WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN NORTH DAKOTA, FISCAL YEARS 1987 AND 1988

Compiled by Cathy R. Martin

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DEPARTMENT OF THE INTERIOR

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FOREWARD

The North Dakota District of the U.S. Geological Survey, Water Resources Division, has had a longstanding cooperative program with the State of North Dakota, local, and other Federal agencies. In cooperation with the North Dakota State Water Commission, the North Dakota Geological Survey, and the counties of the State, the U.S. Geological Survey participated in a cooperative program to develop a statewide inventory of ground-water resources. The last of the county ground-water reports, McKenzie County, has been published, thus ending a farsighted program to provide a reconnaissance-level data base (framework), which the North Dakota State Water Commission and the U.S. Geological Survey can continue to expand and which can be used to better manage the ground-water resources of North Dakota.

Having completed the county ground-water studies, the U.S. Geological Survey and the North Dakota State Water Commission have undertaken additional cooperative efforts to advance the knowledge of the hydrologic systems and processes within the State. Current projects include studies of the effect of frozen soils on recharge to the shallow aquifer systems and studies of the hydrology of the Devils Lake system.

The District is continuing a cooperative effort with the U.S. Bureau of Reclamation and the North Dakota State Water Commission to evaluate the viability of aquifer recharge near the town of Oakes. The Garrison Diversion Unit Commission has proposed aquifer recharge as an additional method for providing irrigation water supplies during peak irrigation periods. Other projects with the U.S. Bureau of Reclamation and the State are designed to provide information that will be of use in developing plans for water management consistent with the Garrison Diversion Unit Commission's recommendations.

The District also is moving forward in the development of Geographic Information Systems (GIS) application to hydrologic studies. One project to delineate drainage basins and to estimate contributing and noncontributing areas in a prairie pothole setting has been completed. Presently, an effort is underway to use GIS as a tool to analyze the availability and transport of certain chemical constituents from soils by irrigation water.

A joint research project also is in progress with the North Dakota State University to develop a laser spectroscopy unit for field use. The instrument would be very beneficial for *in-situ* water-quality screening in aquifer systems.

During the year, the District has continued the development of a statewide data-collection network with the support of various Federal, State, and local agencies. This network continues to provide the core of information necessary for management activities, flood forecasting, and interpretative studies.

L. Grady Moore

L. Grady Moore
District Chief

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[1/]The term "Fort Union Group" conforms to the usage of the North Dakota Geological Survey and does not conform to the usage of the U.S. Geological Survey.

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WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN NORTH DAKOTA, FISCAL YEARS 1987 AND 1988

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INTRODUCTION

The mission of the U.S. Geological Survey, Water Resources Division, is to provide the hydrologic information and understanding needed for the optimum utilization and management of the Nation's water resources for the overall benefit of the people of the United States. This report, which lists all ongoing water-resources projects in North Dakota in fiscal years 1987 and 1988, was prepared to accomplish a part of the Water Resources Division mission. Information on each project includes objectives, approach, progress in 1986 and 1987, plans for 1988, completed and planned report products, and the name of the project chief.

Origin of the U.S. Geological Survey

The U.S. Geological Survey was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific 'classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain.' An integral part of that original mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nation's energy, land, mineral, and water resources.

Since 1879, the research and factfinding role of the U.S. Geological Survey has grown and been modified to meet the changing needs of the Nation. As part of that evolution, the U.S. Geological Survey has become the Federal Government's largest earth-science research agency, the Nation's largest civilian mapmaking agency, the primary source of data on the Nation's surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs are designed to meet the needs of a diverse group of users. Programs include:

--Conducting detailed assessments of the energy and mineral potential of the Nation's land and offshore areas;
--Investigating and issuing warnings of earthquakes, volcanic eruptions, landslides, and other geologic and hydrologic hazards;
--Conducting research on the geologic structure of the Nation;
--Studying the geologic features, structure, processes, and history of the other planets of our solar system;
--Conducting topographic surveys of the Nation and preparing topographic and thematic maps and related cartographic products;
--Developing and producing digital cartographic data bases and products;
--Collecting data on a routine basis to determine the quantity, quality, and use of surface and ground water;

--Conducting water-resource appraisals in order to describe the consequences of alternative plans for developing land and water resources;
--Conducting research in hydraulics and hydrology and coordinating all Federal water-data acquisition;
--Using remotely sensed data to develop new cartographic, geologic, and hydrologic research techniques for natural resources planning and management;
--Providing earth-science information through an extensive publications program and a network of public access points.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the U.S. Geological Survey remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation--providing 'Earth Science in the Public Service.'

Mission of the Water Resources Division

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization and management of the Nation's water resources for the overall benefit of the people of the United States. This is accomplished, in large part, through cooperation with other Federal and non-Federal agencies, by:
--Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources;
--Conducting analytical and interpretative water-resource appraisals describing the occurrence, the availability, and the physical, chemical, and biological characteristics of surface and ground water;
--Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade;
--Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases;
--Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters;
--Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Power Commission, and to international agencies on behalf of the Department of State.

Sources of Information and Water Resources Division Publications

The U.S. Geological Survey, as part of its original mission, publishes and disseminates earth-science information needed to understand, plan the use of, and manage the Nation's energy, land, mineral, and water resources. This information is provided through a network of public access points and an extensive publications program. Information on U.S. Geological Survey programs may be obtained from the Public Inquiries Office, U.S. Geological Survey, 169 Federal Building, 1961 Stout Street, Denver, CO 80294, or from U.S. Geological Survey Circular 900, "A Guide to Obtaining Information from the U.S. Geological Survey."

National Water Data Exchange (NAWDEX) Program

The Water Data Sources Directory (WDSD) is a computerized data base developed and maintained by the National Water Data Exchange (NAWDEX) Program Office. The directory contains information about organizations that collect, store, and disseminate water data. This information includes the type of each organization; the major orientation of water-data activities conducted by each organization; the names, addresses, and telephone numbers of offices within each organization from which water data may be obtained; the types of data available from each organization and the geographic locations where these data have been collected; and alternate sources of an organization's data.

Water Data Storage and Retrieval (WATSTORE) System

The national Water Data Storage and Retrieval (WATSTORE) system is a large-scale computerized storage and retrieval system used by the U.S. Geological Survey to store and disseminate water data. The WATSTORE system has data-processing, storage, and retrieval capabilities as well as the capability of providing computer-printed tables and graphs, statistical analyses of data, and digital plots.

The WATSTORE system, which basically has remained unchanged for about 10 years, gradually is being replaced by a new water-data management system. The new system, when complete, will be called the National Water Information System (NWIS). A fundamental change from the WATSTORE system to the NWIS is to download water data from a central computer in Reston, Va., to minicomputers at district offices throughout the Nation. Data-management software is being enhanced to streamline data processing, allow for direct entry of data relayed via satellite, and permit processing of variable-interval data in addition to fixed-interval data. Results so far appear encouraging. Data management has become easier, and data can be processed more quickly than before. Improvements in timeliness of data availability are expected to occur in the near future as additional software is developed for the new system.

All of the surface-water streamflow and stage data were downloaded to the North Dakota District computer during 1984. All 1984 water year data processing for surface-water data was done on the District computer. A new Automatic Data Processing System (ADAPS) was installed on the North Dakota District computer in August 1987. Surface-water data collected during the 1987 water year will be prepared for publication using the ADAPS software.

In May 1985, all ground-water site information and water levels were downloaded from Reston. Water-quality data were downloaded to the District computer during 1986. Several utility programs, such as Log-Pearson Flood Frequency Analysis and Daily Values Duration, are scheduled to be available in the future.

Water-Data Program

Water-data stations at selected locations throughout the Nation are used by the U.S. Geological Survey to obtain records of stream discharge (flow) and stage (height), reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. These data provide a continuing record of the quantity and quality of the Nation's surface- and ground-water resources and thus provide the hydrologic information needed by Federal, State, and local agencies and the private sector for the development and management of land and water resources. All data collected are stored in the WATSTORE system and also are published, by water year, for each state in a publication series entitled "U.S. Geological Survey Water-Resources Data Reports" (see section "Water Resources Division Publications" for availability of these reports). Information about the water-data program can be obtained from the Assistant Chief Hydrologist for Operations or from the District Chief of the state of interest.

