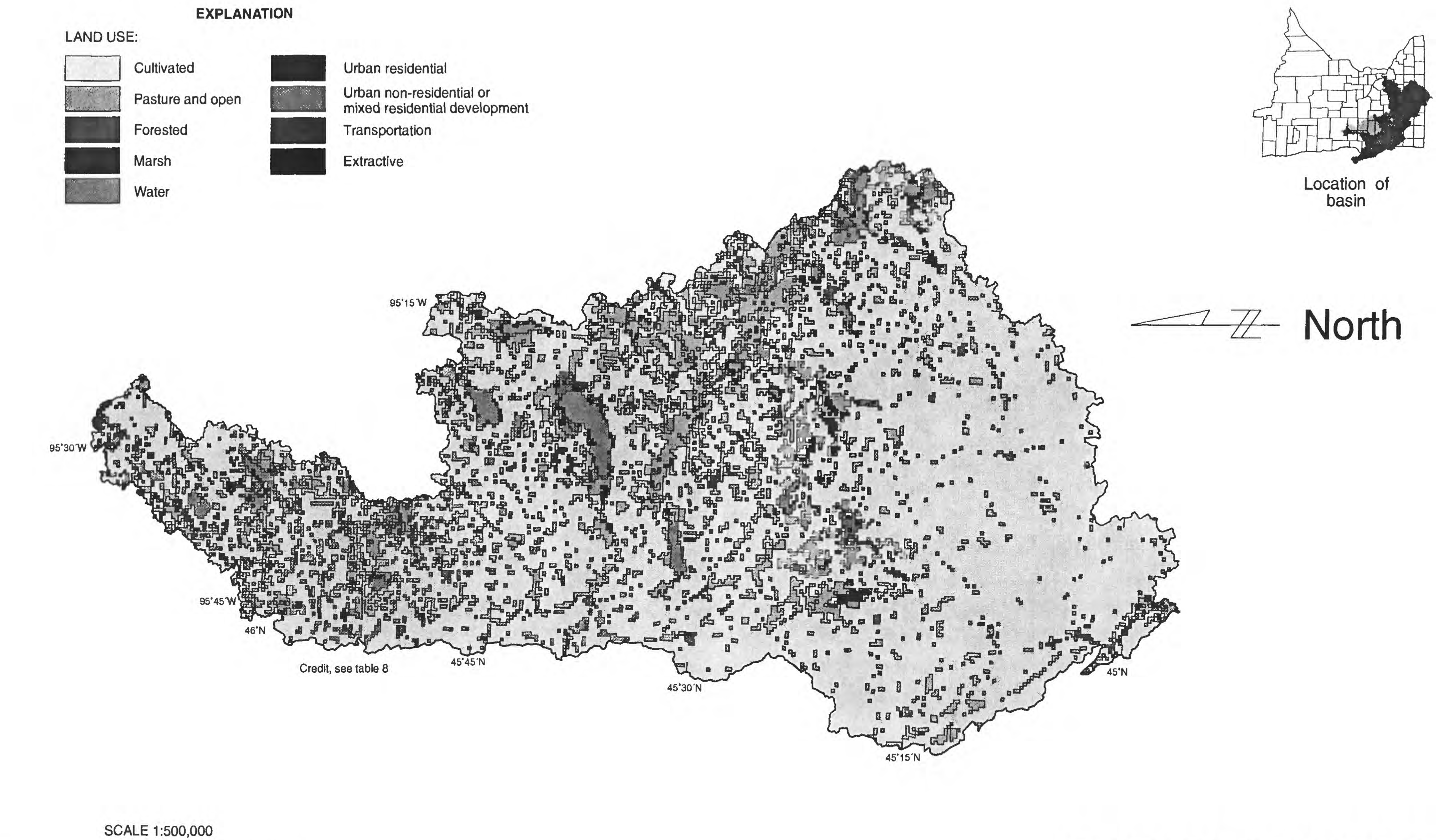


Figure 49.--Land use in the Chippewa River Basin.

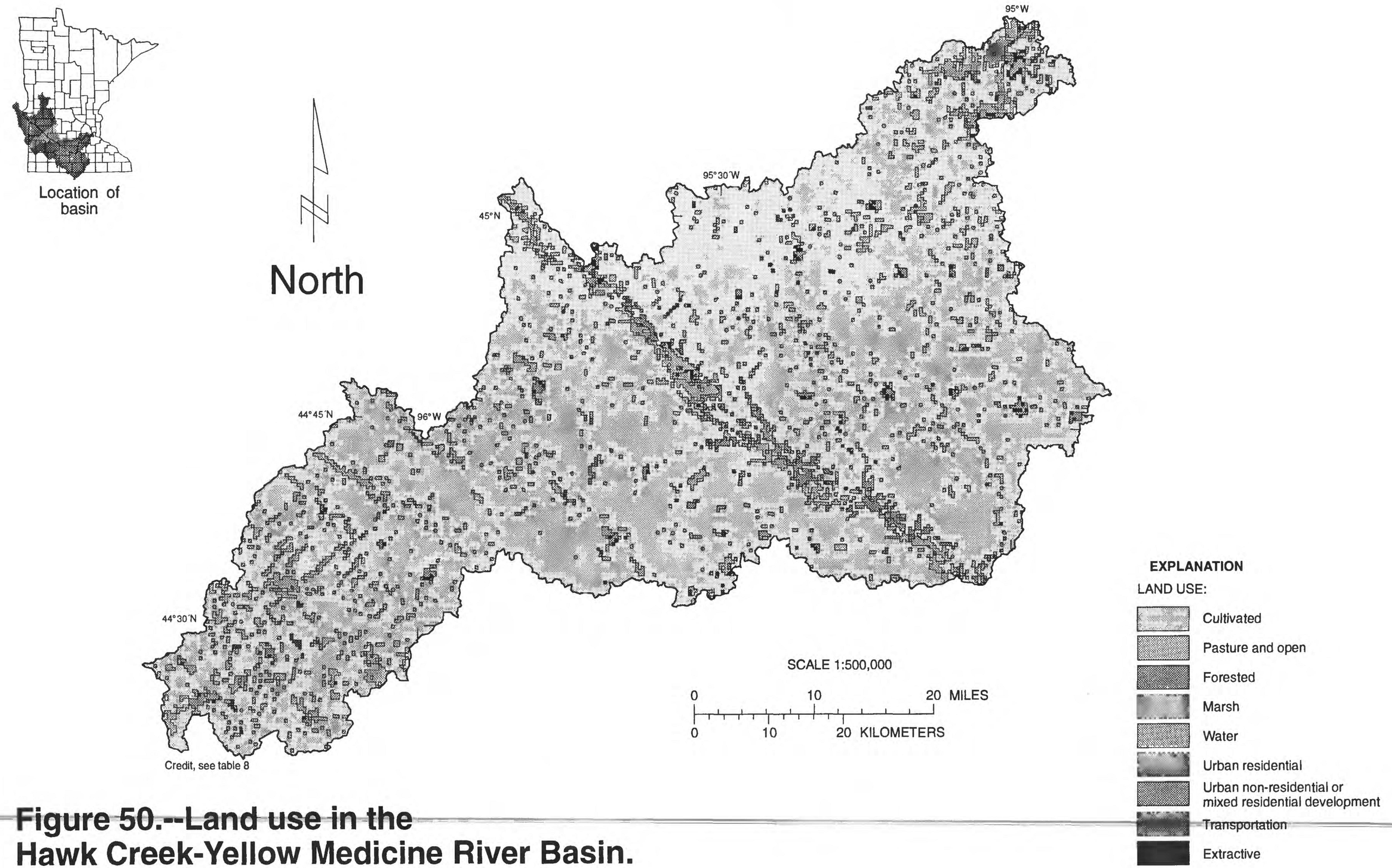


Figure 50.--Land use in the Hawk Creek-Yellow Medicine River Basin.

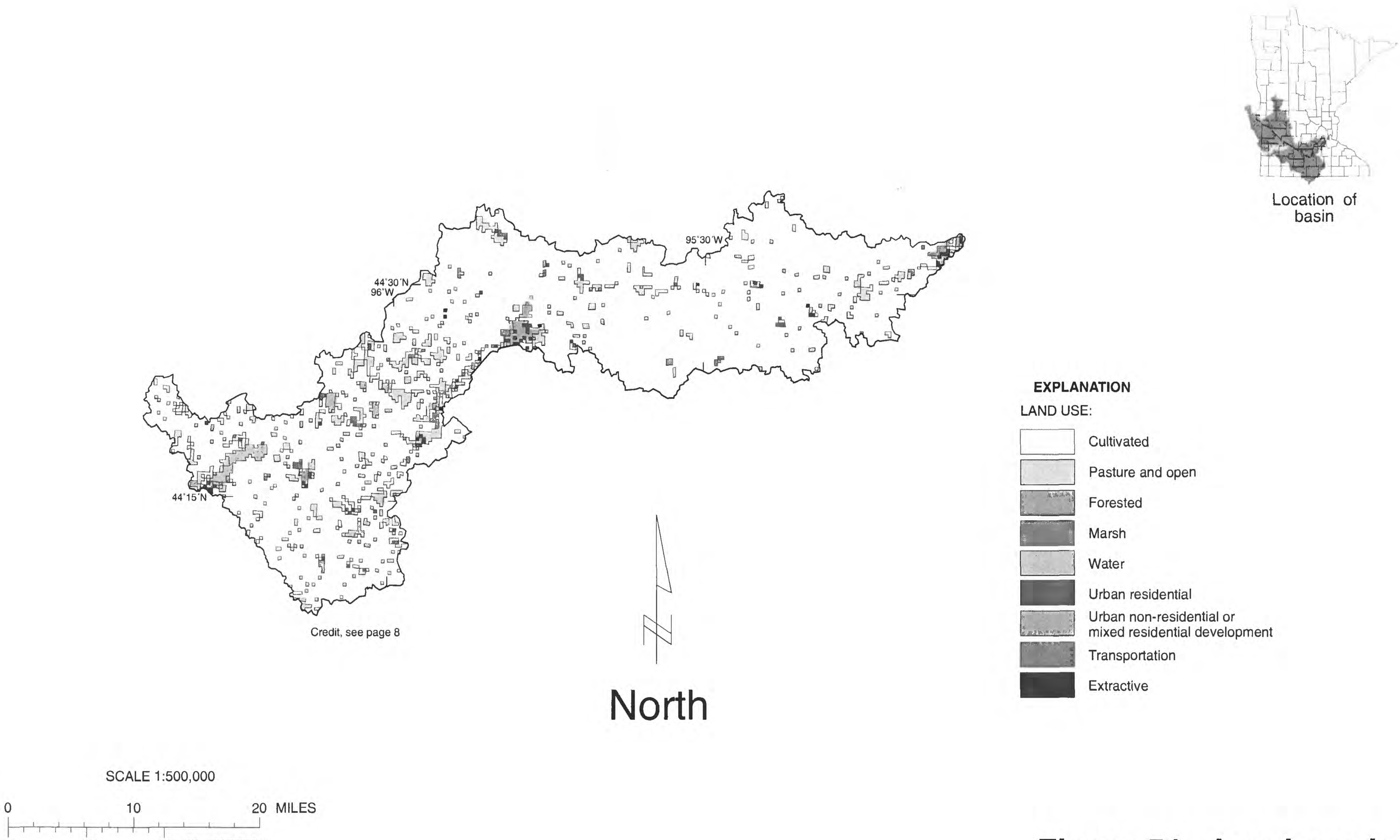


Figure 51.--Land use in the Redwood River Basin.

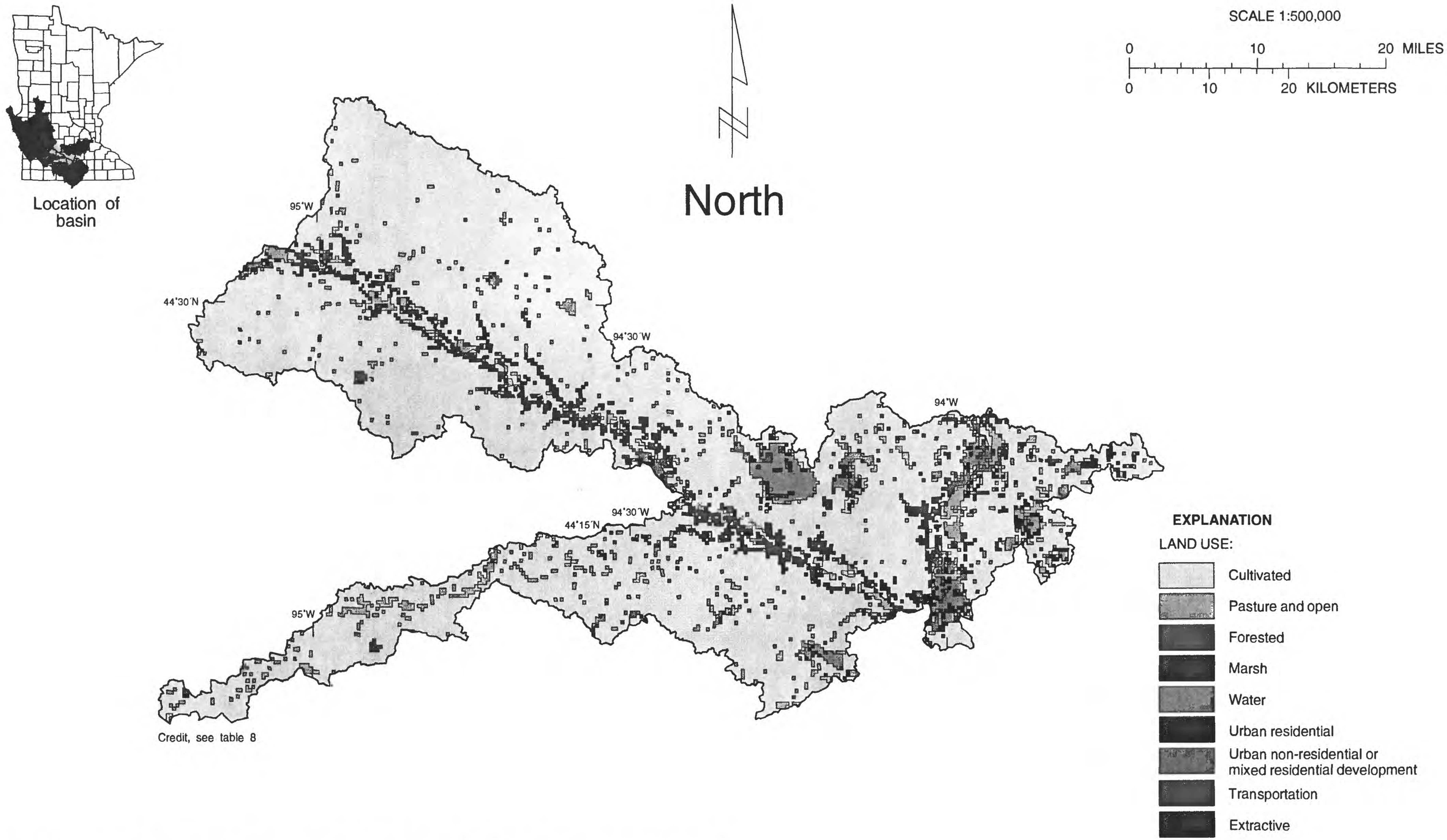


Figure 52.--Land use in the Little Cottonwood-Middle Minnesota Rivers Basin.

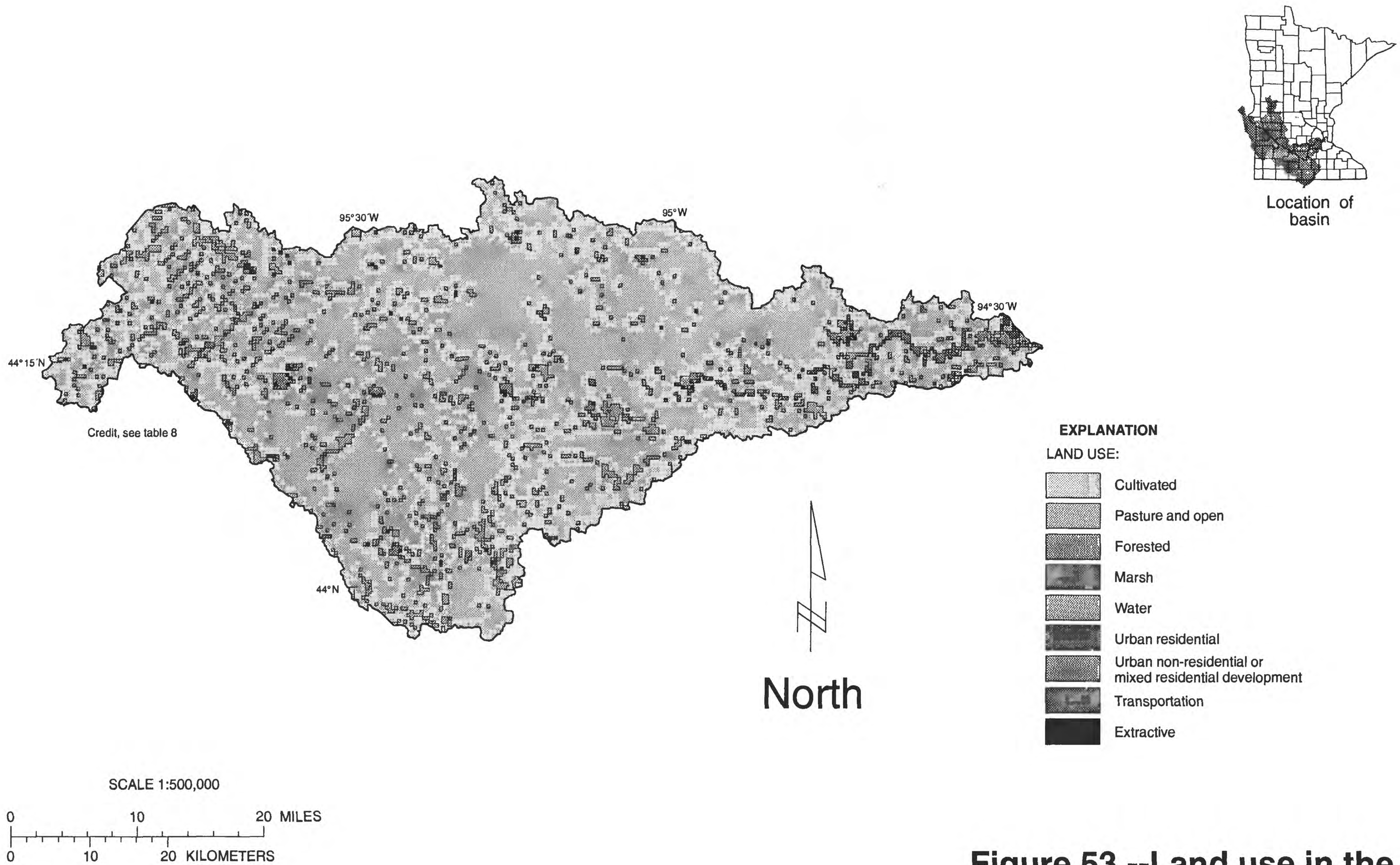


Figure 53.--Land use in the Cottonwood River Basin.