Water Resources Division Publications

Information on a wide variety of earth-science specialties is published in many forms, including the Federal book series and the map series. Book publications include a formal series of water-supply papers, professional papers, bulletins, circulars, techniques of water-resources investigations, and special reports and an informal series of water-resources investigations reports, open-file reports, and administrative reports. Map publications include a formal series of hydrologic investigations atlases and miscellaneous investigations maps and an informal series of water-resources investigations reports, open-file reports, and miscellaneous field studies maps.

Formal series book publications are sold by the U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 810, Box 25425, Denver, CO 80225; single copies of circulars still in print are available upon request from that address. Map publications pertaining to North Dakota are sold by the U.S. Geological Survey, Western Distribution Branch, Box 25286, Federal Center, Denver, CO 80225.

Water-resources investigations reports and open-file reports pertaining to North Dakota are available for inspection at the U.S. Geological Survey, Water Resources Division, 821 East Interstate Avenue, Bismarck, ND 58501; information on their availability also may be obtained from the District Chief at that address. In addition, those reports having an alpha-numeric designation in parentheses at the end of the citation may be purchased as paper copy or microfiche from the U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 810, Box 25425, Denver, CO 80225--the alpha-numeric designation is required when ordering from Books and Open-File Reports.

The series of reports entitled "Water-Resources Data for (State) for (Year)," describing surface water, ground water, and water quality in each state, may be purchased from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, but can be inspected in U.S. Geological Survey libraries and in Water Resources Division district offices in the region of the report.

New reports are announced monthly in "New Publications of the Geological Survey," subscriptions to which are available upon request from the U.S. Geological Survey, 582 National Center, Reston, VA 22092. Information on North Dakota District publications for 1985, 1986, and 1987 is given in supplement 1.

NORTH DAKOTA DISTRICT

The North Dakota District is 1 of 42 districts of the U.S. Geological Survey, Water Resources Division. The District, which is defined by the State boundaries, has offices in Bismarck, Dickinson, and Grand Forks (table 1). District organization is shown in figure 1.

Funding

Funds to support water-resources activities of the North Dakota District are derived from three principal sources:

(1) Federal Program--Funds are appropriated by Congress and are specifically identified. In fiscal year 1987, Federal funding for North Dakota District program activities was $447,050. In fiscal year 1988, Federal funding for North Dakota District program activities is $222,365.

(2) Federal-State Cooperative Program--Federal funds are appropriated by Congress and used to match those furnished by State and other tax-supported agencies on a 50-50 basis. These funds are used for a variety of hydrologic data-collection activities and water-resources investigations in which the U.S. Geological Survey represents the national interest and the cooperating agencies represent State and local interests. In fiscal year 1987, Federal-State Cooperative funding for the North Dakota District was $1,299,080. In fiscal year 1988, Federal-State Cooperative funding for the North Dakota District is $1,174,820.

(3) Other Federal Agencies (OFA) Program--Funds are transferred to the U.S. Geological Survey as reimbursement for work performed at the request of another Federal agency. In fiscal year 1987, OFA funding was $1,144,810. In fiscal year 1988, OFA funding is $1,059,825.

The total budget for fiscal year 1987 was $2,890,940. The percentage of funding from each principal source is shown in figure 2. The total budget for fiscal year 1988 is $2,457,010. The percentage of funding from each principal source is shown in figure 3. Agencies cooperating in water-resources investigations during fiscal years 1987 and 1988 are given in table 2.

The broad categories of investigations are research projects, areal appraisals and interpretative studies, collection of hydrologic data, and administrative projects. The percentage of investigations for each category for fiscal year 1987 is shown in figure 4. The percentage for each category for fiscal year 1988 is shown in figure 5.

Summary of Major Water Problems

Water is a subject of major concern to the State of North Dakota. Testimonial to this is the fact that the North Dakota State Water Commission, the chief State water agency, has been one of the largest State agencies over the years and has continued to receive funding from the State Legislature for water-resources investigations. The North Dakota State Water Commission has regulatory authority over all water use within the State and carries out a program of water-related activities with Federal, other State, and local agencies.

Table 1.--*North Dakota District offices*

Office	Telephone number	Address
District office	(701) 250-4601 FTS 783-4601	U.S. Geological Survey 821 East Interstate Avenue Bismarck, ND 58501
Dickinson field headquarters	(701) 225-2051 FTS 783-5771, ask for 225-2051	U.S. Geological Survey Water Resources Division 669 12th Street SW Dickinson, ND 58601
Grand Forks field headquarters	(701) 775-7221 FTS 783-0325	U.S. Geological Survey Water Resources Division P.O. Box 1437 Grand Forks, ND 58206-1437

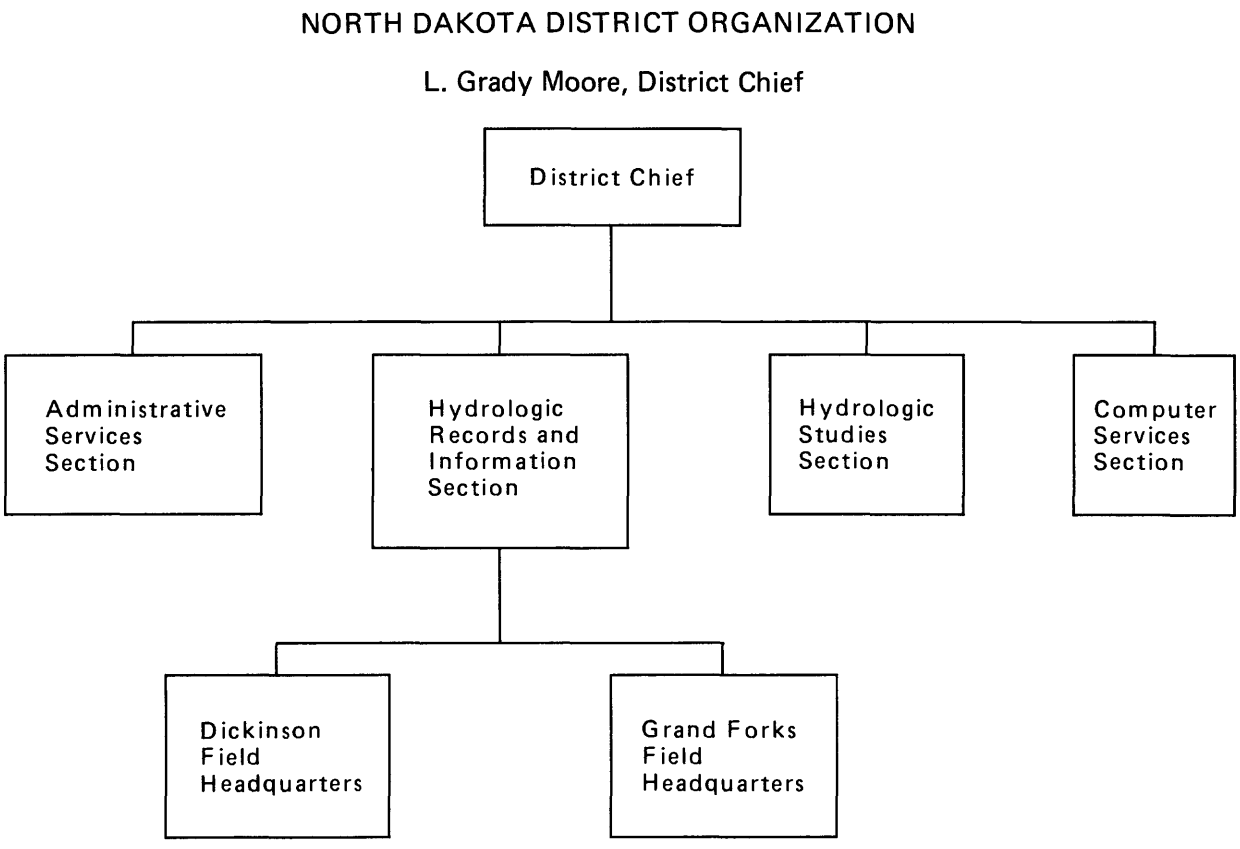


Figure 1.—North Dakota District organizational structure.

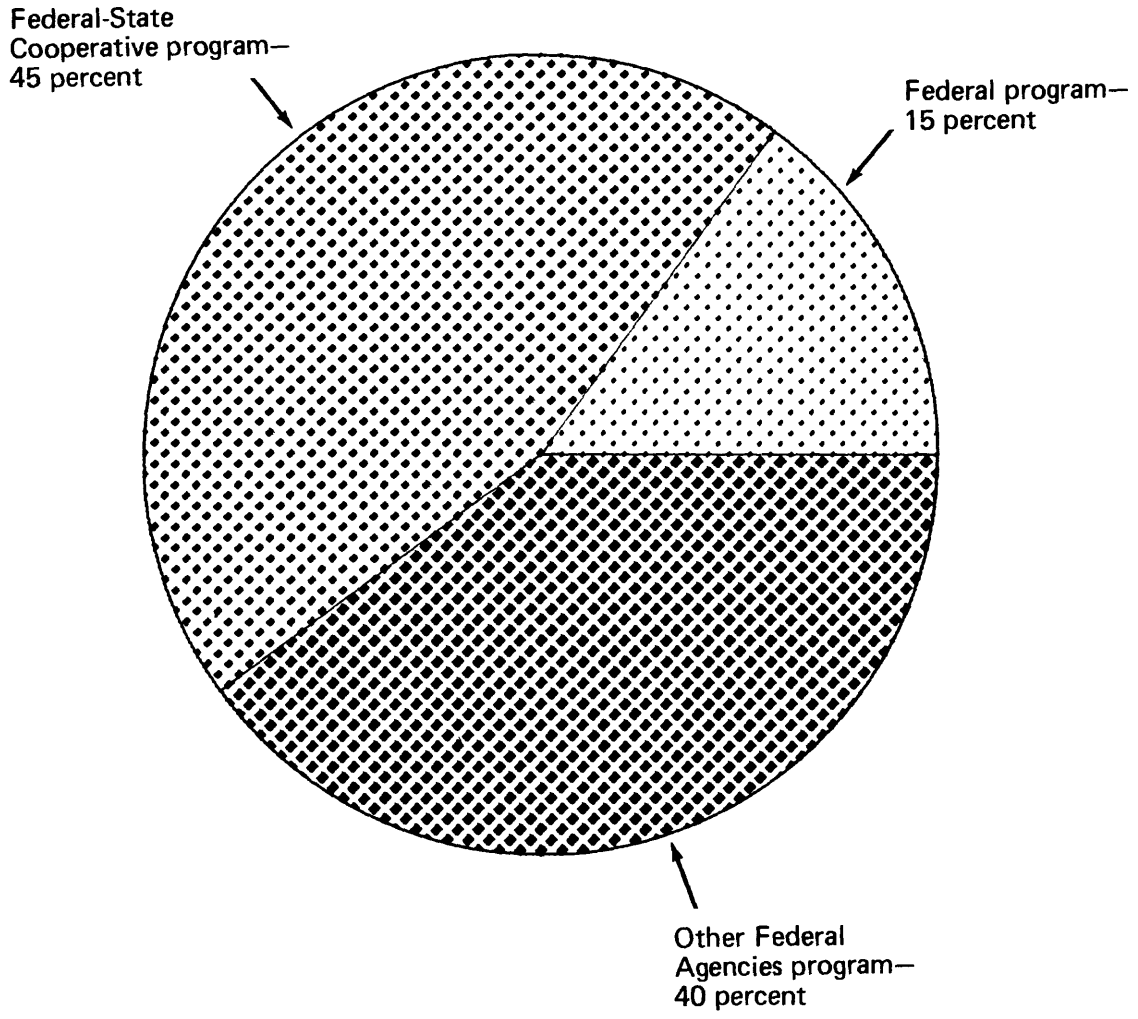


Figure 2.—Percentage of funding from principal sources for fiscal year 1987.

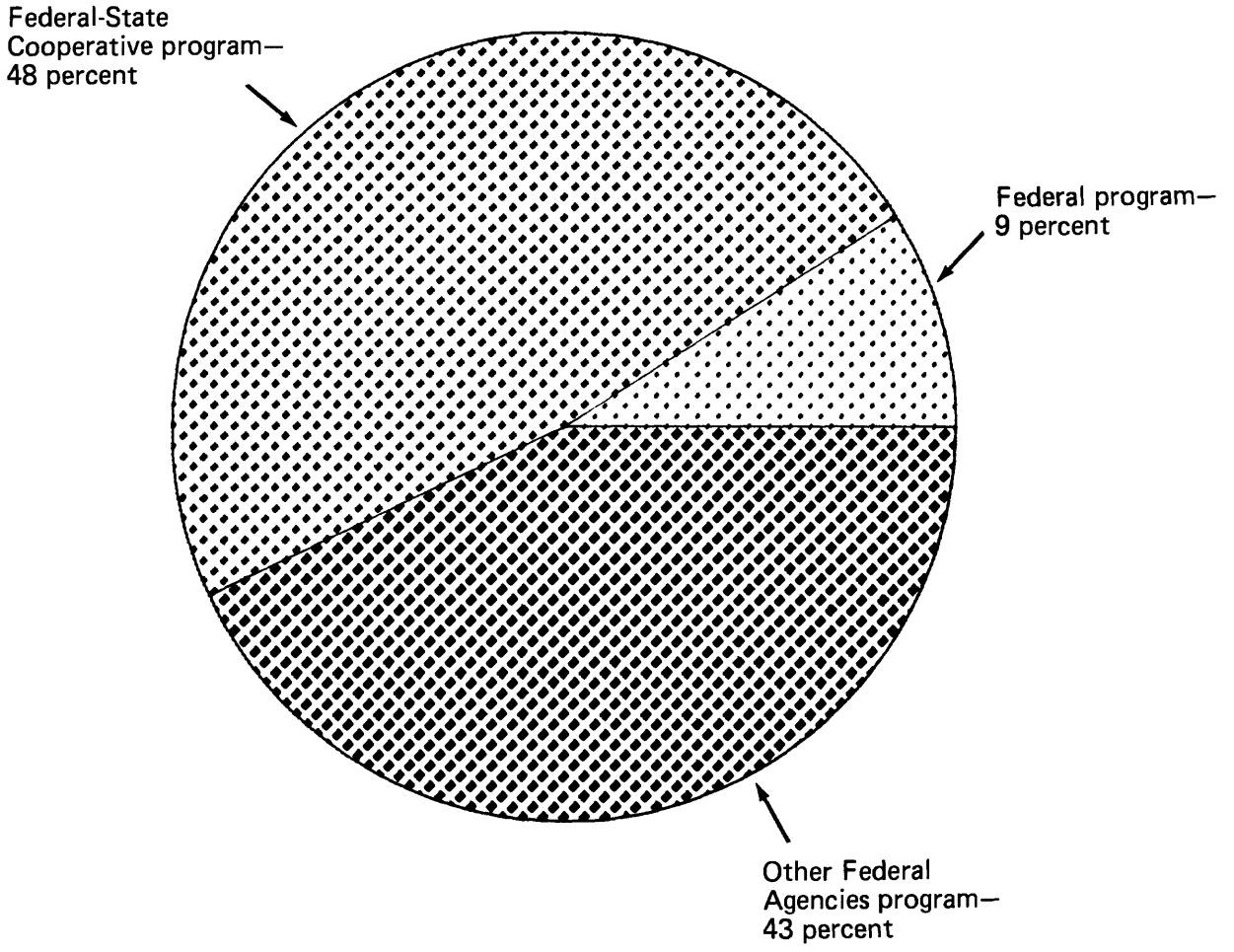


Figure 3.—Percentage of funding from principal sources for fiscal year 1988.