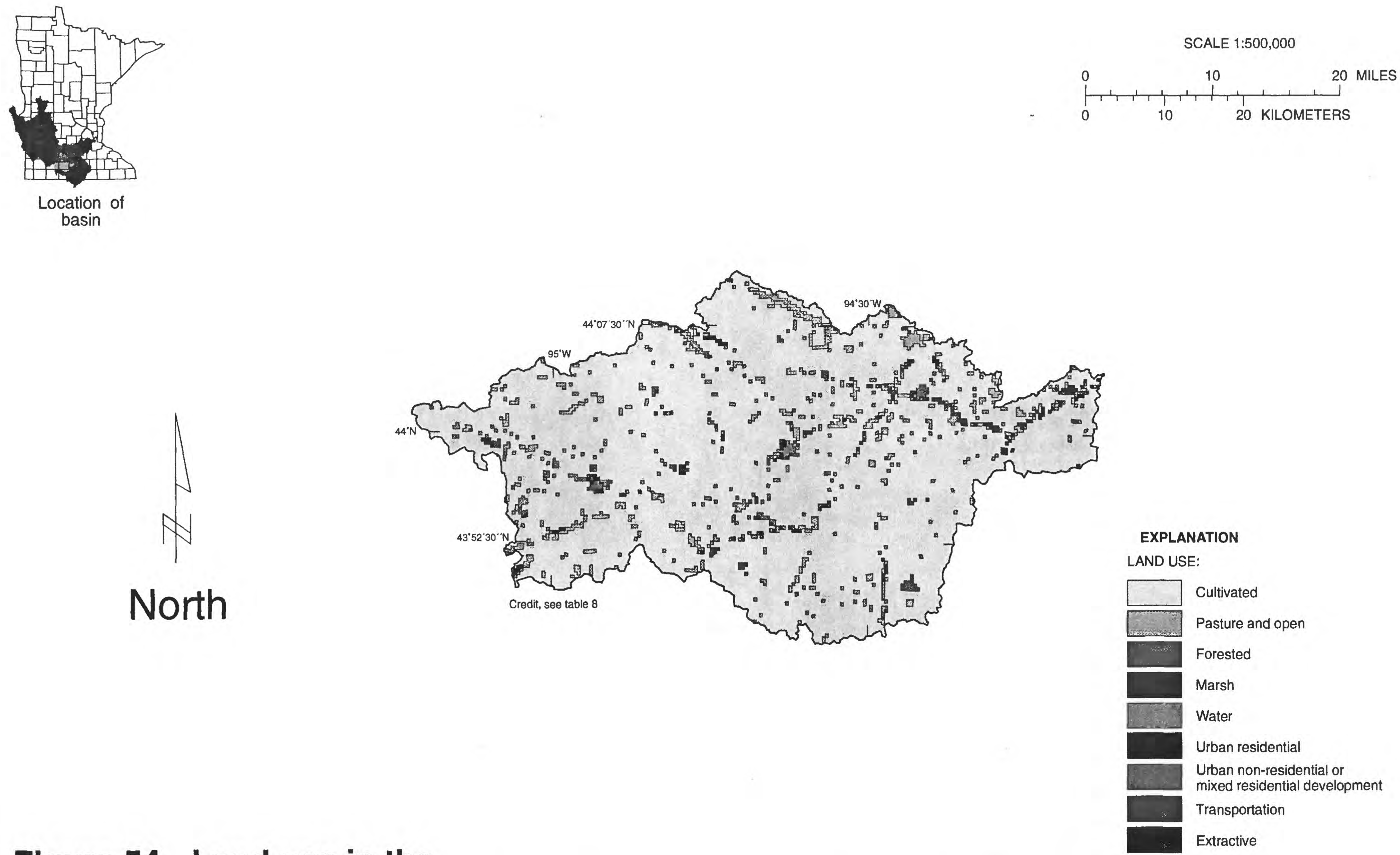


Figure 54.--Land use in the Watonwan River Basin.

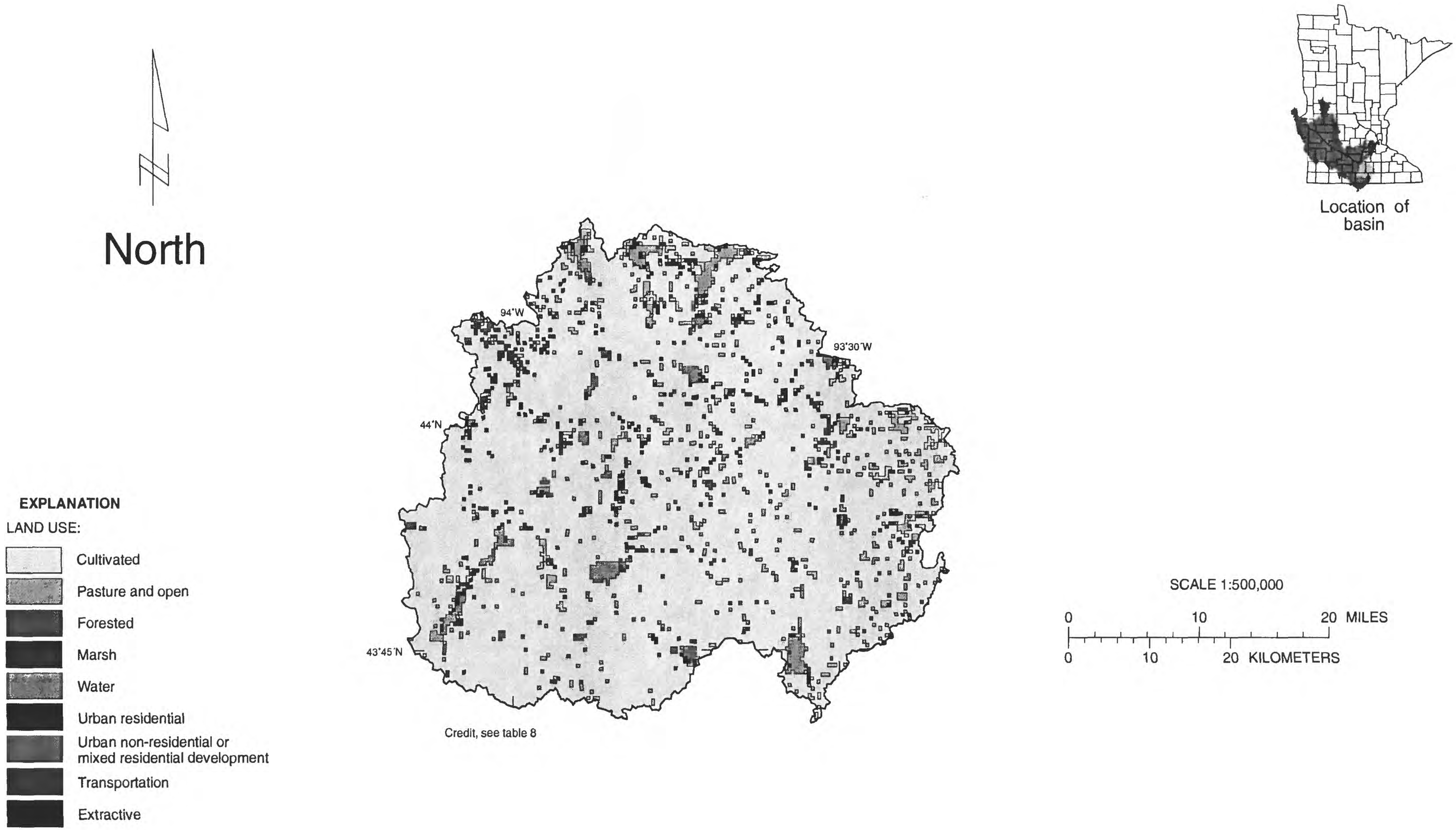


Figure 55.--Land use in the Le Sueur River Basin.

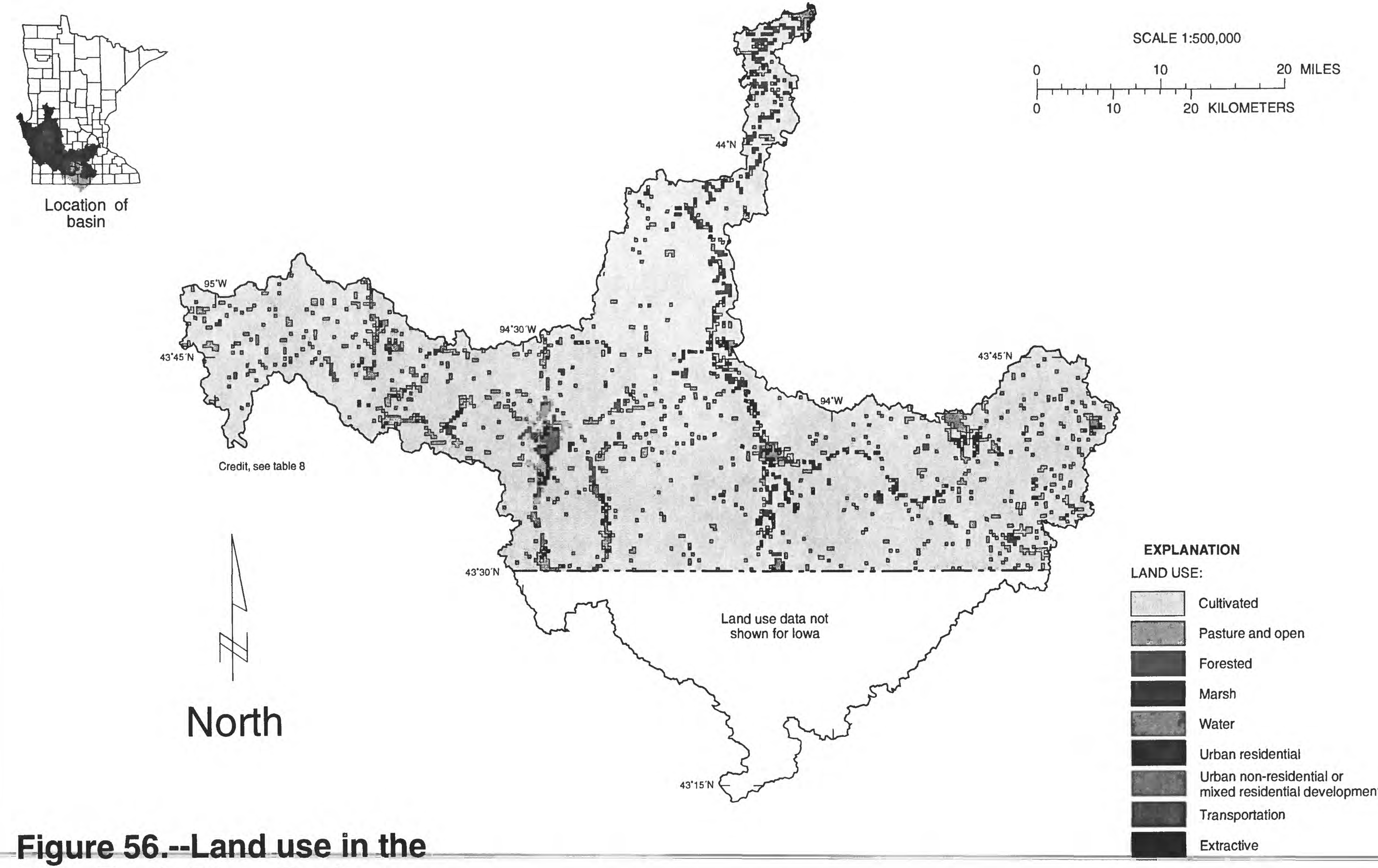


Figure 56.--Land use in the Blue Earth River Basin.

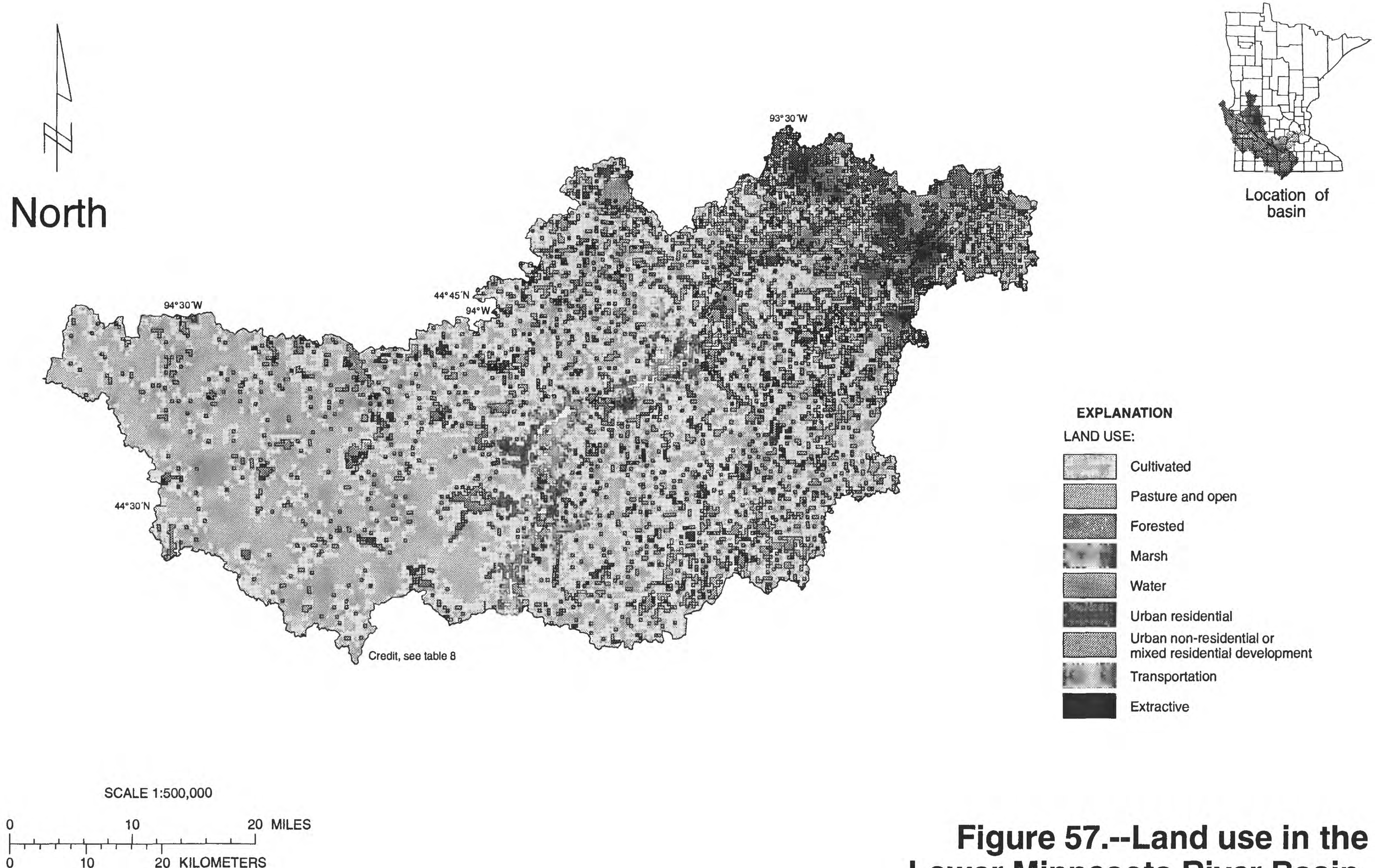


Figure 57.--Land use in the Lower Minnesota River Basin.

The population distribution shown in this figure is from the 1990 census of the United States. The population density is based on the number of people residing in an area called a block group. A block group is a grouping of census blocks within census tracts. The smallest census geographic area is a block which is bounded by streets or other physical features. Blocks may be as small as city blocks, or as large as several square miles in rural areas. The national average population of a city block is 85; in rural blocks it is 30. The national average population of a block group is 650 (Abramowitz, 1990). Only block groups with a population greater than 500 are shown in this figure.