Table 2.--*Cooperating agencies*

Federal agencies
U.S. Department of Agriculture
Soil Conservation Service
U.S. Department of the Army
Corps of Engineers
St. Paul District
Omaha District
U.S. Department of the Interior
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Fish and Wildlife Service
Geological Survey
Geologic Division
National Mapping Division
U.S. Department of State
International Joint Commission
Waterways Treaty
U.S. Environmental Protection Agency
State agencies
North Dakota Geological Survey
North Dakota Public Service Commission
North Dakota State Department of Health
North Dakota State Highway Department
North Dakota State University
North Dakota State Water Commission
Local agencies
City of Dickinson
Lower Heart Water Resource District
Oliver County Board of Commissioners

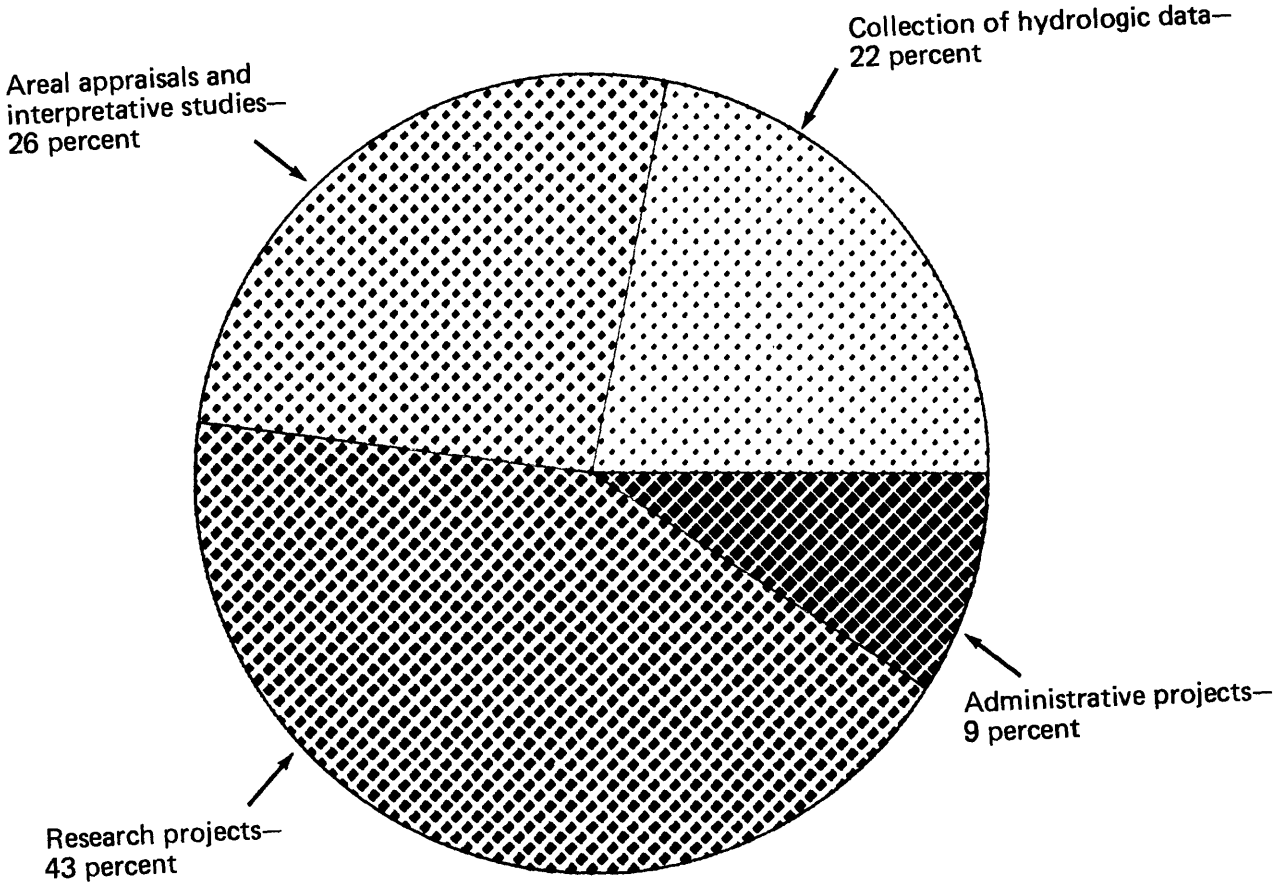


Figure 4.—Percentage of investigations for fiscal year 1987.

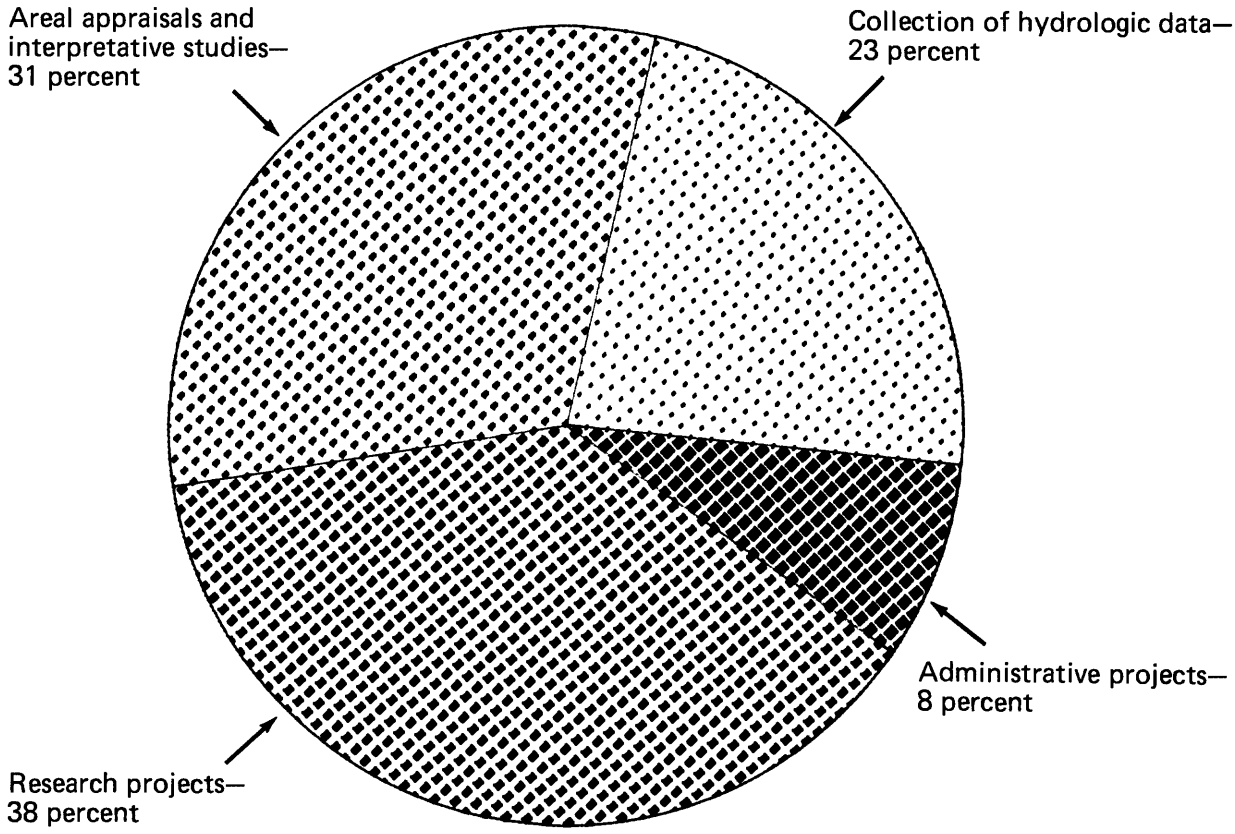


Figure 5.—Percentage of investigations for fiscal year 1988.

Water problems are mostly related to natural conditions of geology and climate but are socioeconomic as well. They are discussed herein under the broad headings of quantity and quality.

Quantity

Average annual precipitation ranges from 14 inches in the northwestern part of the State to about 21 inches in the southeastern part. The areal distribution of average annual precipitation based on data for 1951-80 is shown in figure 6. Precipitation in North Dakota is erratic. No regular cyclic pattern has been demonstrated, but periods of water surplus or water deficiency generally extend over several years.

Two major river systems, the Missouri River system and the Hudson Bay system, drain North Dakota. The Missouri River system includes the Missouri River drainage basin and the James River drainage basin. The Hudson Bay system includes the Souris River drainage basin, the Red River of the North drainage basin, and the noncontributing Devils Lake drainage basin. These five major drainage basins are shown in figure 7. Runoff is extremely variable, seasonally and annually as well as areally. A large part of runoff occurs in the spring as a result of snowmelt. All major rivers in the State are subject to flooding; but for some rivers, such as the Missouri, the risks are low because their flows are regulated by dams.

The Red River of the North valley is particularly vulnerable to flooding because of extremely flat topography and small channel capacity. Since 1950, 10 serious floods have occurred along the main stem of the Red River of the North in North Dakota and Minnesota. The Souris River, which enters northwestern North Dakota from Canada and eventually flows back into Canada from North Dakota, also is flood prone. Since 1950, seven serious floods have occurred along the main stem of the Souris River.

Studies indicate that the natural tendencies toward flooding in the Red River of the North valley and along the Souris River are being affected by man's activities. However, these effects are very difficult to quantify because of insufficient long-range records. Large tracts of formerly noncontributing wetlands in the Red River of the North valley, both in North Dakota and Minnesota, have been drained for agricultural purposes. Drainage of the wetlands has added to the area that contributes runoff to the Red River of the North. Also, a large number of individual dike systems have been built for flood protection. These systems tend to aggravate flood conditions in that they locally cause higher-than-normal flood crests.

Wetland drainage affects water resources in other ways. Wetlands constitute valuable habitat for waterfowl and other wildlife. North Dakota normally produces more waterfowl than any other state in the contiguous United States. Some of the deeper lakes are used for stock-watering purposes, particularly in the Coteau du Missouri, a physiographic division of North Dakota. Also, wetlands may be important sources of ground-water recharge. To date, little quantitative work has been done in North Dakota to quantify areas of ground-water recharge. During the 1985 fiscal year, however, a cooperative project with the North Dakota State Water Commission was begun to address snowmelt recharge to shallow aquifers.

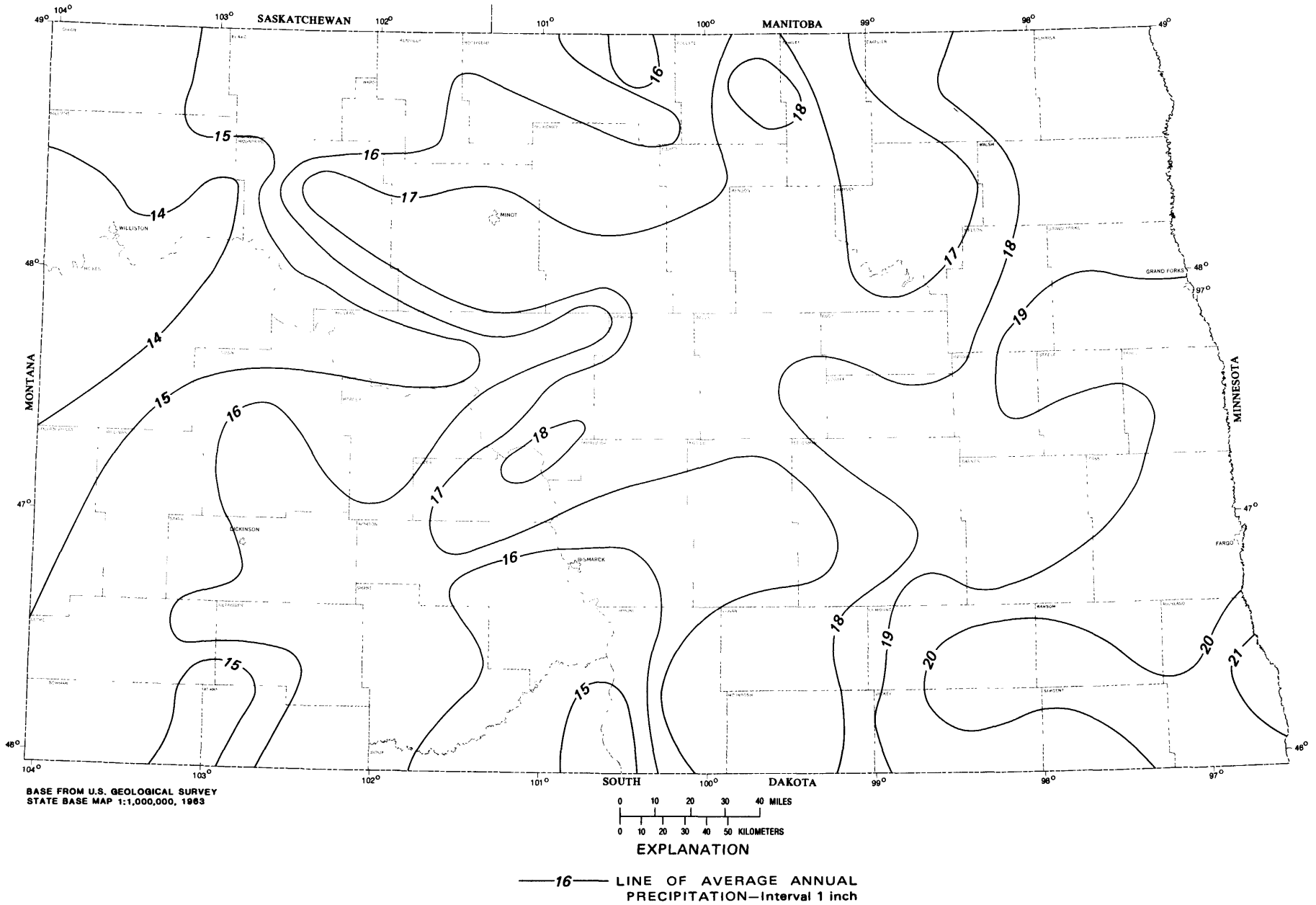


Figure 6.—Average annual precipitation (1951-80), in inches. (John W. Enz, North Dakota State University, written commun., 1984).