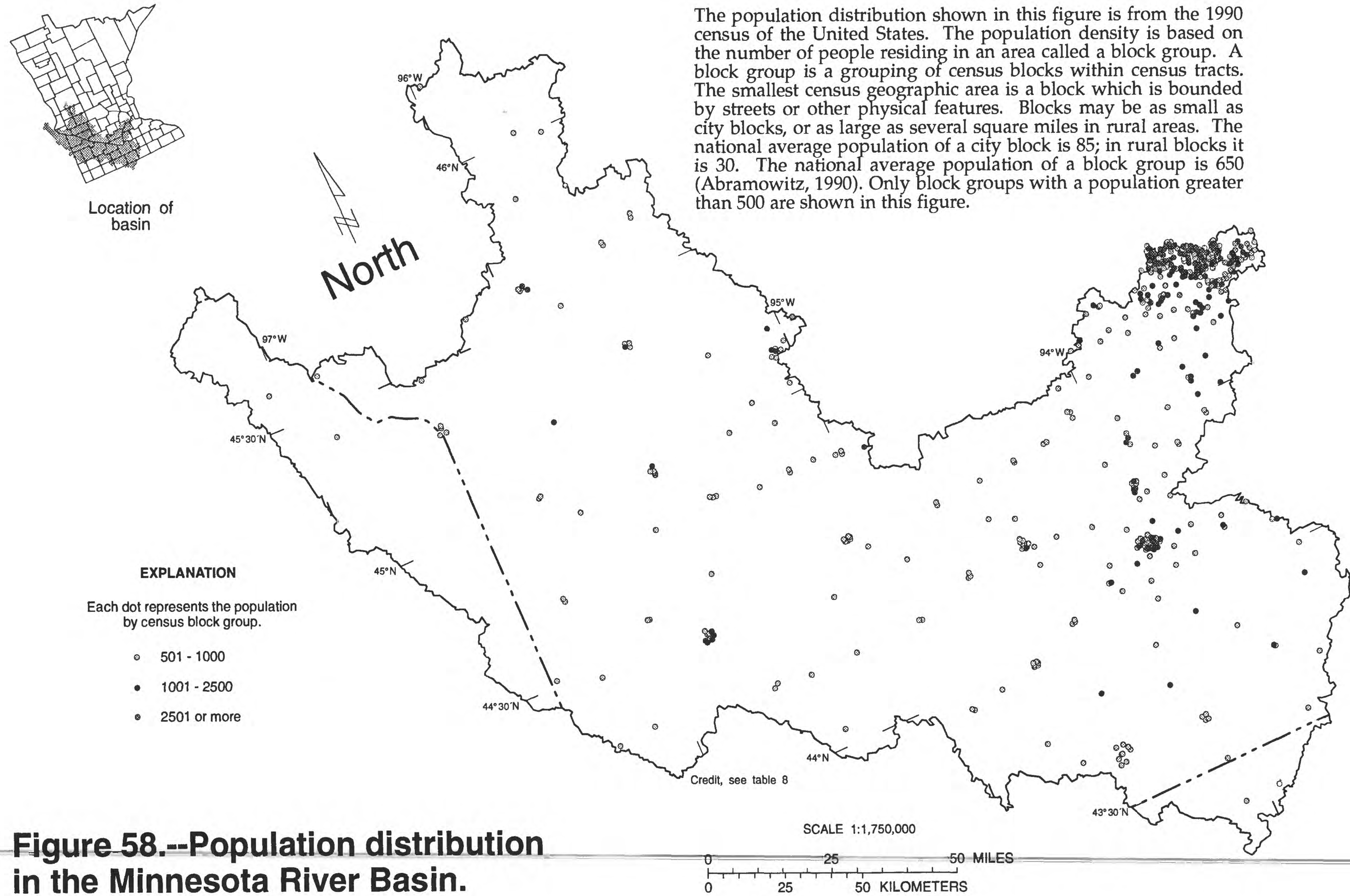


Figure 58.--Population distribution in the Minnesota River Basin.

A classification of non-point source pollution potential was developed by the MPCA. The classification includes seven characteristics of an area, which are: forest cover, percent of an area in cultivation, silt-soil type, sand-soil type, stream orientation, percent of an area having 3-6 percent slope, and percent of an area having greater than 6 percent slope. An index value for each subbasin in an ecoregion was calculated, and subbasins were grouped into categories, each representing 10 percent of the subbasins in an ecoregion. The index values are relative rankings within each ecoregion and may not represent the same non-point source pollution potential in other ecoregions (Fandrei and others, 1983). Non-point source pollution potential classes for the Minnesota River Basin are available from a GIS data base from the USGS.

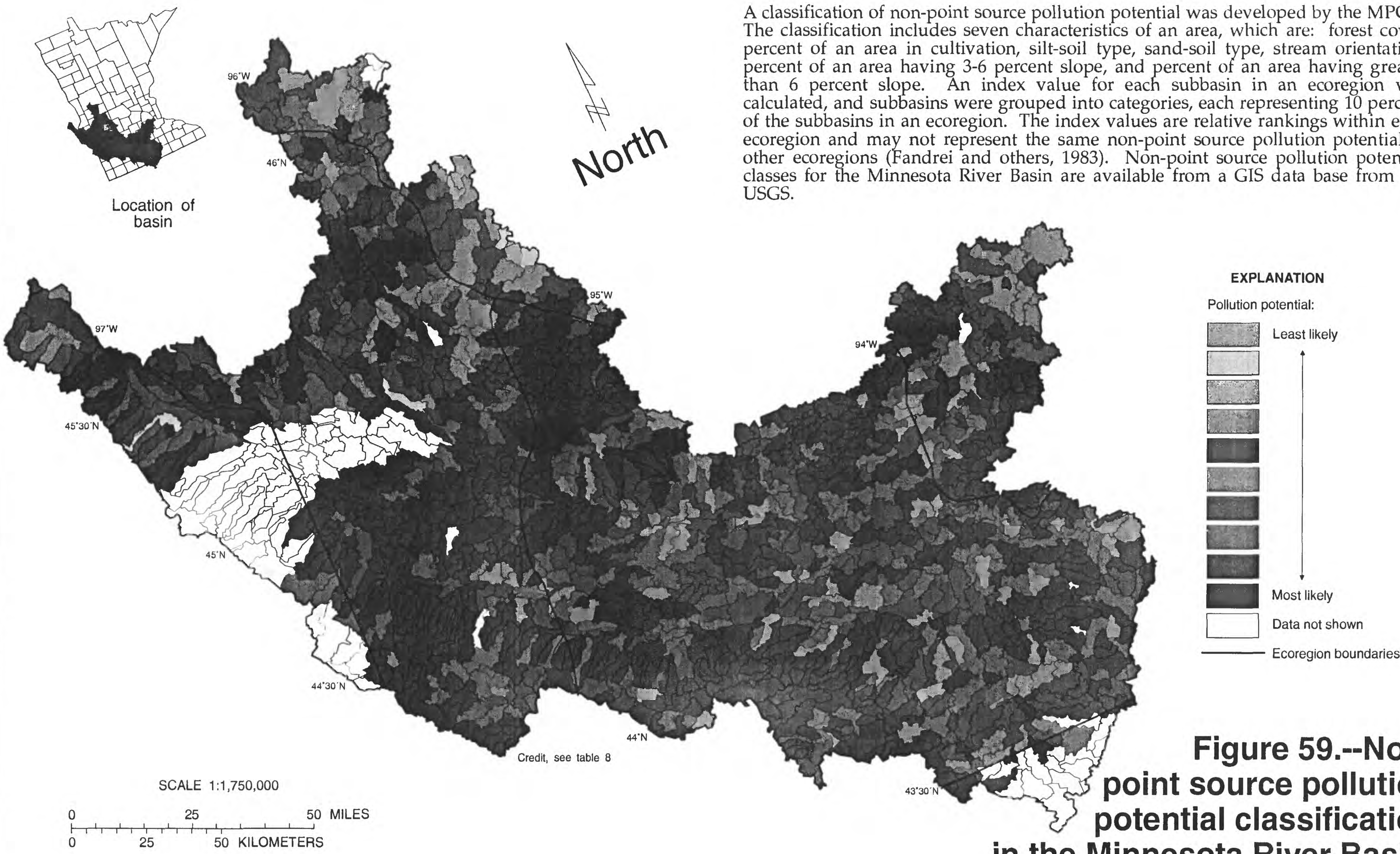


Figure 59.--Non-point source pollution potential classification in the Minnesota River Basin.

SELECTED WATER-QUALITY DATA FOR THE MINNESOTA RIVER

Selected water-quality data for the Minnesota River are shown in figures 60-64. The water-quality sampling sites and river mile locations are listed in table 1. Stream discharge at the time of sample collection is shown in figure 60. Suspended-sediment load, dissolved nitrite plus nitrate nitrogen load, total phosphorus load, and biochemical oxygen demand load are shown in figures 61-64.

SELECTED ANNUAL SUSPENDED-SEDIMENT LOADS FOR THE MINNESOTA RIVER AT MANKATO

Annual suspended-sediment loads for the Minnesota River at Mankato are shown in figure 65. Annual loads were computed from suspended-sediment concentrations in samples collected approximately daily during open-water periods and from daily water-discharge records. During winter periods, samples were collected monthly. Samples were collected since the beginning of water-year 1968 (October 1967).

SELECTED WATER-QUALITY AND HYDROLOGIC DATA FOR THE BLUE EARTH RIVER AT MANKATO, THE MINNESOTA RIVER AT MANKATO, AND THE MINNESOTA RIVER AT MONTEVIDEO

Selected water-quality and hydrologic data for the Blue Earth River at Mankato, the Minnesota River at Mankato, and the Minnesota River at Montevideo are shown in figures 66-80.

SELECTED WATER-QUALITY DATA FOR MINNESOTA RIVER TRIBUTARIES

Boxplots showing selected water-quality data for ten Minnesota River tributaries are shown in figure 81. The sampling sites are listed in table 1 and shown on figure 1 and figures 3B-14B.

SELECTED SEDIMENT-LOAD DATA

Selected sediment-load data for sites within the Watonwan River Basin, Le Sueur River Basin, and Blue Earth River Basin are shown in table 6. Selected sediment-load data for sites within the Redwood River Basin are shown in table 7.

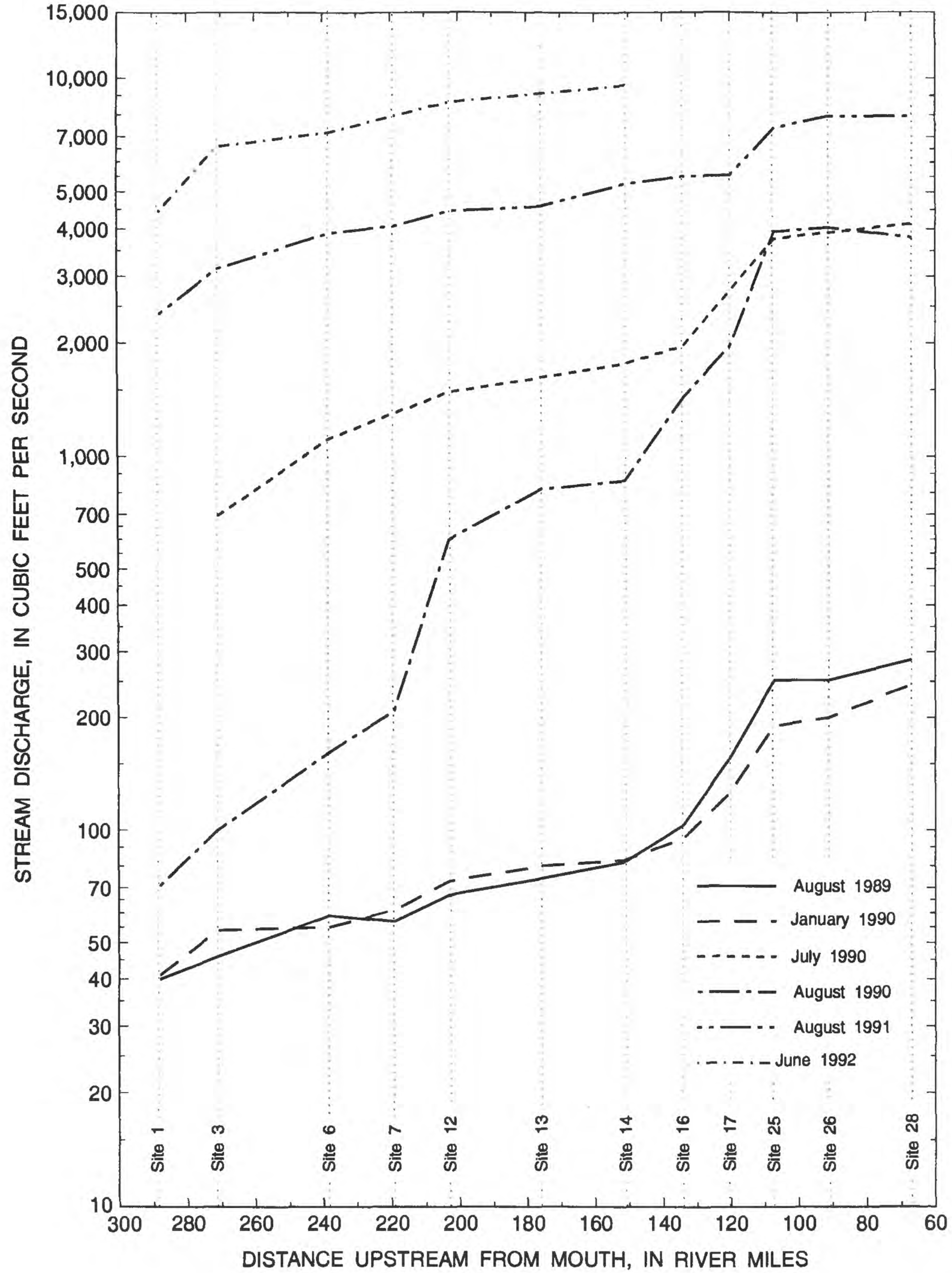


Figure 60.–Stream discharge at time of measurement, by river mile, for Minnesota River water-quality sampling sites, August 1989 to June 1992.

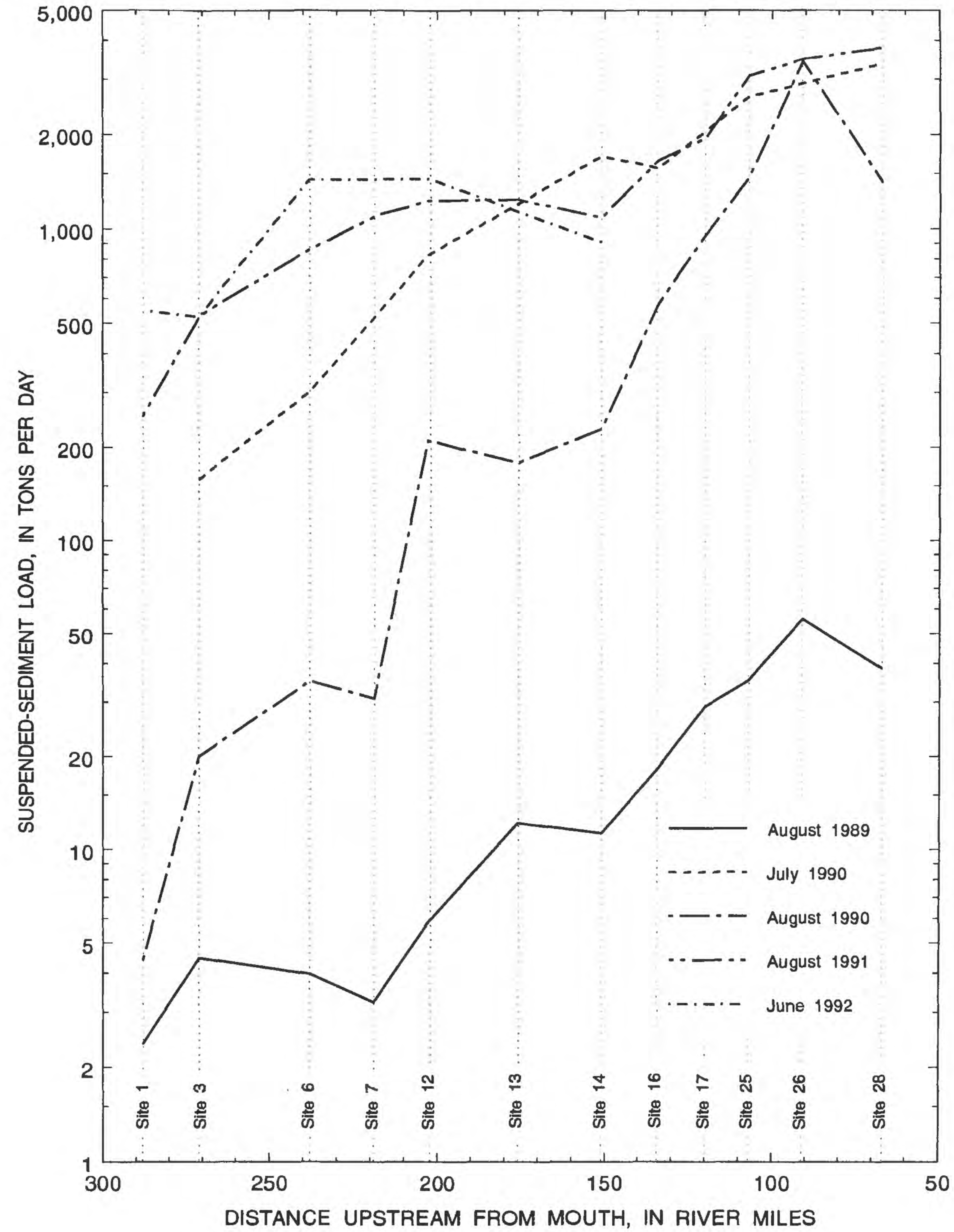


Figure 61.–Suspended-sediment load at time of sampling, by river mile, for Minnesota River water-quality sampling sites, August 1989 to June 1992.

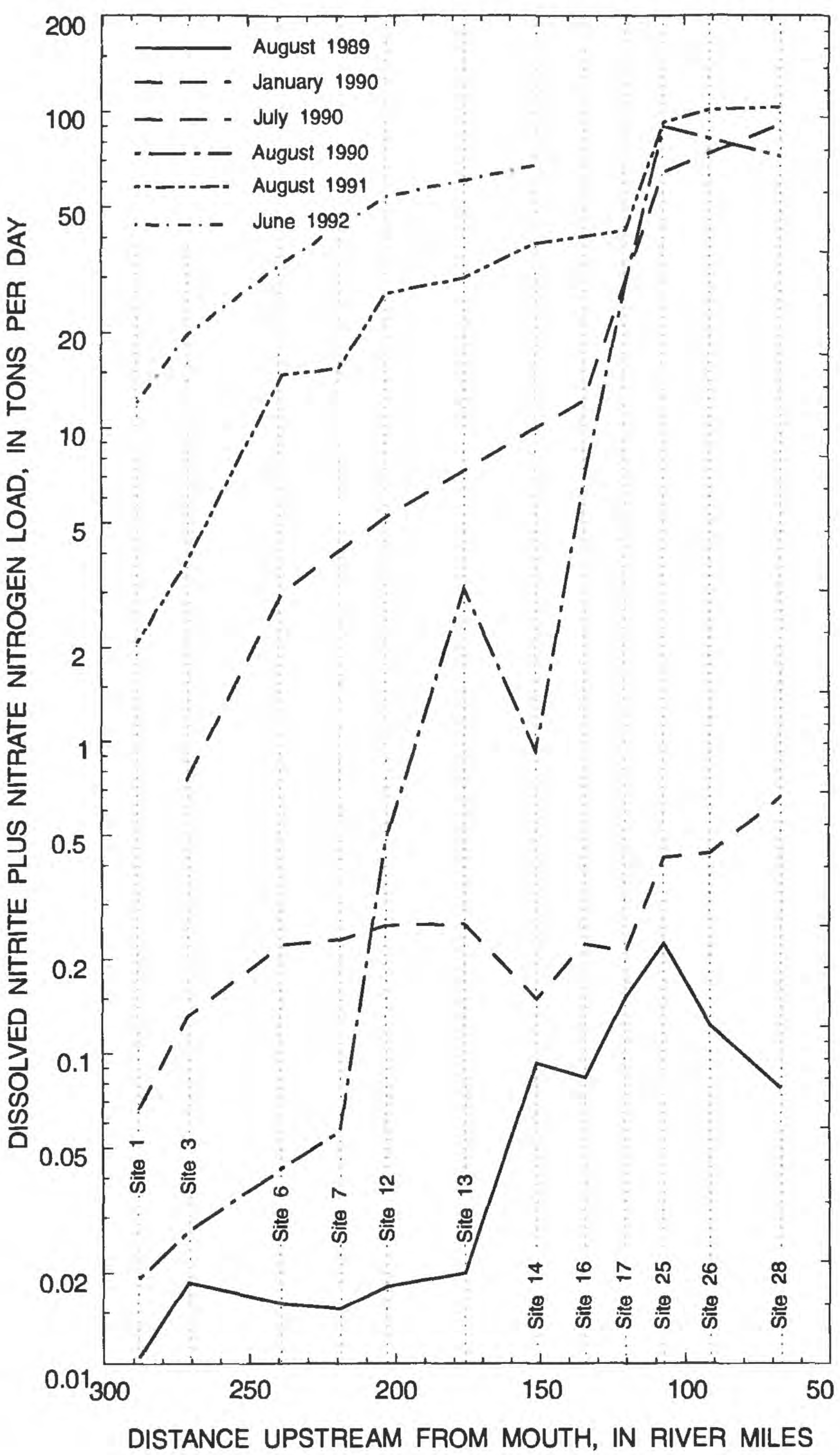


Figure 62.–Dissolved nitrite plus nitrate nitrogen load at time of sampling, by river mile for Minnesota River water-quality sampling sites, August 1989 to June 1992.

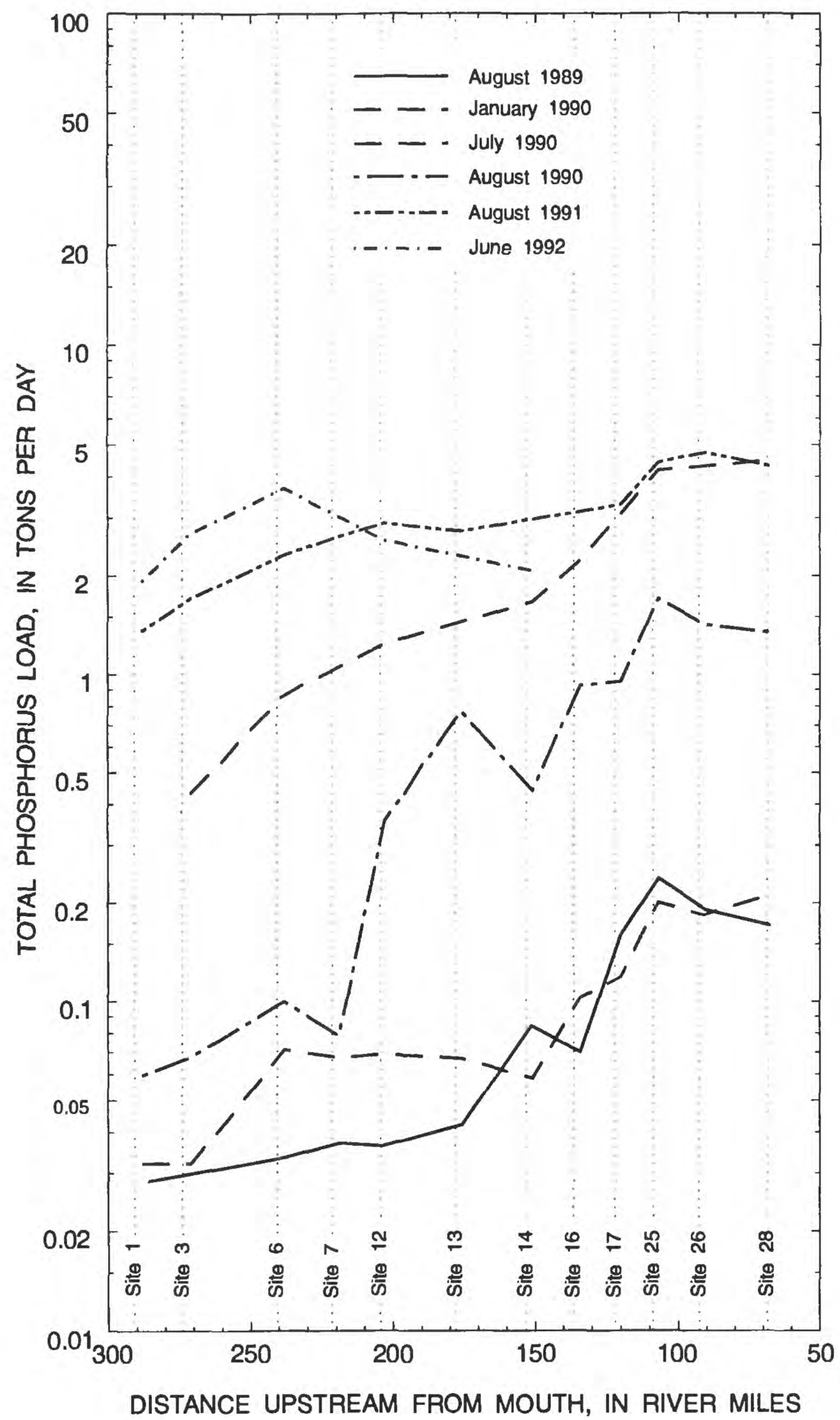


Figure 63.–Total phosphorus load at time of sampling, by river mile, for Minnesota River water-quality sampling sites, August 1989 to June 1992.

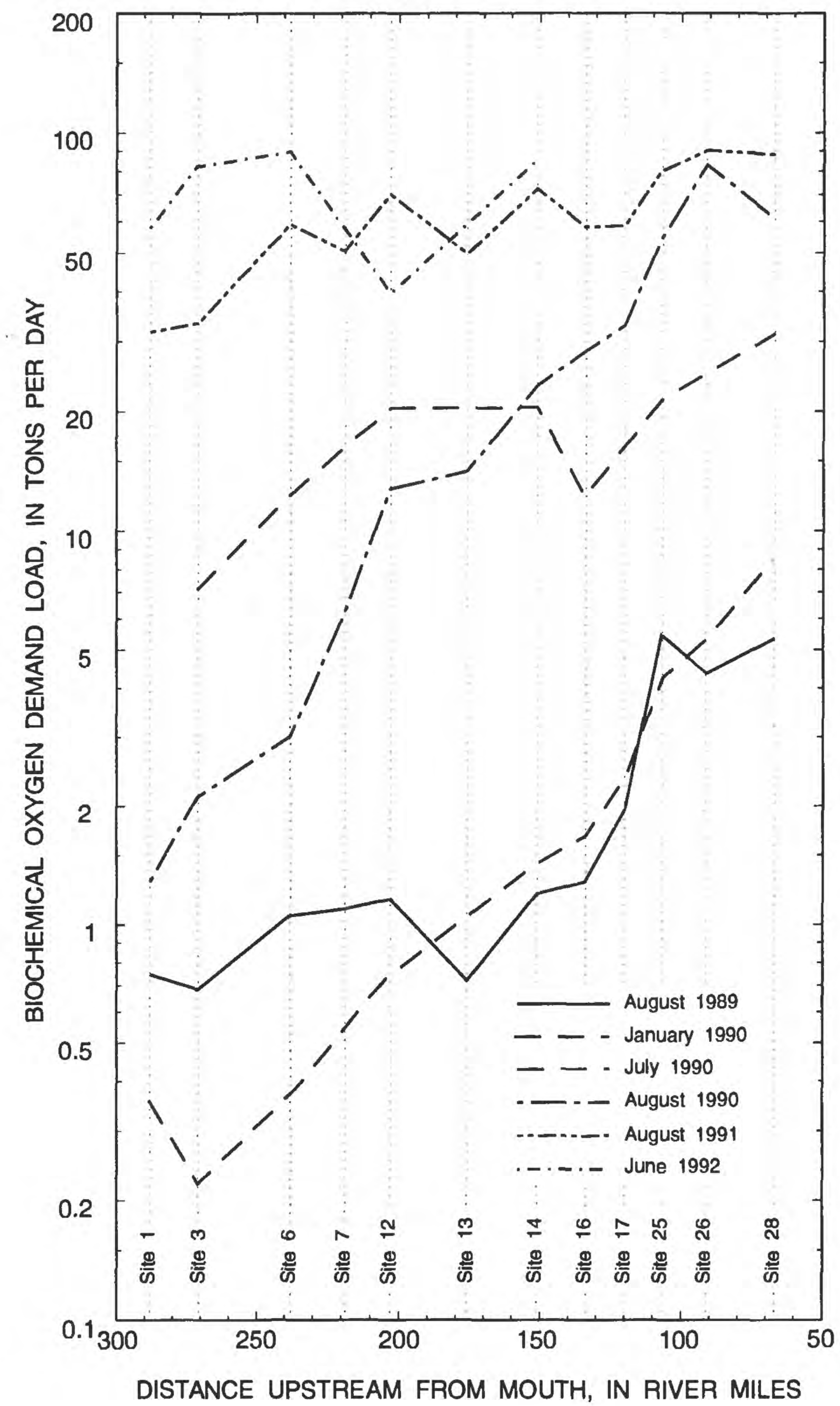


Figure 64.–Biochemical oxygen demand load at time of sampling, by river mile for Minnesota River water-quality sampling sites, August 1989 to June 1992.

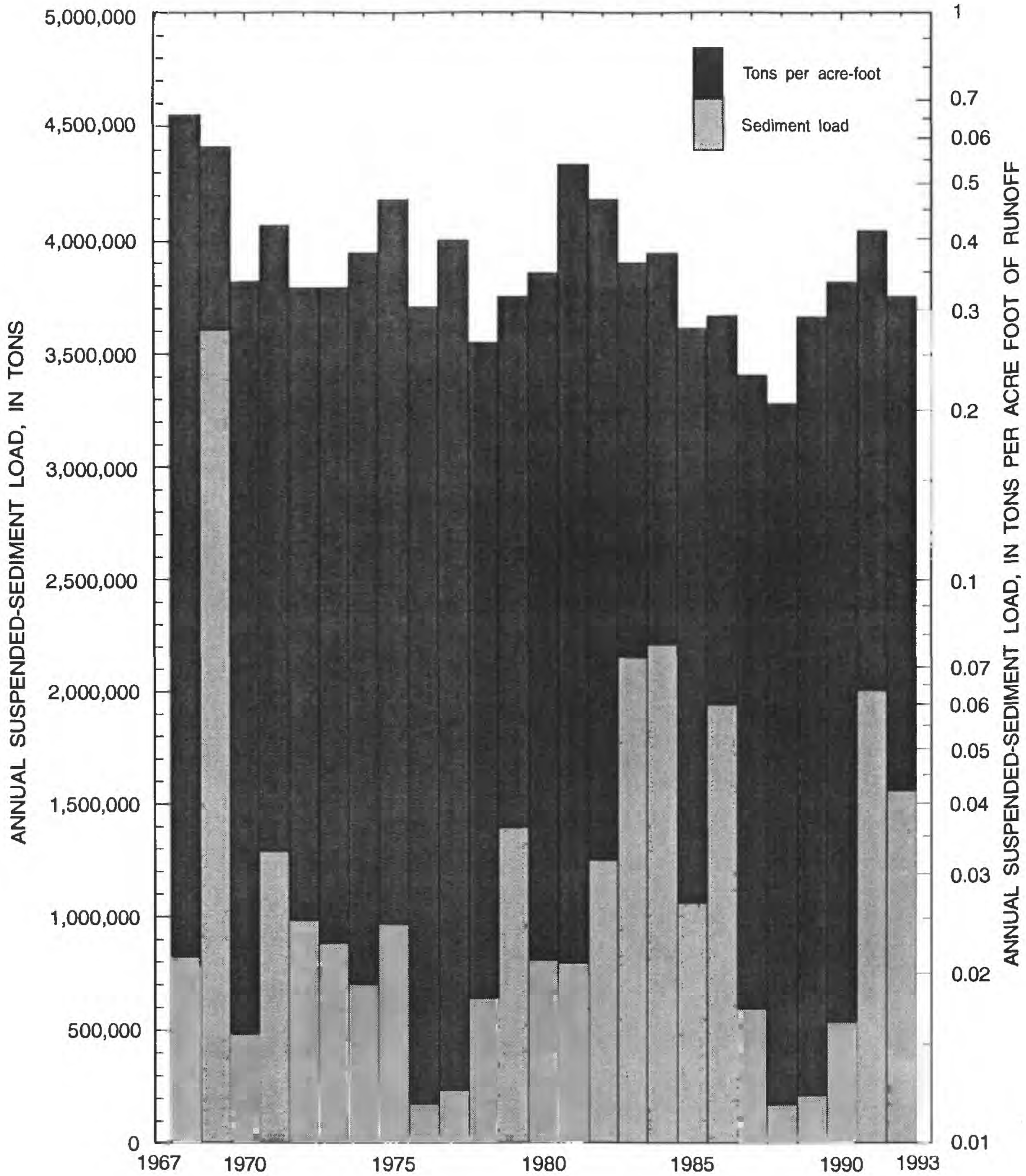


Figure 65.–Annual suspended-sediment load and annual suspended-sediment load per acre-foot of runoff for the Minnesota River at Mankato, water years 1968-92.

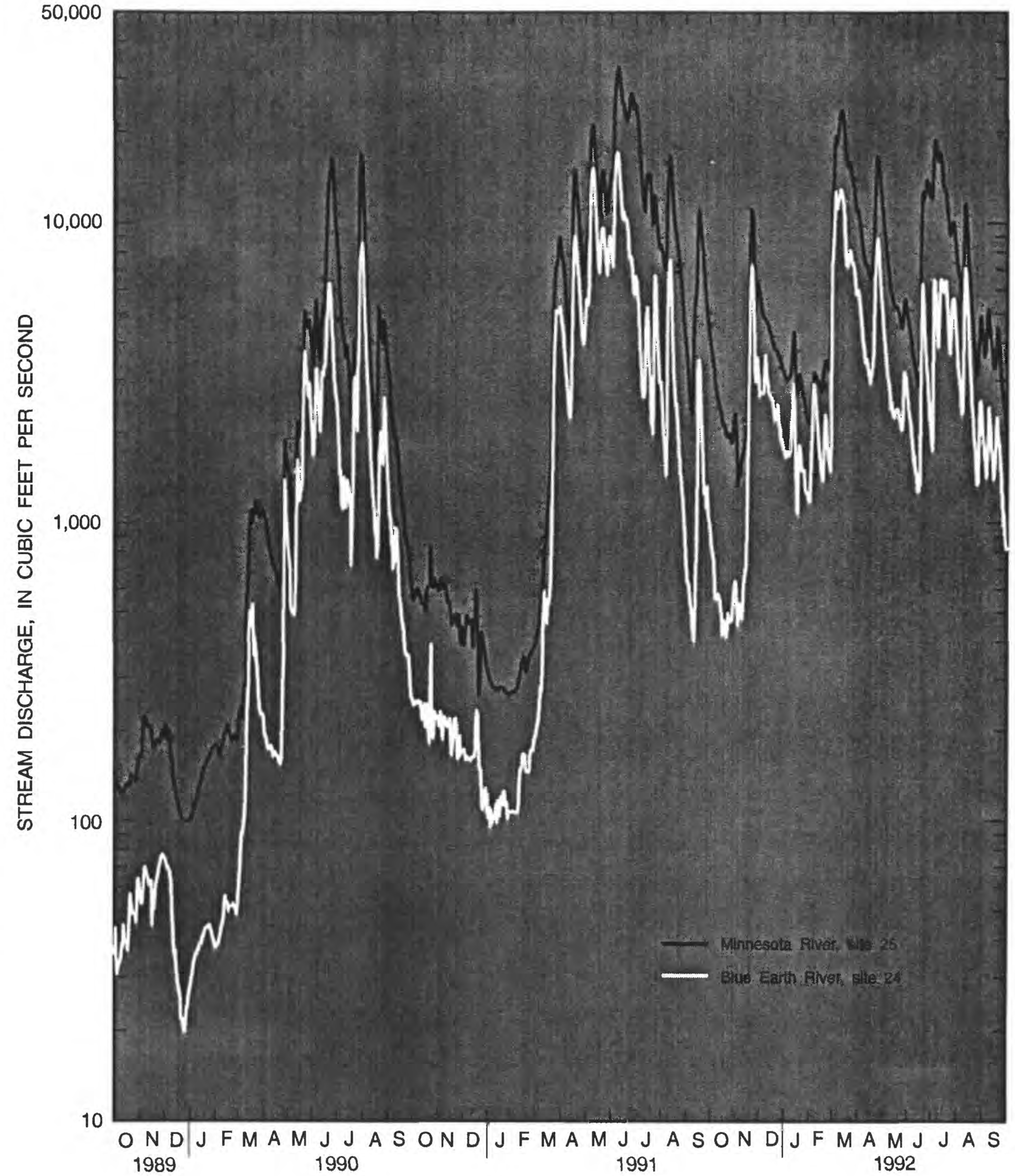


Figure 66.–Mean-daily stream discharge for the Blue Earth River at Mankato (site 24) and the Minnesota River at Mankato (site 25), October 1989-September 1992.