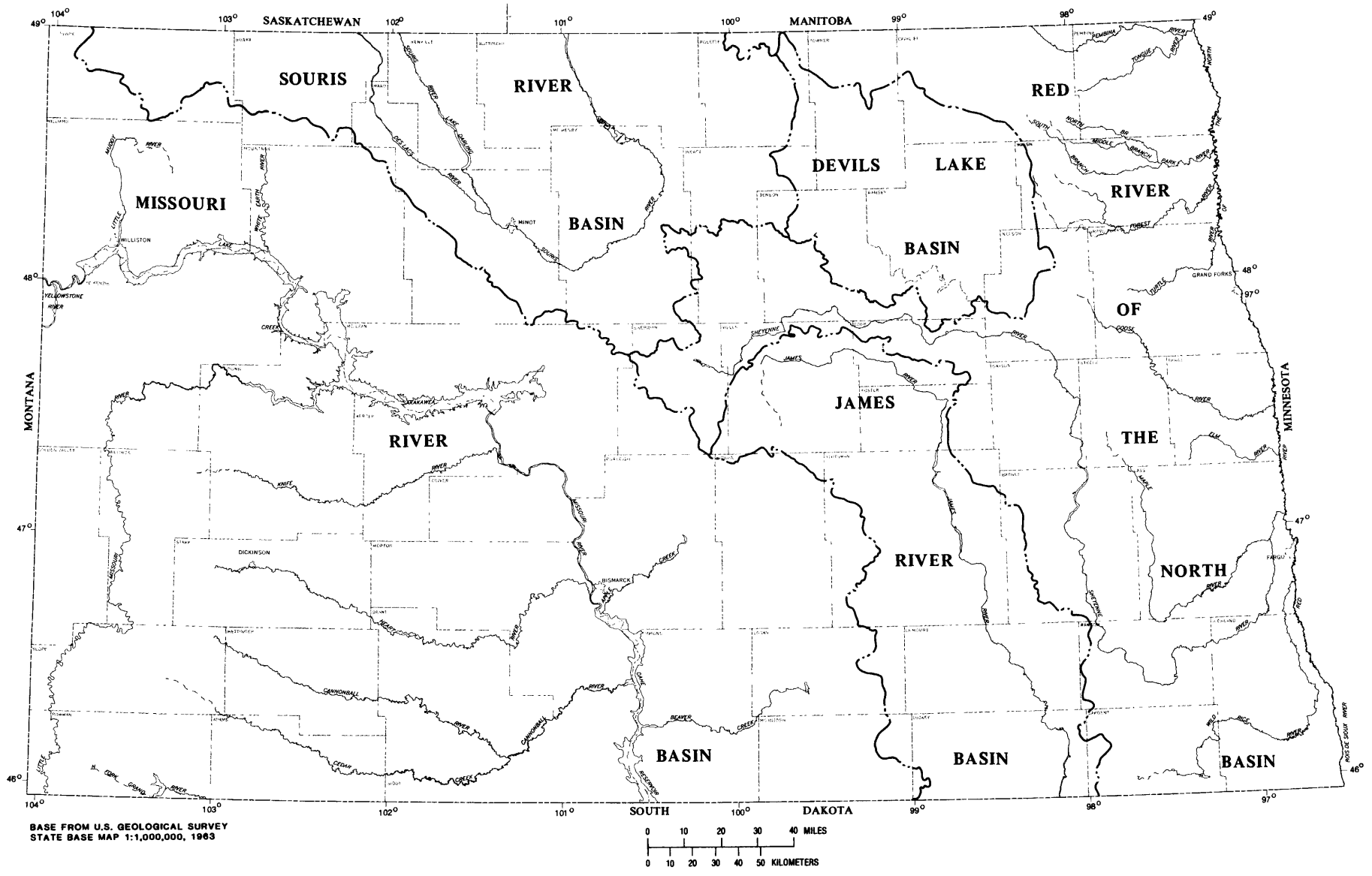


Figure 7.—Locations of major drainage basins of North Dakota.

Generally, the first problems that arise during periods of water deficiency are associated with inadequate streamflow. Municipalities dependent on surface-water sources for public-water supply may have to curtail water use. Ironically, these municipalities may include cities that were damaged by flood waters only a few years earlier. Such has been the case with the city of Fargo on the Red River of the North and the city of Minot on the Souris River. Irrigators may be forced to reduce their irrigated acreages and reallocate part of their resources into dryland farming. This reduction, in turn, may affect cattle-feeder operations, beef prices, etc.

Fish and wildlife resources are severely impacted during prolonged periods of water deficiency. Severely depleted streams and lakes result in fish kills, some to the point where complete restocking is necessary. Wetlands dry up during these periods, greatly reducing the production of waterfowl and other wildlife that use the wetlands for habitat.

Water levels in shallow aquifers, most of which occur in glacial deposits (fig. 8), decline during periods of water deficiency because evapotranspiration losses and other discharges exceed recharge. Also, as surface-water sources are depleted, more dependency is placed on ground water, and withdrawals increase. Irrigation, which in North Dakota is supplemental to rainfall, increases during periods of water deficiency, placing added stresses on aquifers. In the case of shallow aquifers, the additional water pumped may be salvage derived after evapotranspiration losses. However, water from deeper, confined aquifers is pumped from storage that is not replaced within a comparable timeframe. Future ground-water studies in the State will need to focus on both types of ground-water occurrence. Information is needed on rates of withdrawal from, and rates of recharge to, shallow aquifers as well as sources and rates of recharge (such as leakage from confining beds) to the deeper aquifers.

Quality

High salinity, particularly in the western part of North Dakota, is the most serious water-quality problem in the State. Except for the Missouri River and its reservoirs, salinity of both surface- and ground-water sources in western North Dakota commonly exceeds 1,000 mg/L (fig. 9) and at times and in places exceeds 2,000 mg/L. Salinity of the Missouri River and its reservoirs generally is near 500 mg/L. High salinity limits use of the water resources in the western part of the State. Generally, salinity and sodium hazards limit or prohibit use of the water for irrigation. Also, high salinity as well as high concentrations of certain chemical constituents (fig. 10) limit the desirability of the water for domestic use.

Expanded energy development poses a potential threat to water quality in western North Dakota. Leachates from lignite mine spoil piles are several times as saline as water in the undisturbed environment. In addition, because the lignite has a high water content, it cannot economically be hauled great distances for commercial use. Consequently, it usually is utilized (burned) within the State. Preliminary studies indicate the ash contains significant quantities of hazardous materials such as arsenic, molybdenum, selenium, and phenols that under certain conditions could be released into the environment.

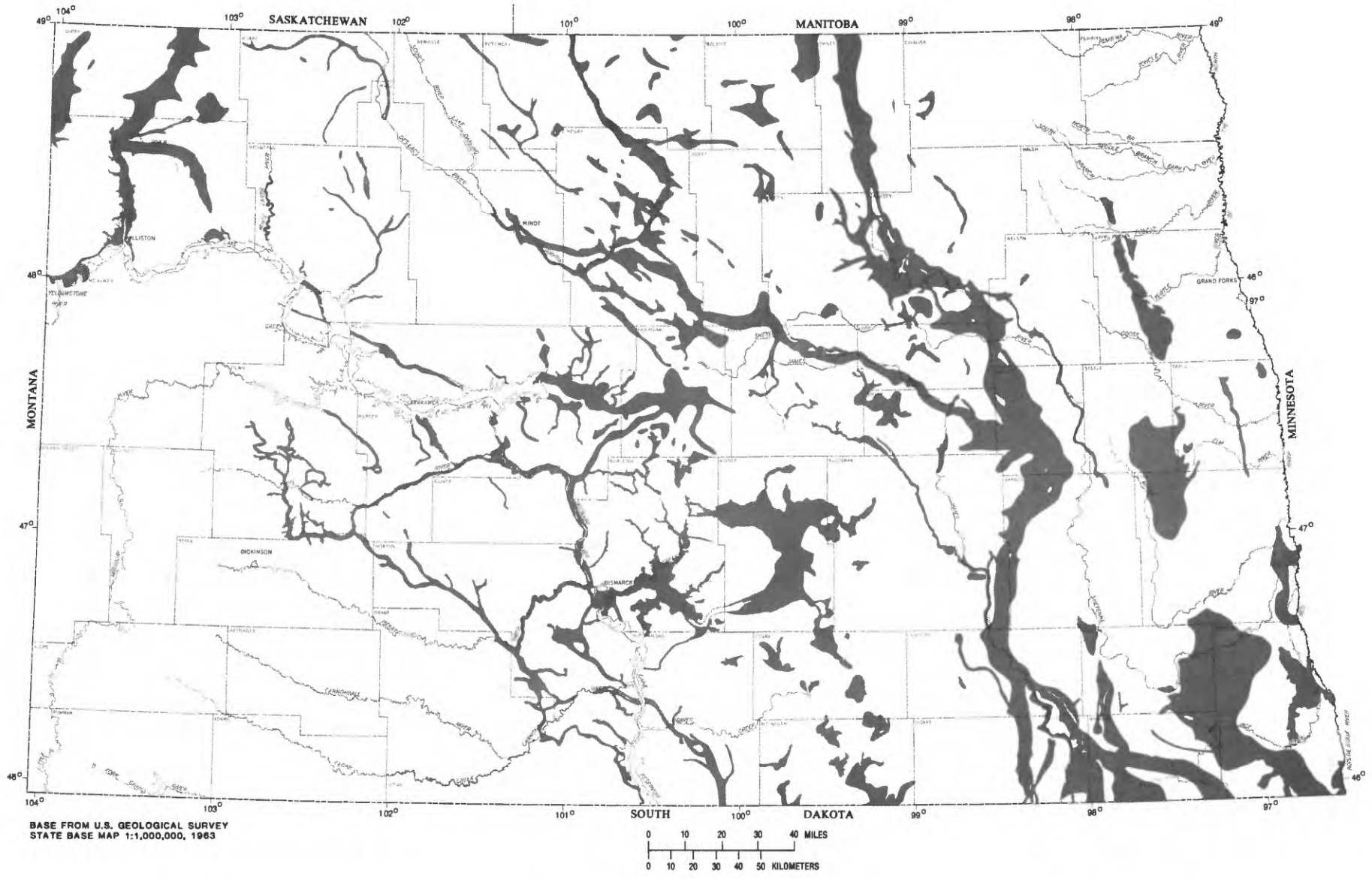


Figure 8.—Locations of major glacial-drift aquifers. (Modified from North Dakota State Water Commission, 1982. Map showing glacial-drift aquifers in North Dakota and estimated potential yields. North Dakota State Water Commission, scale 1:500,000, 1 sheet).