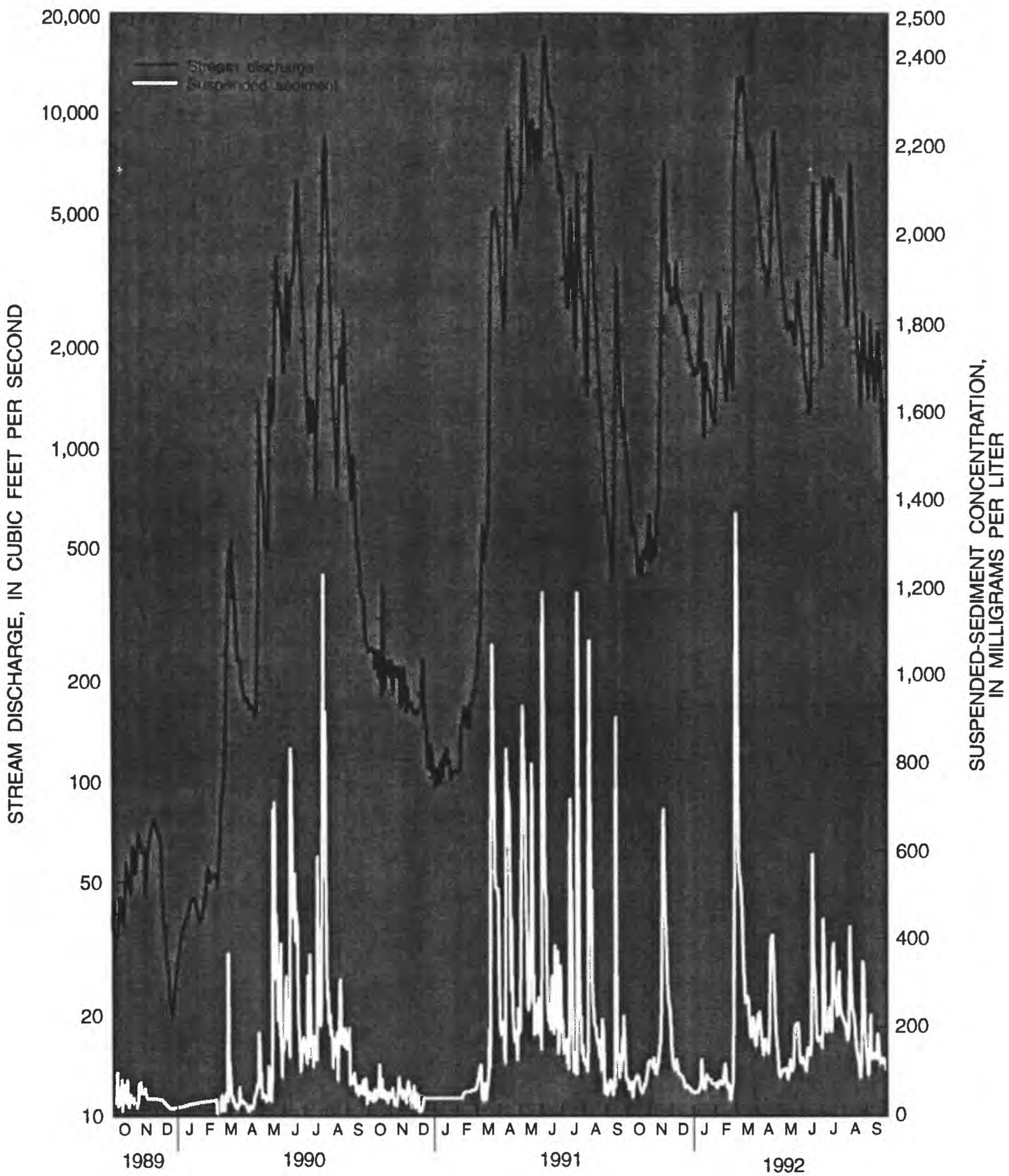


Figure 67.–Mean-daily stream discharge and suspended-sediment concentration for the Blue Earth River at Mankato (site 24), October 1989-September 1992.

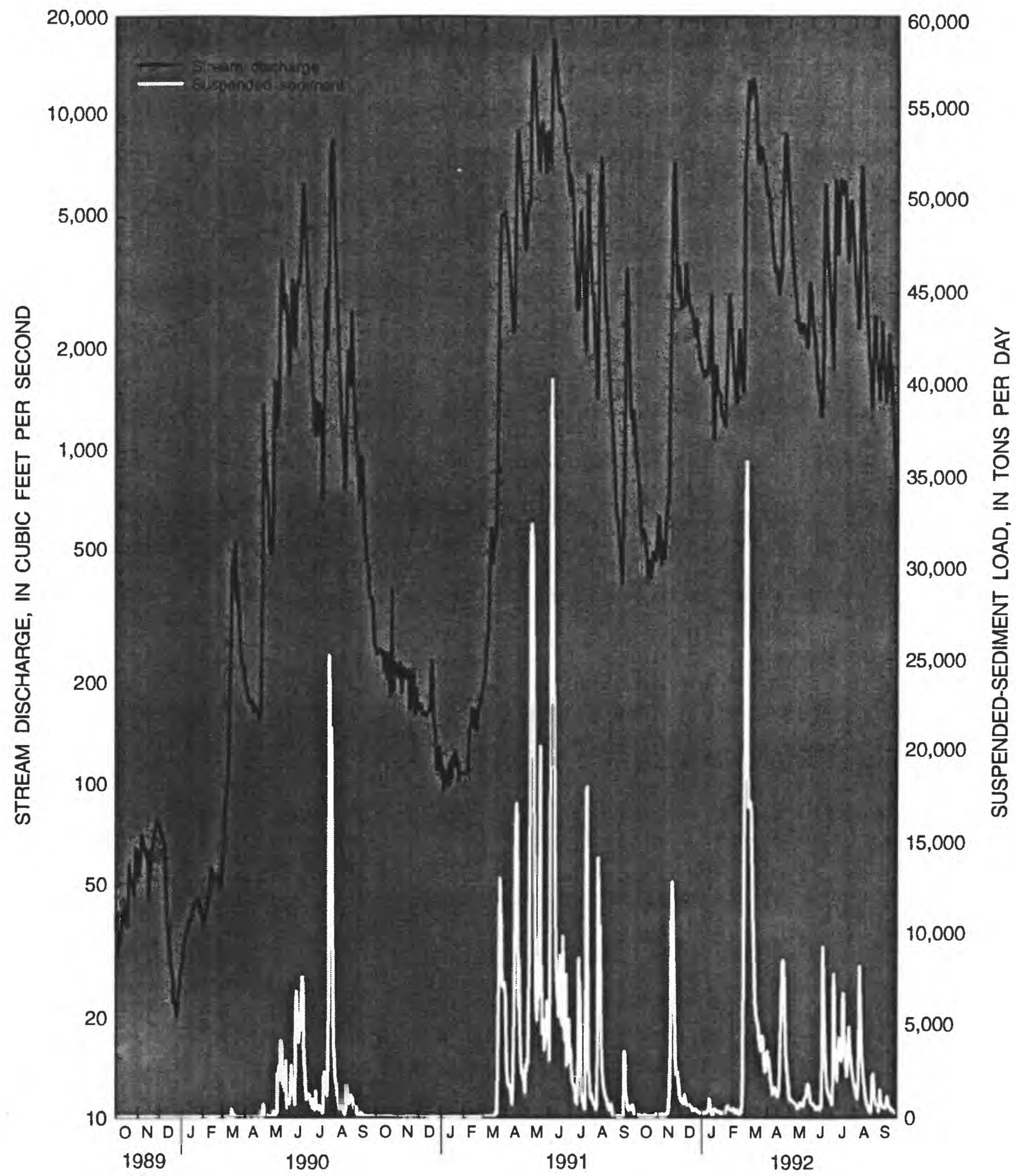


Figure 68.–Mean-daily stream discharge and suspended-sediment load for the Blue Earth River at Mankato (site 24), October 1989-September 1992.

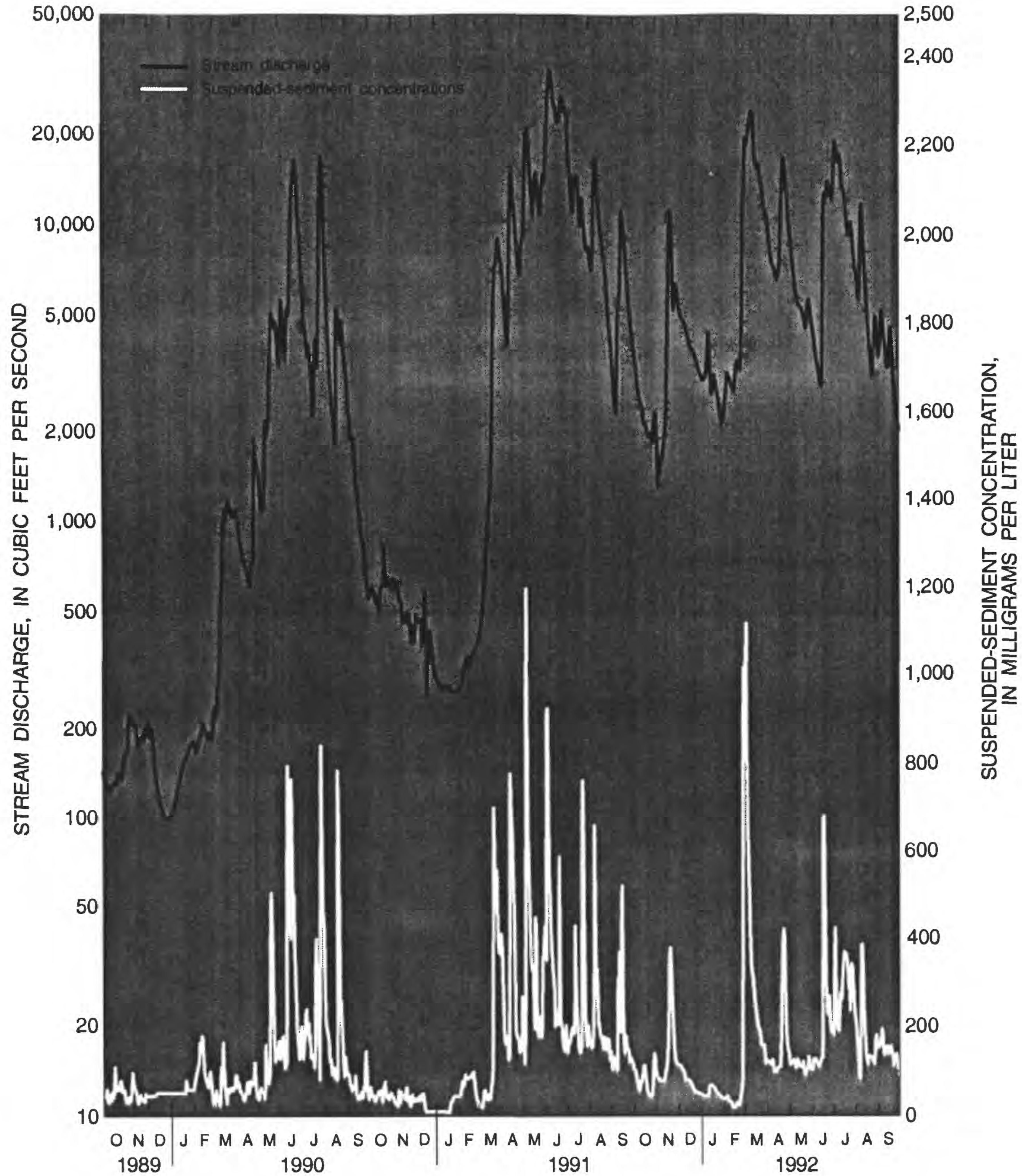


Figure 69.–Mean-daily stream discharge and suspended-sediment concentration for the Minnesota River at Mankato (site 25), October 1989-September 1992.

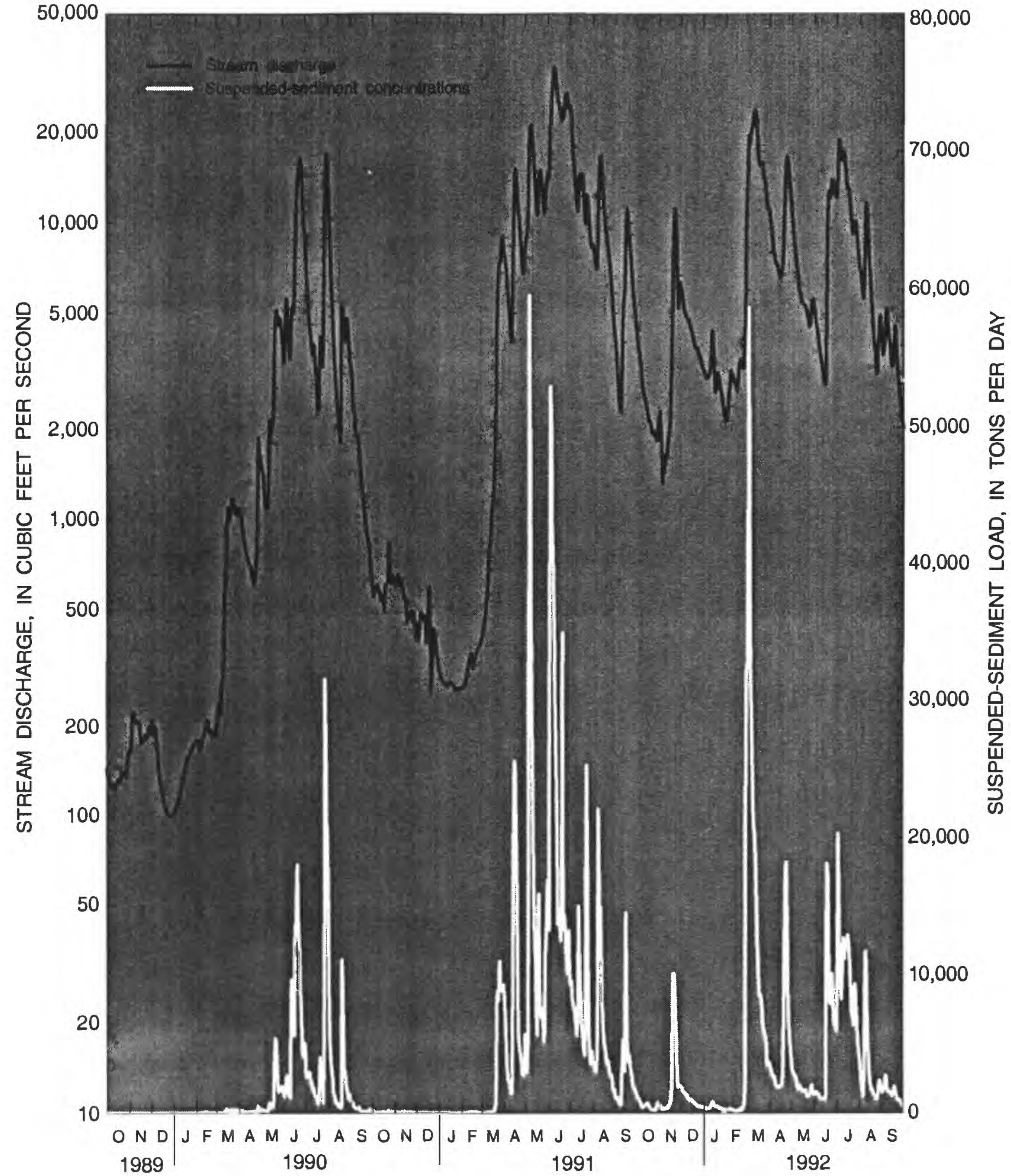


Figure 70.–Mean-daily stream discharge and suspended-sediment load for the Minnesota River at Mankato (site 25), October 1989-September 1992.

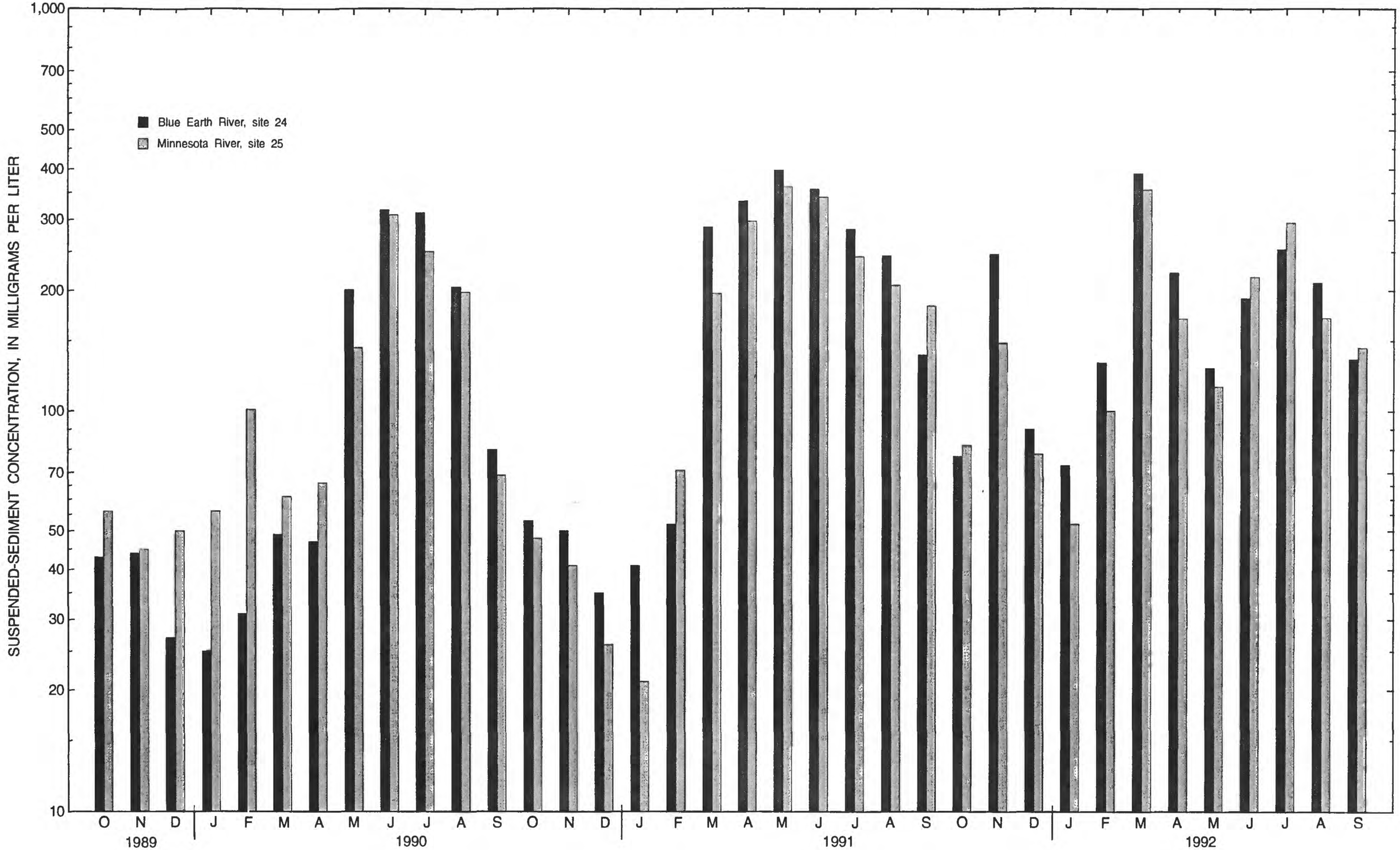


Figure 71.--Mean-monthly suspended-sediment concentration for the Blue Earth River at Mankato (site 24) and the Minnesota River at Mankato (site 25), October 1989-September 1992.

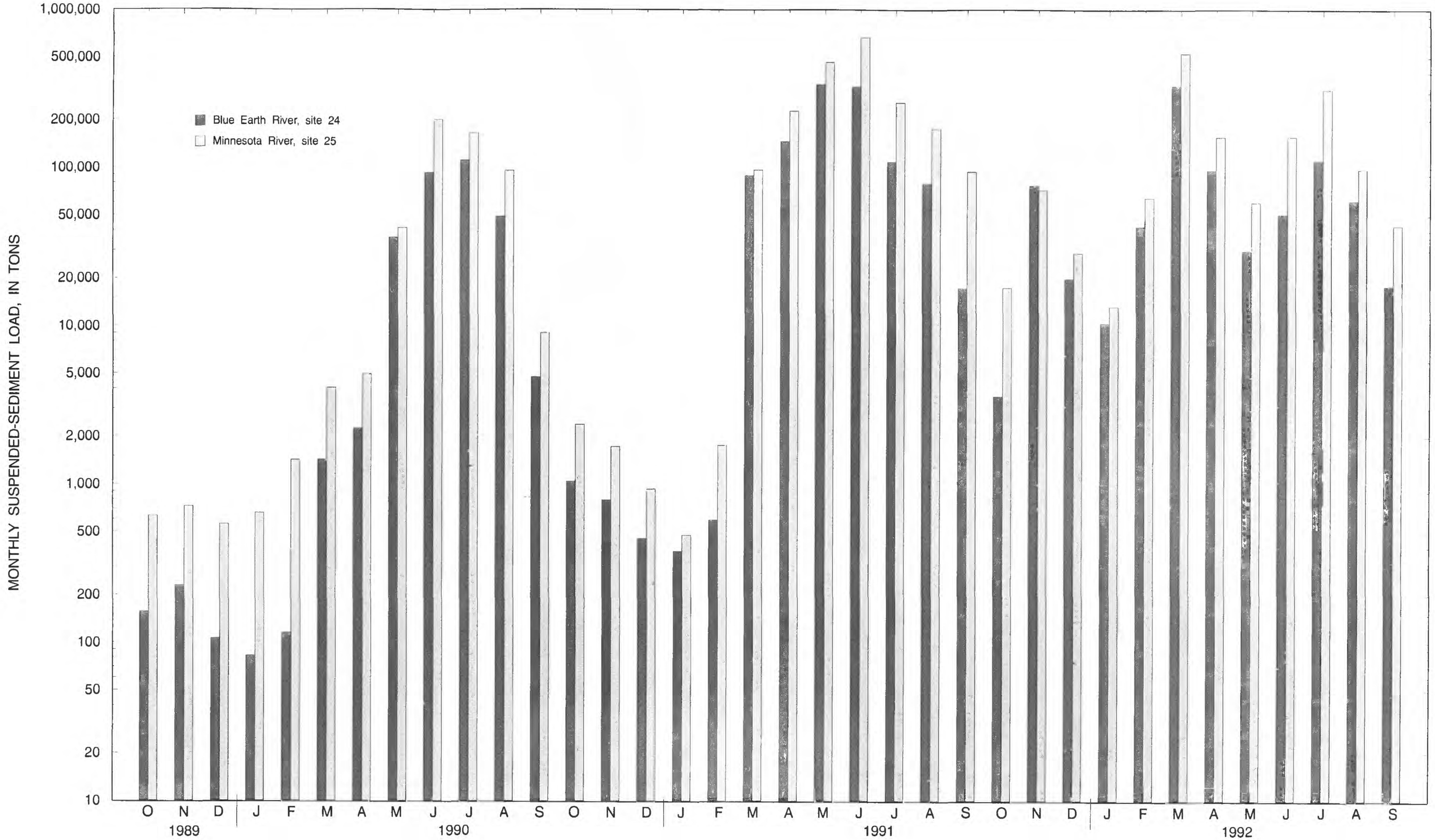


Figure 72.--Monthly suspended-sediment load for the Blue Earth River at Mankato (site 24) and the Minnesota River at Mankato (site 25), October 1989-September 1992.

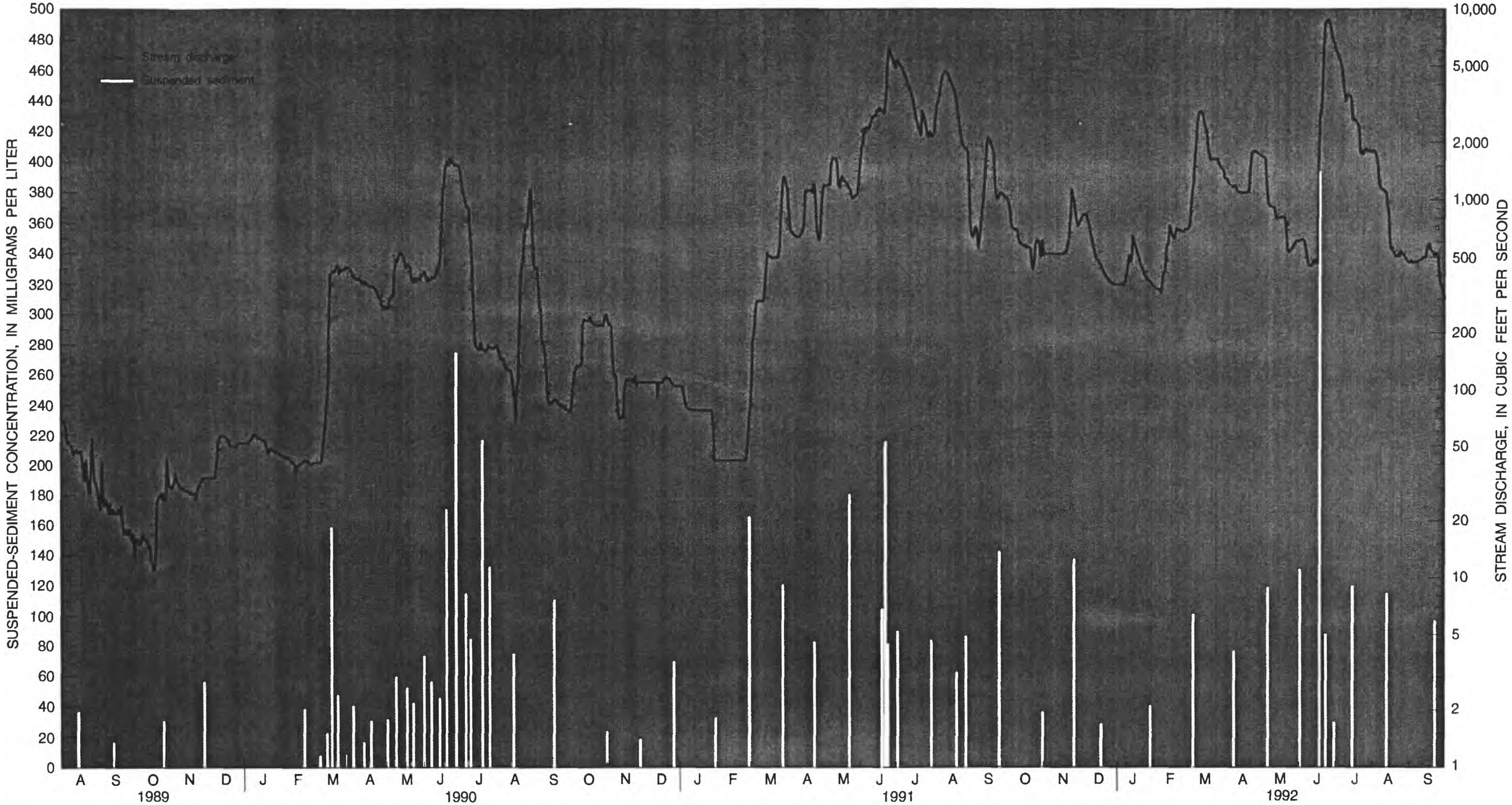


Figure 73.--Suspended-sediment concentration and stream discharge for the Minnesota River at Montevideo (site 3), August 1989-September 1992.

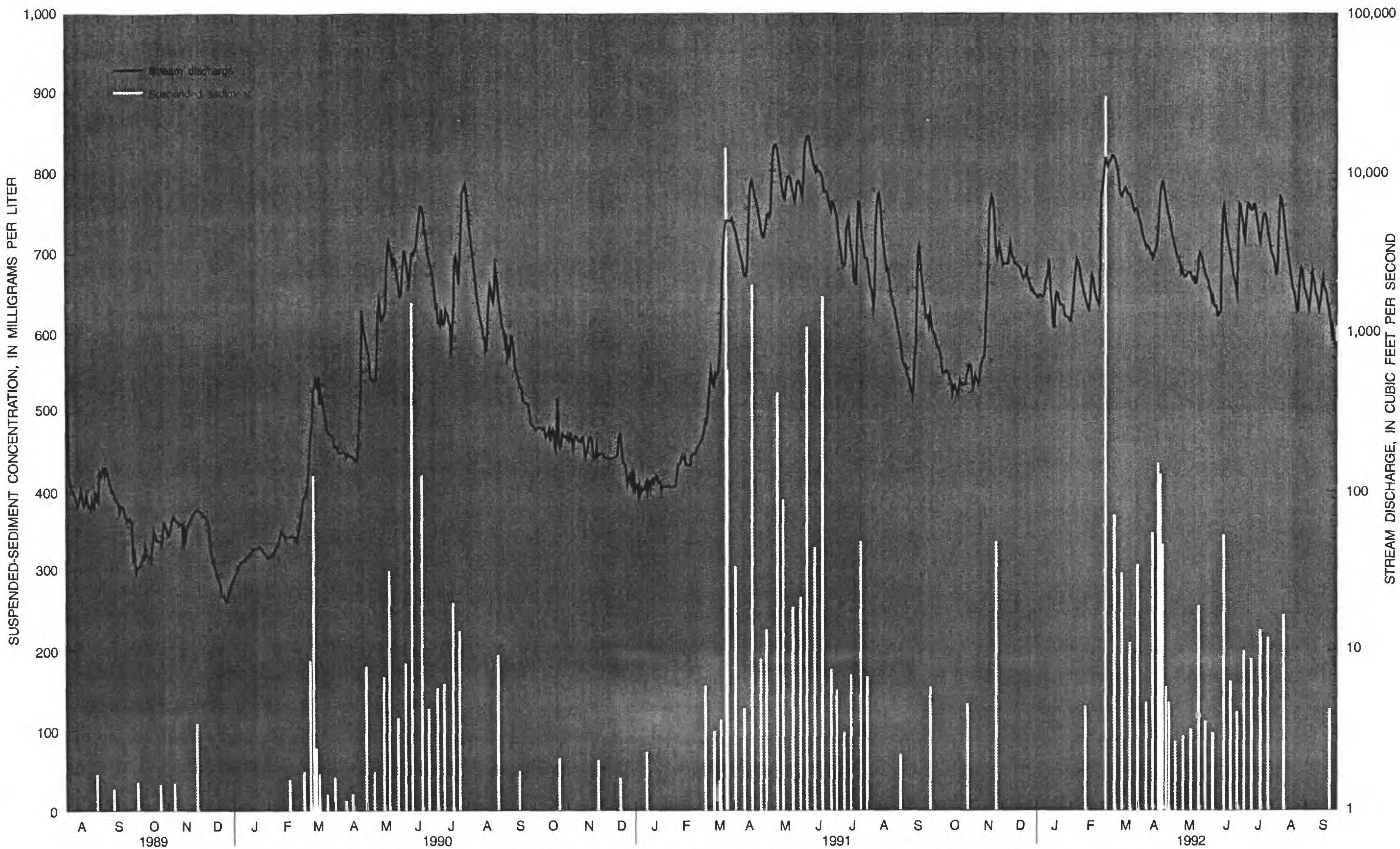


Figure 74.–Suspended-sediment concentration and stream discharge for the Blue Earth River at Mankato (site 24), August 1989-September 1992.

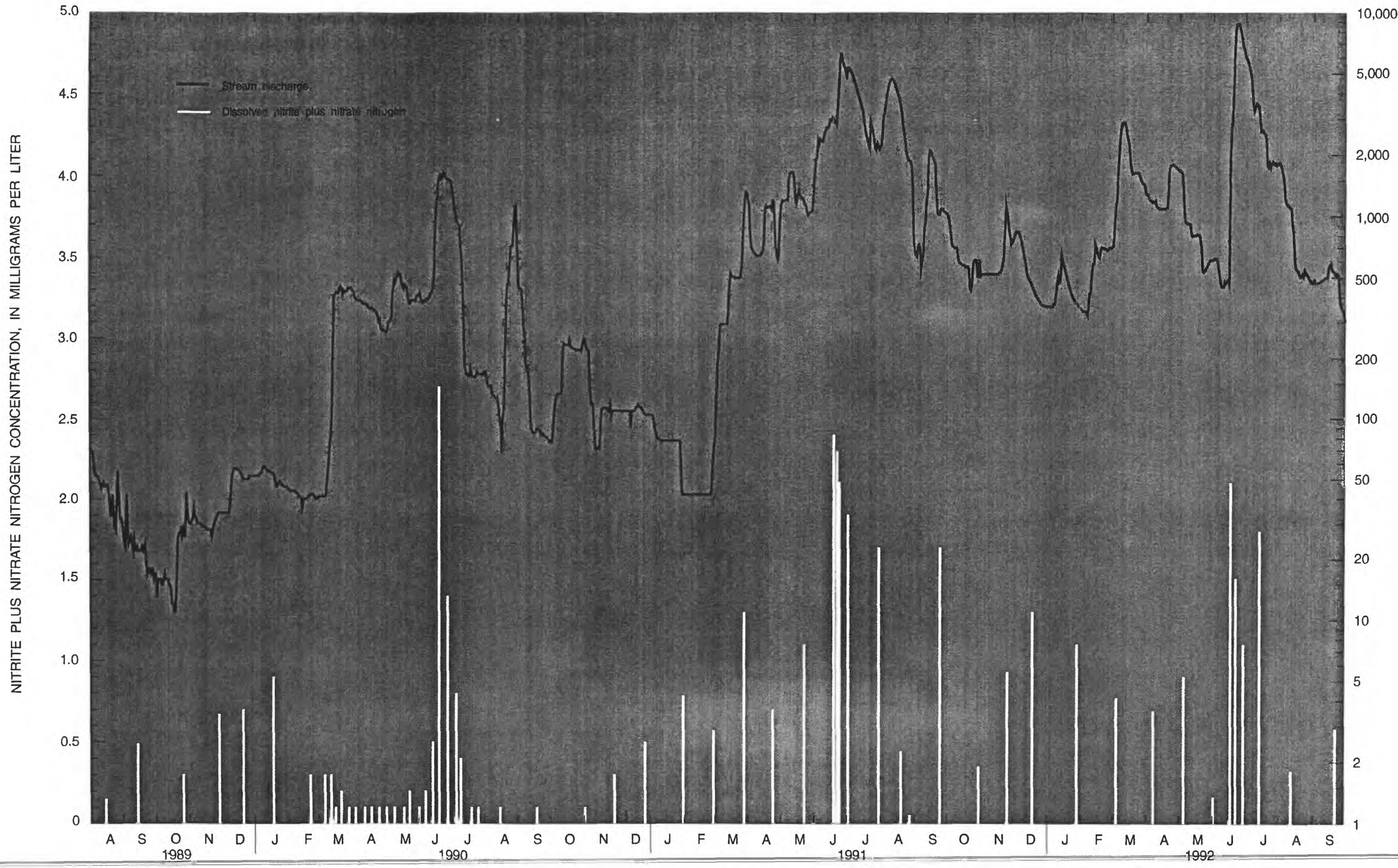


Figure 75.–Dissolved nitrite plus nitrate nitrogen concetration and stream discharge for the Minnesota River at Montevideo (site 3), August 1989-September 1992.

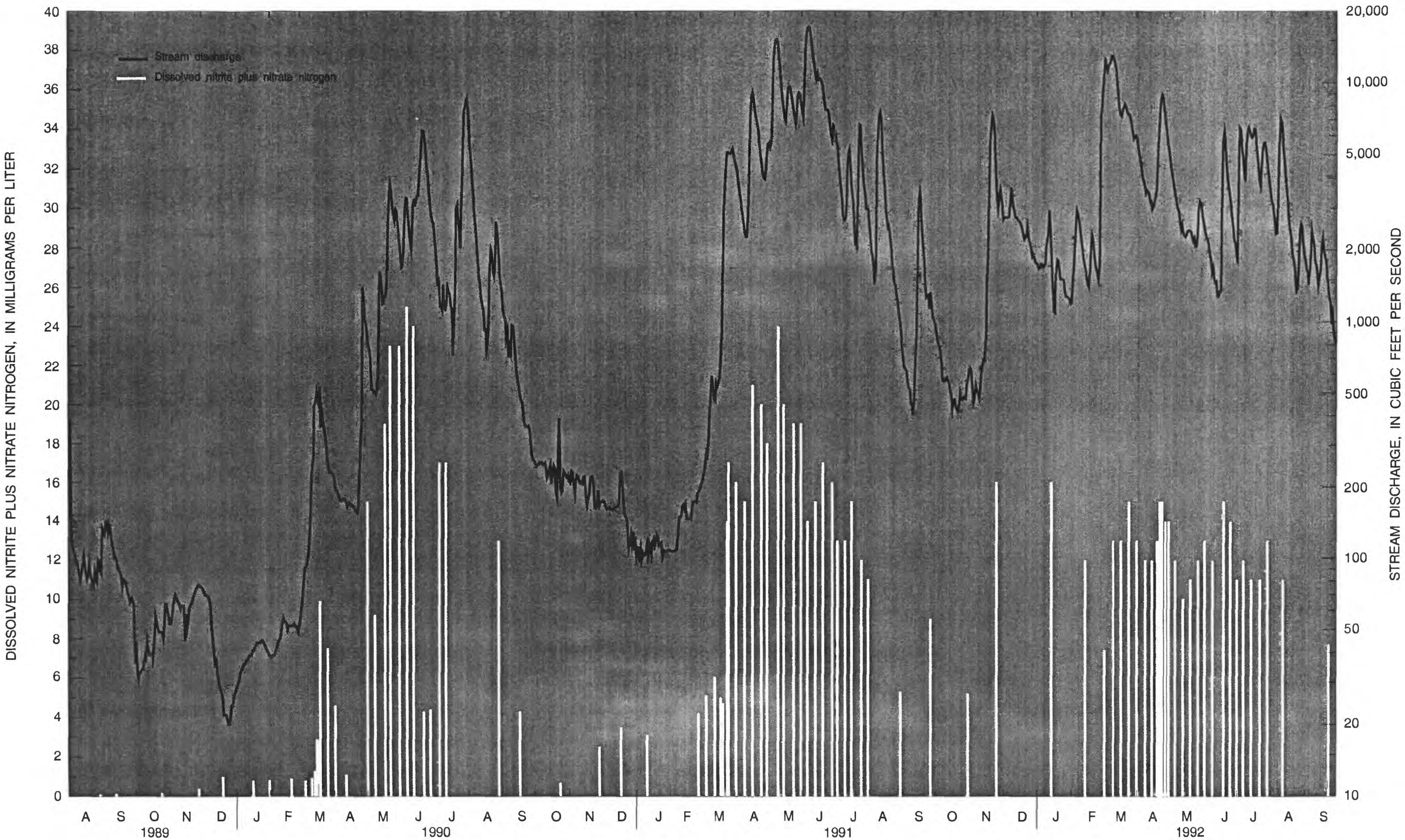


Figure 76.--Dissolved nitrite plus nitrate nitrogen concentration and stream discharge for the Blue Earth River at Mankato (site 24), August 1989-September 1992.