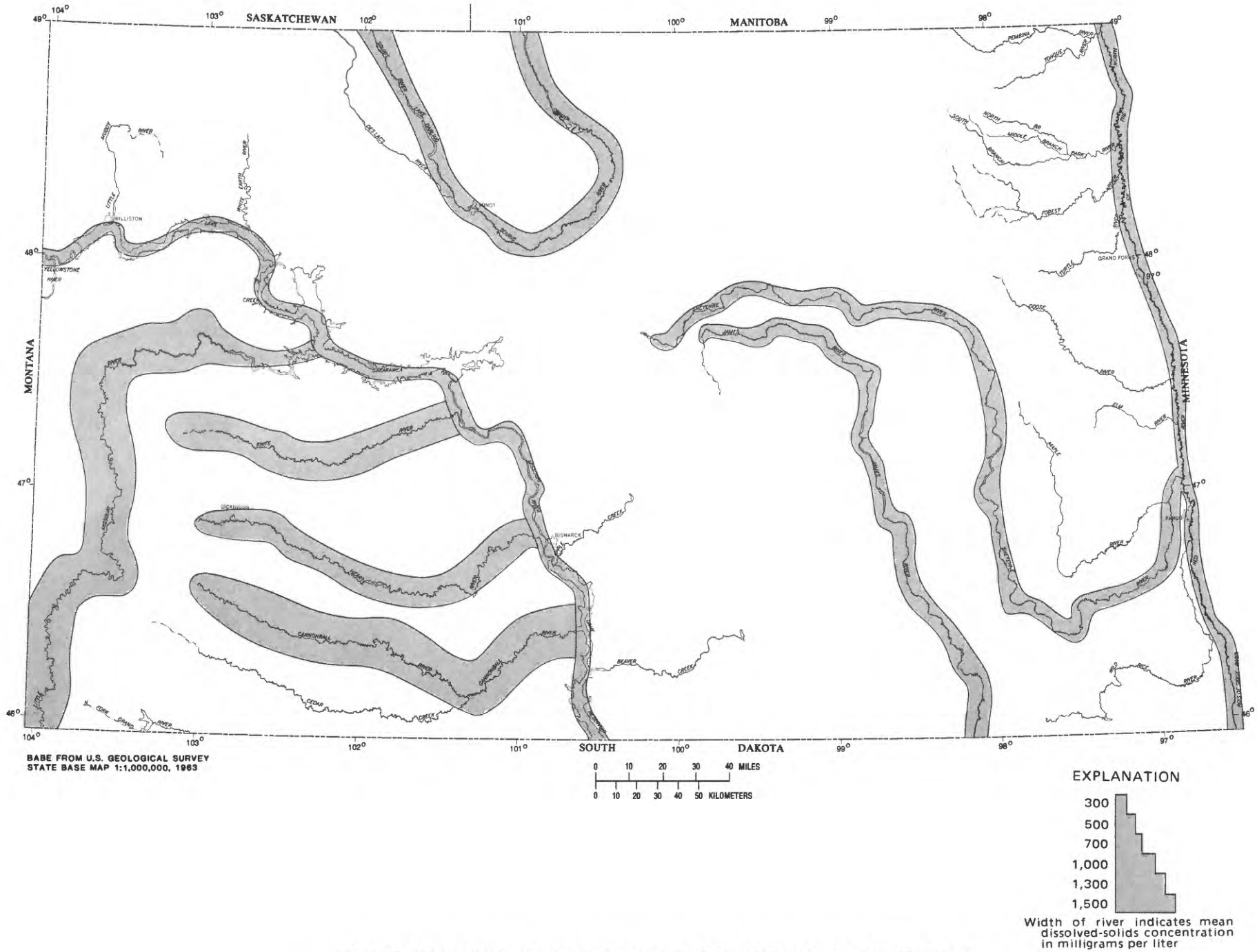


Figure 9.—Mean dissolved-solids concentration of the principal rivers of North Dakota.

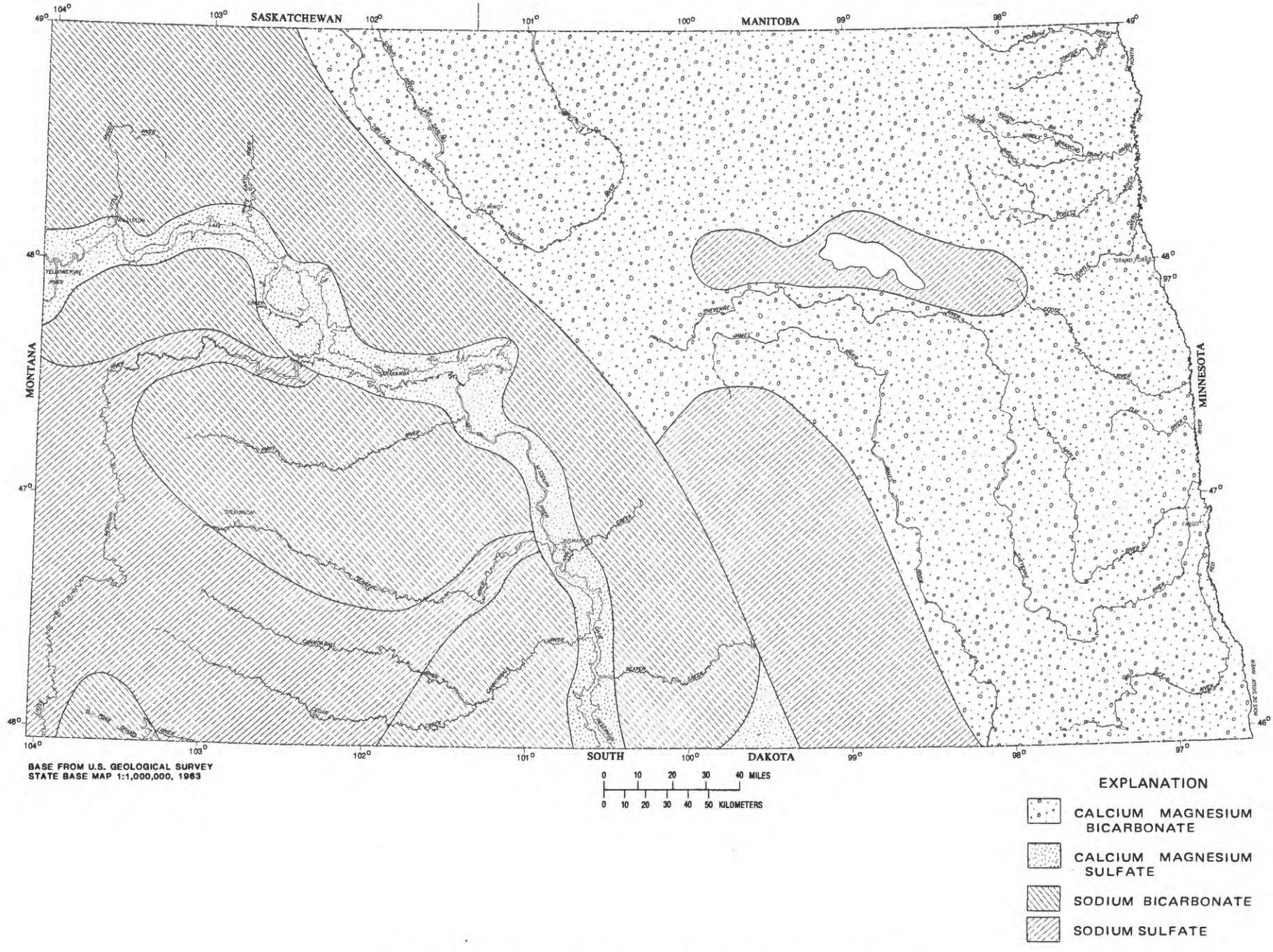


Figure 10.—Prevalent principal dissolved constituents in surface waters.