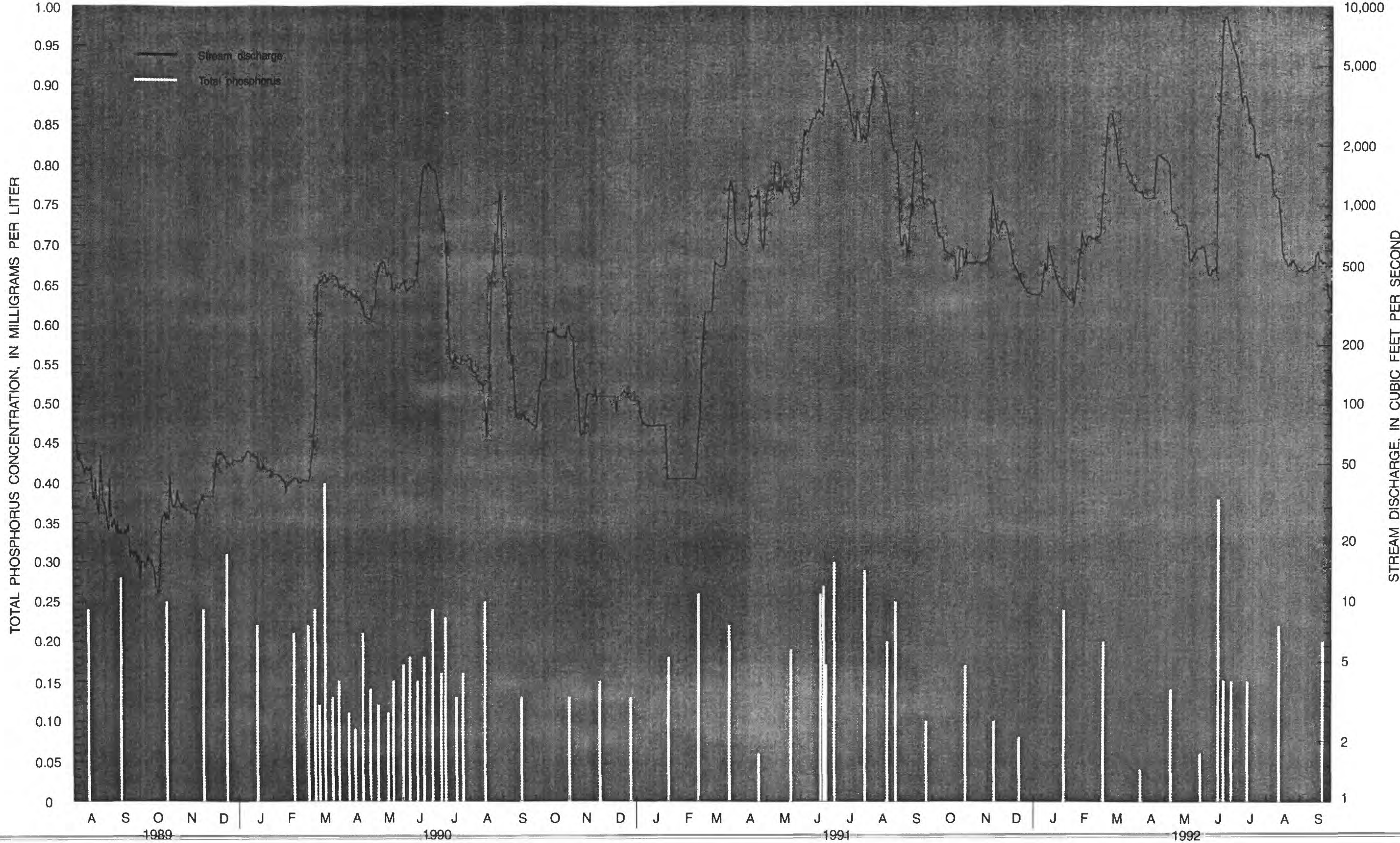


Figure 77.--Total phosphorus concentration and stream discharge for the Minnesota River at Montevideo (site 3), August 1989-September 1992.

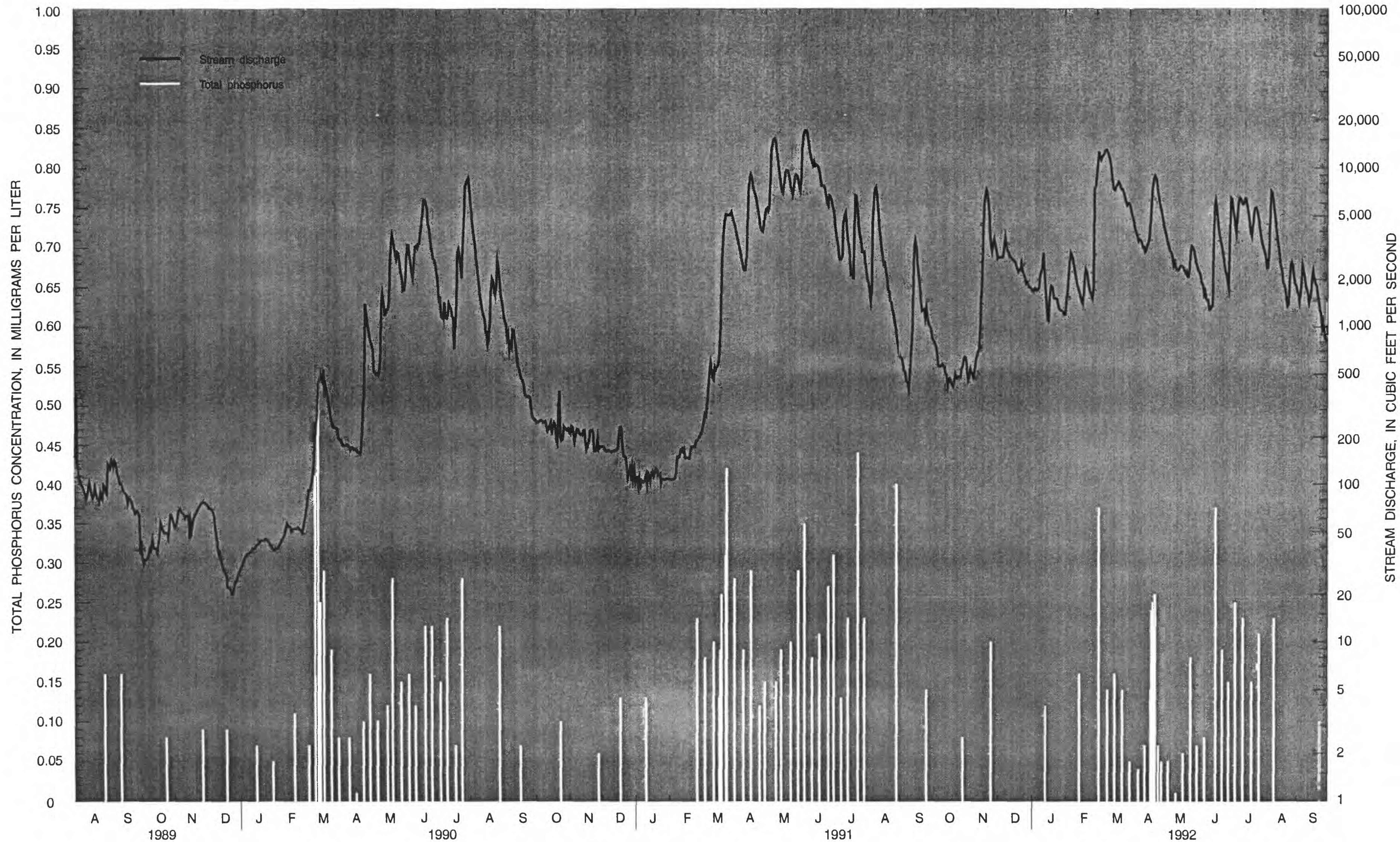


Figure 78.–Total phosphorus concentration and stream discharge for the Blue Earth River at Mankato (site 24), August 1989-September 1992.

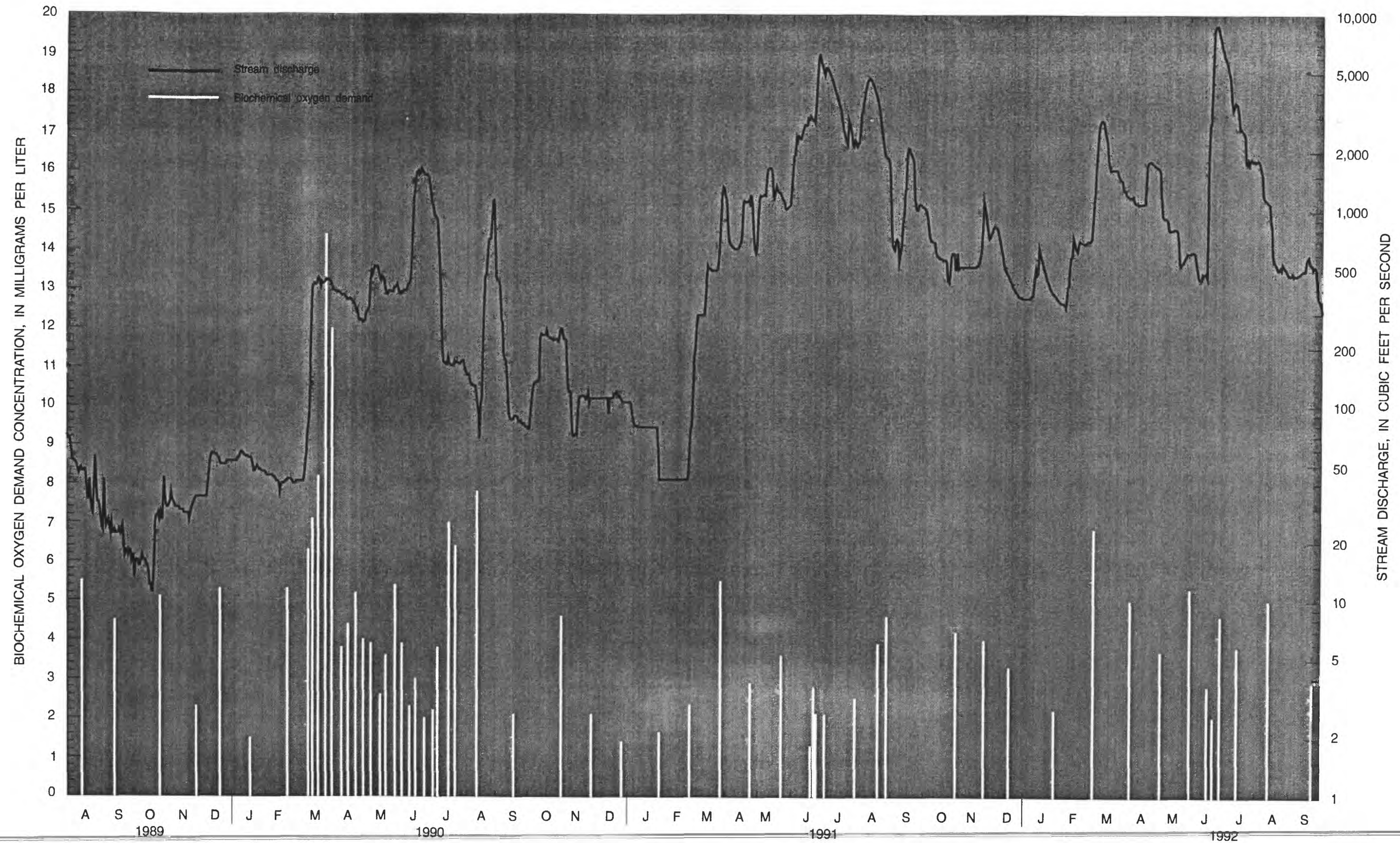


Figure 79.–Biochemical oxygen demand concentration and stream discharge for the Minnesota River at Montevideo (site 3), August 1989-September 1992.

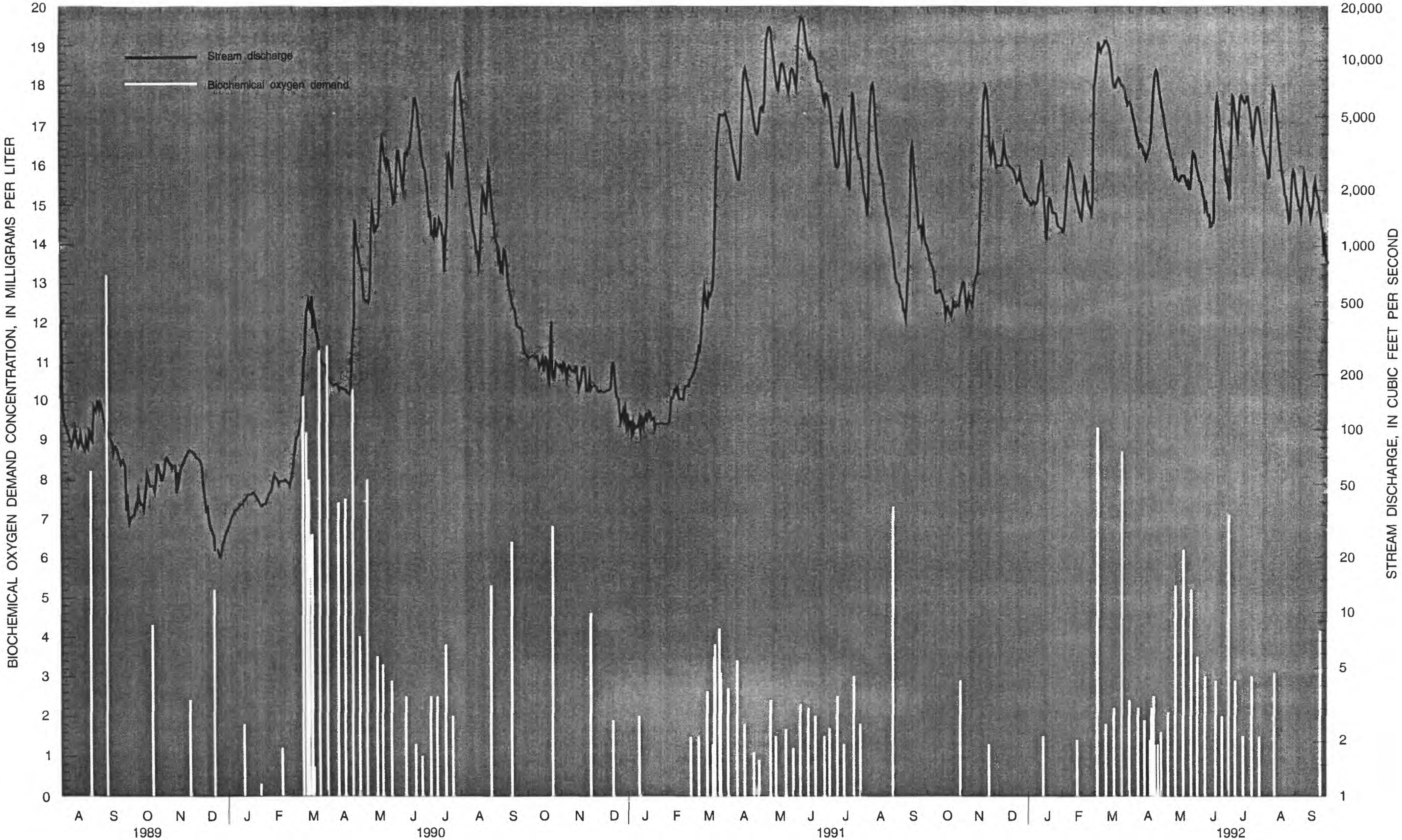


Figure 80.--Biochemical oxygen demand concentration and stream discharge for the Blue Earth River at Mankato (site 24), August 1989-September 1992.

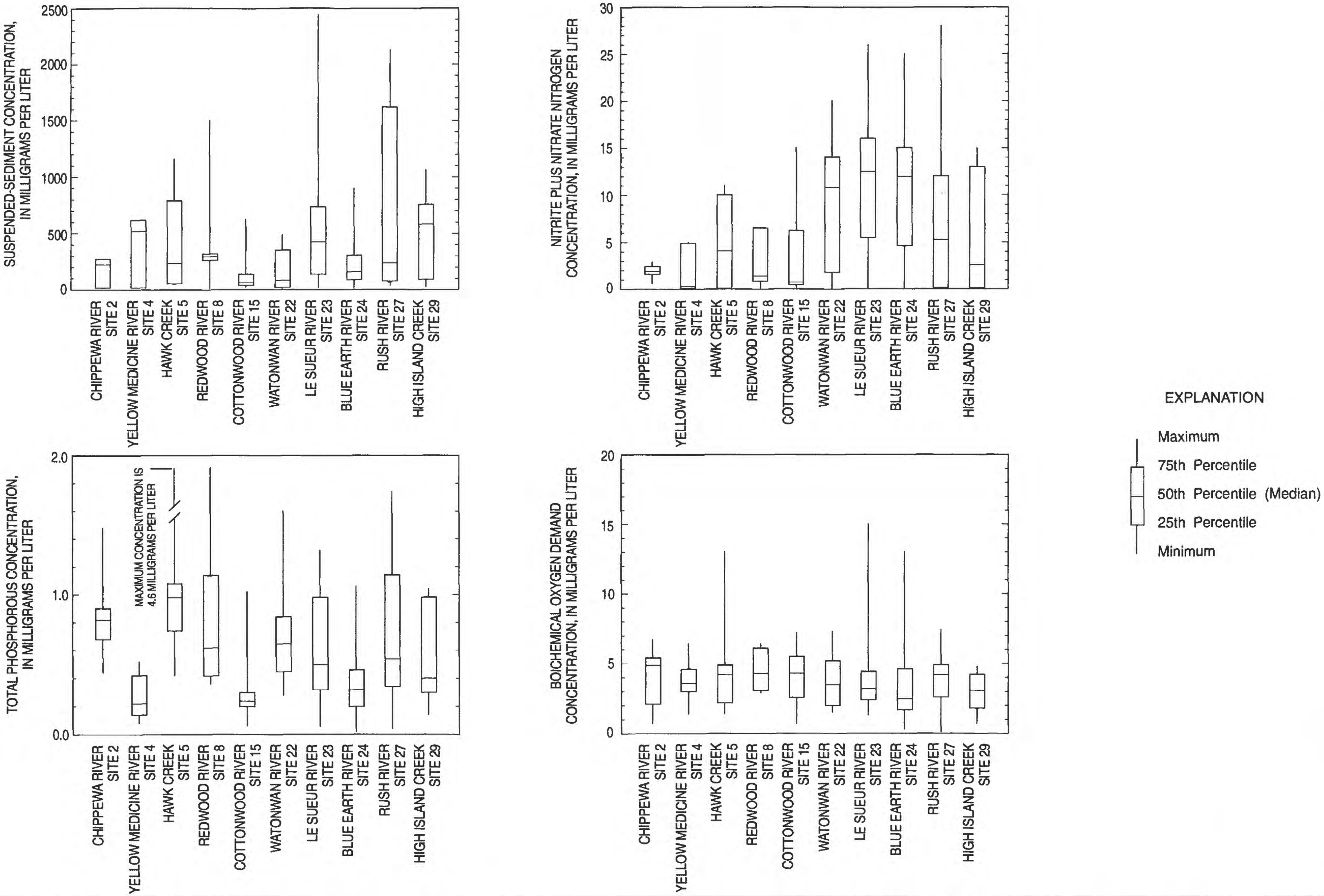


Figure 81.--Concentrations of suspended-sediment, dissolved nitrite plus nitrate nitrogen, total phosphorus, and biochemical oxygen demand for water-quality sampling sites at ten major Minnesota River tributaries.

Table 1.--Stream data-collection sites for the Minnesota River Assessment Project

Site identification number	USGS identification number	Stream Site	Distance upstream from mouth, in miles
1	05301000	Minnesota River near Lac qui Parle, Minn.	288
2	05305400	Chippewa River at Montevideo, Minn.	
3	05311000	Minnesota River at Montevideo, Minn.	271
4	05313510	Yellow Medicine River on Highway 67 near Granite Falls, Minn.	
5	05314550	Hawk Creek at Mouth near Sacred Heart, Minn.	
6	05314560	Minnesota River near Sacred Heart, Minn.	238
7	05314740	Minnesota River near Delhi, Minn.	219
8	05316470	Redwood River at County Road 30 near Seaforth, Minn.	
9	05316490	Judicial Ditch 5 at County Road 30 near Redwood Falls, Minn.	
10	05316500	Redwood River near Redwood Falls, Minn.	
11	05316541	Redwood River below Ramsey Creek at Redwood Falls, Minn.	
12	05316580	Minnesota River at Morton, Minn.	203
13	05316685	Minnesota River near Fairfax, Minn.	176
14	05316760	Minnesota River near New Ulm, Minn.	151
15	05317000	Cottonwood River near New Ulm, Minn.	
16	05317250	Minnesota River at Courtland, Minn.	134
17	05317500	Minnesota River at Judson, Minn.	120
18	05318135	Blue Earth River above South Creek near Winnebago, Minn.	
19	05318140	South Creek near Winnebago, Minn.	
20	05318141	Blue Earth River at County Road 5 near Winnebago, Minn.	
21	05318290	Blue Earth River near Good Thunder, Minn.	
22	05319500	Watonwan River near Garden City, Minn.	
23	05320500	Le Sueur River near Rapidan, Minn.	
24	05322000	Blue Earth River at Mouth at Mankato, Minn.	
25	05325000	Minnesota River at Mankato, Minn.	107
26	05325200	Minnesota River at St. Peter, Minn.	91
27	05326400	Rush River near Henderson, Minn.	
28	05326450	Minnesota River at Henderson, Minn.	67
29	05327000	High Island Creek near Henderson, Minn.	

Table 2.--Springs sampled for the Minnesota River Assessment Project

Site ID	USGS identification number	Spring
D	444750095332001	Baker Spring near Granite Falls
P	441827093573301	Seepage at Face Spring at St. Peter, Minn.
C	445425095402301	Seepage Face Wehrspann Spring, Minn.
G	443631095094801	Seepage Cedar Rock Spring near Delhi, Minn.
F	443921095203301	Boiling Spring near Belview, Minn.
A	450026095514001	Seepage at Baldwin Farm near Lac qui Parle, Minn.
U	444132093383201	Seepage Face near Jordan, Minn.
R	442204093532301	Rogers Creek Spring near St. Peter, Minn.
K	441636094272701	Flandrau Spring at New Ulm, Minn.
L	441531094203001	Courtland Bridge Spring near Courtland, Minn.
N	440230094101001	Birr Spring near Garden City, Minn.
H	443317095073401	Redwood Spring near Redwood Falls, Minn.
Q	442006093545601	Paulson Spring near St Peter, Minn.
T	443418093552201	Seepage Face on High Island Creek Spring, Minn.
J	442859094490301	Peterson Spring near Fairfax, Minn.
B	445630095462101	Seepage at Envoldsen Farm near Montevideo, Minn.
E	444413095251701	Seepage Face at Hawk Creek Spring, Minn.
I	443110094530001	Seepage at Franklin Spring near Franklin, Minn.
S	443129093530501	Spring near Henderson Station, Minn.
O	440558094072301	Davis Hole Spring near Rapidan, Minn.
M	441206094115101	Seepage Face at Spring near Judson, Minn.

Table 3.--Basins in the Minnesota River Basin and areal extent of each

Basin	Area, in square miles	Number of subbasins in the basin
Upper Minnesota River	2,090	99
Pomme de Terre River	870	52
Lac qui Parle River	1,100	78
Chippewa River	2,080	129
Hawk Creek--Yellow Medicine River	2,070	160
Redwood River	700	52
Cottonwood River	1,310	108
Little Cottonwood River--Middle Minnesota River	1,350	104
Watonwan River	880	59
Le Sueur River	1,110	86
Blue Earth River	1,550	115
Lower Minnesota River	1,820	144

Table 4.--Generalized bedrock hydrogeologic units in the Minnesota River Basin [adapted from Kanivetsky, 1979a]

Geologic age	Hydrogeologic units defined for this study	Description and water-bearing characteristics
Cretaceous	Cretaceous rocks, undifferentiated	Shale, sandstone, clay. Low to moderate yields, good quality to slightly saline
Devonian-Ordovician	Cedar Valley-Maquoketa-Dubuque-Galena	Limestone, dolomite. Moderate yields, good quality
Ordovician	St. Peter Sandstone	Moderate yields, good quality
Ordovician-Cambrian	Prairie du Chien-Jordan	Dolomite, sandstone. Moderate to high yields, good quality
Cambrian	Franconia-Ironton-Galesville	Sandstone, some shale. Moderate to high yields, good quality
Cambrian/Precambrian	Mt. Simon-Hinckley-Fond du Lac	Sandstone, siltstone, shale at base. Moderate to high yields, slightly saline
Precambrian	Precambrian igneous and metamorphic rocks	Generally not an aquifer except in faulted zones

Table 5.--Land use in the 12 basins of the Minnesota River Basin
[Land use from the MLMIS100 data set. Table shows number of 100 meter by 100 meter cells in each land use category]

Land use classification	Upper Minnesota River	Pomme de Terre River	Lac qui Parle River	Hawk Creek--Yellow Medicine River	Lac qui Parle River	Redwood River
Forested	2,453	7,839	1,099	8,775	15,431	1,320
Cultivated	143,996	172,923	170,120	468,347	390,598	158,976
Water	9,354	17,699	811	5,512	27,751	2,102
Marsh	3,260	3,853	1,024	2,278	10,846	765
Urban residential	766	1,232	260	1,595	2,878	791
Extractive	81	419	16	181	129	113
Pasture and open	35,775	20,680	21,986	43,964	87,376	16,076
Non/mix residential	1,667	1,443	1,636	5,736	3,491	2,201
Transportation	64	129	50	84	145	195

Land use classification	Little Cottonwood --Middle Minnesota Rivers	Cottonwood River	Blue Earth River	Watonwan River	Le Sueur River	Lower Minnesota River
Forested	18,305	3,645	6,431	2,069	5,816	33,463
Cultivated	289,944	304,476	277,431	205,667	252,542	334,230
Water	7,801	1,884	4,277	2,904	6,238	11,291
Marsh	2,265	806	1,037	804	2,973	10,097
Urban residential	2,634	808	1,470	55	1,217	14,517
Extractive	341	79	16	27	36	355
Pasture and open	21,009	23,826	17,959	12,648	16,604	51,599
Non/mix residential	5,882	3,394	3,730	2,124	2,666	13,746
Transportation	246	146	111	20	23	1,002

Table 6.--Suspended-sediment loads and yields for water-quality sampling sites in the Watonwan, Le Sueur, and Blue Earth River Basins for two runoff periods

	Suspended-sediment load, in tons			
Date	Blue Earth River near Good Thunder	Watonwan River near Garden City	Le Sueur River near Rapidan	Blue Earth River at Mankato
	Snowmelt-runoff period March 16-April 9, 1991			
03/16/91	28	5	18	101
03/17/91	33	5	23	126
03/18/91	68	5	37	149
03/19/91	146	6	89	353
03/20/91	475	19	233	275
03/21/91	2140	90	529	2210
03/22/91	3290	269	1070	6120
03/23/91	3360	759	2450	7850
03/24/91	3900	1040	3340	13000
03/25/91	4940	1280	3290	11400
03/26/91	4830	1420	2710	10500
03/27/91	4050	1340	2640	7600
03/28/91	3300	1160	2590	7100
03/29/91	2890	1090	2560	7120
03/30/91	2500	916	2340	7330
03/31/91	2180	788	1900	6910
04/01/91	1880	748	1610	6520
04/02/91	1650	696	1270	3720
04/03/91	1380	550	1000	2460
04/04/91	1070	379	789	2050
04/05/91	944	265	631	1760
04/06/91	1020	193	506	1770
04/07/91	1150	135	420	1680
04/08/91	1160	100	358	1620
04/09/91	960	77	304	1180
Total load[1]	49344	13335	32689	110904
Percent[2]	44.5	12.0	29.5	100
Sediment yield[3]	32.2	15.7	29.4	31.3
	Rainfall-runoff period May 5-13, 1992			
05/05/91	3870	1960	11300	16700
05/06/91	11400	2560	25000	31700
05/07/91	10500	1380	19800	32400
05/08/91	9020	817	18600	31800
05/09/91	11900	640	16100	30600
05/10/91	12100	536	10700	22000
05/11/91	10300	435	7330	15900
05/12/91	8000	346	5380	11700
05/13/91	6250	274	4300	6620
Total load[1]	83340	8948	118510	199420
Percent[2]	41.8	4.5	59.4	100
Sediment yield[3]	54.5	10.5	107.0	56.3

[1] Load contributions from tributaries do not equal total load at the mouth of the Blue Earth River because of losses caused by deposition or gains from other sediment sources such as bank erosion and channel scour.
[2] Percent of total load at mouth of Blue Earth River.
[3] Yield in tons per square mile for runoff period.

Table 7.--Suspended-sediment loads and yields for water-quality sampling sites in the Redwood River Basin for the rainfall-runoff period June 17-20, 1992

	Suspended sediment load, in tons		
Date	Redwood River at County Road 30 near Seaforth	Judicial Ditch 5 at County Road 30 near Redwood Falls	Redwood River near Redwood Falls
06/17/92	3210	97	5950
06/18/92	1380	49	2240
06/19/92	818	17	1070
06/20/92	444	9.3	664
Total[1]	5852	172.3	9924
Yield[2]	9.52	19.5	15.8

[1] Total load for runoff period.
[2] Yield in tons per square mile for runoff period.

Table 8.--Map credits
[The projection for all maps is Albers Equal-Area Conic projection, standard parallels 44° 15′ and 48° 15′, central meridian -94°00′]

8a. Base credits

Figure	Map data	Source	Date	Scale
All	Boundaries of the Minnesota River Basin	U.S. Geological Survey digital data	1993	1:24,000
2, 3a-14b, 59	Subbasin boundaries	U.S. Geological Survey digital data	1993	1:24,000
All	Minnesota state boundary	U.S. Bureau of the Census, TIGER/Line Census Files	1990	1:100,000
3a-14a	Minnesota county boundaries	U.S. Bureau of the Census, TIGER/Line Census Files	1990	1:100,000
All	South Dakota, Iowa, and North Dakota county boundaries	U.S. Geological Survey maps		1:100,000
3a-14a	Roads	U.S. Geological Survey digital data	1983	1:100,000
1, 3b-14b	Rivers	U.S. Geological Survey digital data	1983	1:100,000

8b. Digital thematic data

Figure	Map data	Source
15	Bedrock hydrogeology	Land Information Management Center
16	Quaternary geology	Land Information Management Center
17	Quaternary hydrogeology	Land Information Management Center
18	Geomorphic regions	Land Information Management Center
19-30	Soil landscape units	Land Information Management Center
31-42	Wetlands	U.S. Fish and Wildlife Service
43	Average annual precipitation	Minnesota Department of Natural Resources
44	Average annual runoff	U.S. Geological Survey
45	Ecoregions	U.S. Geological Survey
46-57	Land use	Land Information Management Center
58	Population	U.S. Bureau of the Census
59	Non-point-source pollution potential	Minnesota Pollution Control Agency

REFERENCES CITED

Abramowitz, Molly, 1990, Census '90 Basics: U.S. Department of Commerce, Bureau of Census publication 1990 CPH-I-8, p. 5-7

Agricultural Experiment Station, 1973, Minnesota Soil Atlas, St. Paul Sheet: Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 120-1973, 57 p., 1 plate.

_____1979, Minnesota Soil Atlas, St. Cloud Sheet: Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 159-1979.

_____1981, Minnesota Soil Atlas, New Ulm Sheet: Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 162-1981.

Britton, L.J., and Greeson, P.E., eds., 1989, Methods for collection and analysis of aquatic biological and microbiological samples: Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 5, Chapter A4, 363 p.

Buchanan, T.J., and Somers, W.P., 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water Resources Investigations, Book 3, Chapter A8, 65 p.

Bureau of the Census, 1991, TIGER/Line Census Files, 1990 Technical Documentation: Bureau of the Census, 94 p.

Carter, V., Bedinger, M.S., Novitzki, R.P., and Wilen, W.O., 1979, Water resources and wetlands, *in* Greeson, P.E., Clark, J.R., and Clark, J.E., eds., Wetland functions and values--the state of our understanding, Proceedings of the National Symposium on Wetlands, November 1978, Minneapolis, Minnesota: American Water Resources Association, p. 344-376

Cowardin, L. M., Carter, Virginia, Golet, F. C., and LaRoe, E. T., 1979, Classification of Wetlands and Deepwater Habitats of the United States: U. S. Fish and Wildlife service; Biological services Program FWS/OBS-79/31, 103 p.

Edwards, T.K., and Glysson, G.D., 1988, U.S. Geological Survey Open-File Report 86-531, 118 p., 13 p., *in* Field measurement of fluvial sediment: Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 3, Chapter C2, 13 p. (in press).

Fandrei, G.S., Heiskary, S., and McCollor, S., 1983, Descriptive characteristics of the seven ecoregions in Minnesota: Minnesota Pollution Control Agency, Division of Waters, Program Development Section, 139 p.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water Resources Investigations, Book 5, Chapter A1, 545 p.

Gebert, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average annual runoff in the United States, 1951-80: U.S. Geological Survey Hydrologic Investigations Atlas H-710, scale 1:750,000, 1 plate.

Hobbs, H. C., and J. E. Goebel, 1982, Geologic map of Minnesota, Quaternary geology: Minnesota Geological Survey State Map series S-1, 1:500,000, 1 sheet.

Kanivetsky, R., 1979a, Bedrock map of Minnesota, bedrock hydrogeology, Minnesota Geological Survey State Map Series S-3, 1:500,000, 1 sheet.

_____1979b, Hydrogeologic map of Minnesota, Quaternary hydrogeology, Minnesota Geological Survey State Map Series S-2, scale 1:500,000, 2 sheets.

Land Management Information Center, 1989, Data documentation for 40-acre and 100-meter data for use with EPPL7 on IBM PCs, PS/2s, of compatibles: Minnesota State Planning Agency, 93 p.

Minnesota Pollution Control Agency, 1982, Minnesota River subbasin water quality, an assessment of non-point source pollution, St. Paul, Minnesota, 161 p.

_____1985, Lower Minnesota River wasteload allocation study, St. Paul, Minnesota, 190 p.

Omernick, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, vol. 77, p. 118-123, scale 1:7,500,000

Omernik, J.M., and Gallant, A.L., 1988, Ecoregions of the Upper Midwest states: U.S. Environmental Protection Agency, EPA/600/3-88/037, 56 p.

U.S. Fish and Wildlife Service, 1991a, National Wetlands Inventory--Wheaton N.W., Minnesota quadrangle: U.S. Fish and Wildlife Service National Wetlands Inventory, 1 map, scale 1:24,000.

U.S. Geological Survey, 1976, Hydrologic Unit Map - 1974, State of Minnesota: U.S. Geological Survey Hydrologic Unit Map--1974, 1 pl.

_____1986, National Water Summary 1985--Hydrologic events and surface-water resources: U.S. Geological Survey Water-Supply Paper 2300, 506 p.

_____1989, Digital line graphs from 1:100,000-scale maps: U.S. Geological Survey National Mapping Program Technical Instructions, Data Users Guide 2, 88 p.

Ward, J.R., and Harr, C.A., 1990, Methods for collection and processing of surface water and bed material samples for physical and chemical analysis: U.S. Geological Survey Open-File Report 90-140, 71 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1983, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Open-File Report 82-1004, 173 p.