Certain lignite deposits in western North Dakota contain uranium in contents as great as 2.5 percent. During the 1950's and 1960's, a process was developed for further concentrating the uranium through *in situ* burning. Although mining is no longer active, there are at least nine unreclaimed uranium mines, ranging in size from 40 to 200 acres, that the U.S. Environmental Protection Agency has designated potential hazardous-waste sites. Few hydrologic data are available for these sites, and additional work is being undertaken to determine the consequences on the hydrologic system in the area, if any, due to the mining and processing activities.

Extensive oil and gas exploration and extraction have continued in North Dakota since the first oil discovery in 1951. There are two principal consequences of these activities on the hydrologic system: (1) Air emissions of acid-forming sulfur compounds due to flaring of gas and leakage of sour gas from oil wells and (2) underground migration of salts and hazardous wastes from drilling-mud pits and brine-disposal pits. The practice of brine disposal in pits has been discontinued since 1972 when legislation was put into effect requiring underground injection to deep-lying formations. Some work has been done by State agencies to investigate the extent of these consequences, including at least two projects conducted by the North Dakota Water Resources Research Institute. These studies will add to the knowledge of the consequences on the hydrologic system due to oil and gas exploration and extraction.

Another byproduct of expanded energy development may be acid rain and other deteriorations of precipitation quality. Since 1980, precipitation in the State has been characterized by mean annual volume-weighted pH values less than 4.8 and by elevated concentrations of mercury, selenium, and molybdenum relative to regional soils. Most of the State is characterized by calcareous soils and alkaline waters that offer some buffering protection against acidification. However, wetlands situated on noncalcareous glacial till in the Coteau du Missouri and Turtle Mountains may be vulnerable to acidification. Monitoring of water quality in potholes in both areas suggests enrichment from snowmelt in trace metals such as mercury, selenium, and molybdenum and a slight lowering in pH of about 0.7 to 1.6 units. Examination of available data indicates that precipitation acidity may increase (1) surface-water alkalinity and (2) nutrient loading due to increased dissolution of carbonate minerals and nutrients in bottom materials. These increases can accelerate eutrophication of some small lakes.

DATA-COLLECTION PROGRAM

The U.S. Geological Survey continually records stage, discharge, quality of water, sediment concentrations, and ground-water levels at selected sites throughout North Dakota. Some of the sites are operated on a long-term basis to sample trends in the gross water supply. Others are operated for short periods of time for correlation with long-term sites to extend areal coverage or for specific investigations. This information is published annually in water-data reports and stored in computer files for retrieval and processing.

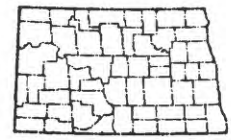
Surface-Water Stations

PROJECT NUMBER: ND 00-001.

LOCATION: Statewide.

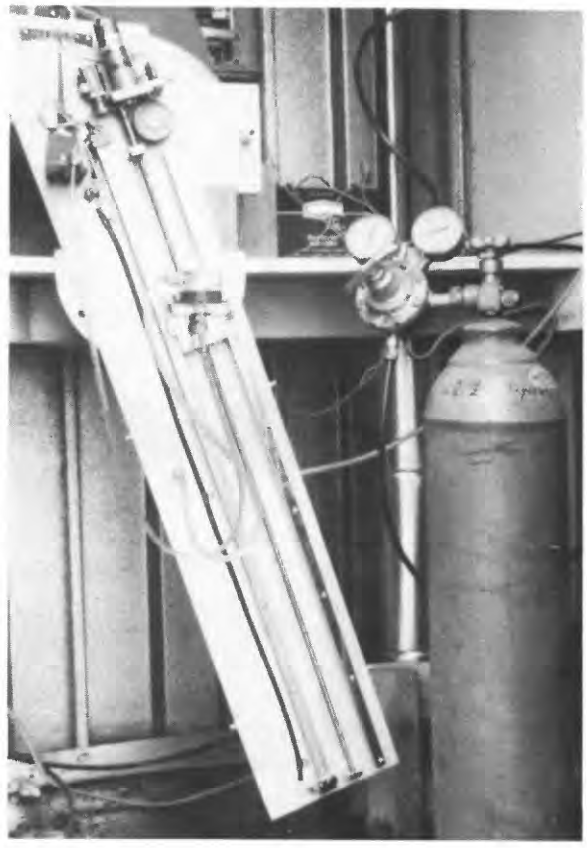
PERIOD OF PROJECT: Continuous.

PROJECT CHIEF: Russell E. Harkness.



STATEWIDE

COOPERATING AGENCIES: (1) City of Dickinson; (2) Lower Heart Water Resource District; (3) North Dakota Public Service Commission; (4) North Dakota State Water Commission; (5) Oliver County Board of Commissioners; (6) U.S. Department of Agriculture, Soil Conservation Service; (7) U.S. Department of the Army, Corps of Engineers; (8) U.S. Department of the Interior, Bureau of Reclamation; (9) U.S. Department of the Interior, Fish and Wildlife Service; (10) U.S. Department of State, International Joint Commission, Waterways Treaty; and (11) other Federal agencies of the U.S. Department of the Interior for the development of the Missouri River basin.



MANOMETER USED FOR COLLECTING SURFACE-WATER DATA

PROBLEM: Operation of existing water projects and planning future works requires the availability of accurate and unbiased streamflow and water-level data. The information must be available in a timely manner in order to assure efficient and effective operation of existing projects. The data also must be available over a wide range of space and time in order to provide statistically accurate projections used for planning.

OBJECTIVES: Objectives are (1) to collect surface-water data needed for assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and pollution controls, discharge data to accompany water-quality measurements, compact and legal requirements, and research or special studies and (2) to collect data necessary for analytical studies at specific locations to define statistical distributions of, and trends in, the occurrence of water in streams, lakes, etc., for use in planning and design.

APPROACH: Standard methods of data collection will be used as described in the U.S. Geological Survey techniques of water-resources investigations report series. Partial-record gaging will be used instead of complete-record gaging where it serves the required purpose. Discharge and stage data will be obtained for the stations shown in figures 11 and 12. A station-classification summary is given in table 3.

PROGRESS IN 1986 AND 1987: All network data were collected on schedule. The 1986 water year data were prepared for publication and sent to the Government Printing Office in mid-April 1987, 4 months earlier than the previous year.

One new continuous-record and four seasonal discharge stations were started for the 1986 water year. During the 1987 water year, one continuous-record discharge station and five short-duration project stations were installed. At the end of the 1986 water year, three discharge stations were discontinued, two seasonal discharge stations were downgraded to crest-stage gages, one lake station was discontinued, and one lake gage was turned over to another agency.

PLANS FOR 1988: One new continuous streamflow station and two seasonal streamflow stations will be installed. Repair or removal of cableways that are no longer used or that are unsafe will continue. Three to four artificial controls will be installed at gaging stations.

REPORT PRODUCTS: U.S. Geological Survey, 1986, Water-resources data, North Dakota, Water year 1985: U.S. Geological Survey Water-Data Report ND-85-1, 368 p.

U.S. Geological Survey, 1987, Water-resources data, North Dakota, Water year 1986: U.S. Geological Survey Water-Data Report ND-86-1, 388 p.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1987 (planned).

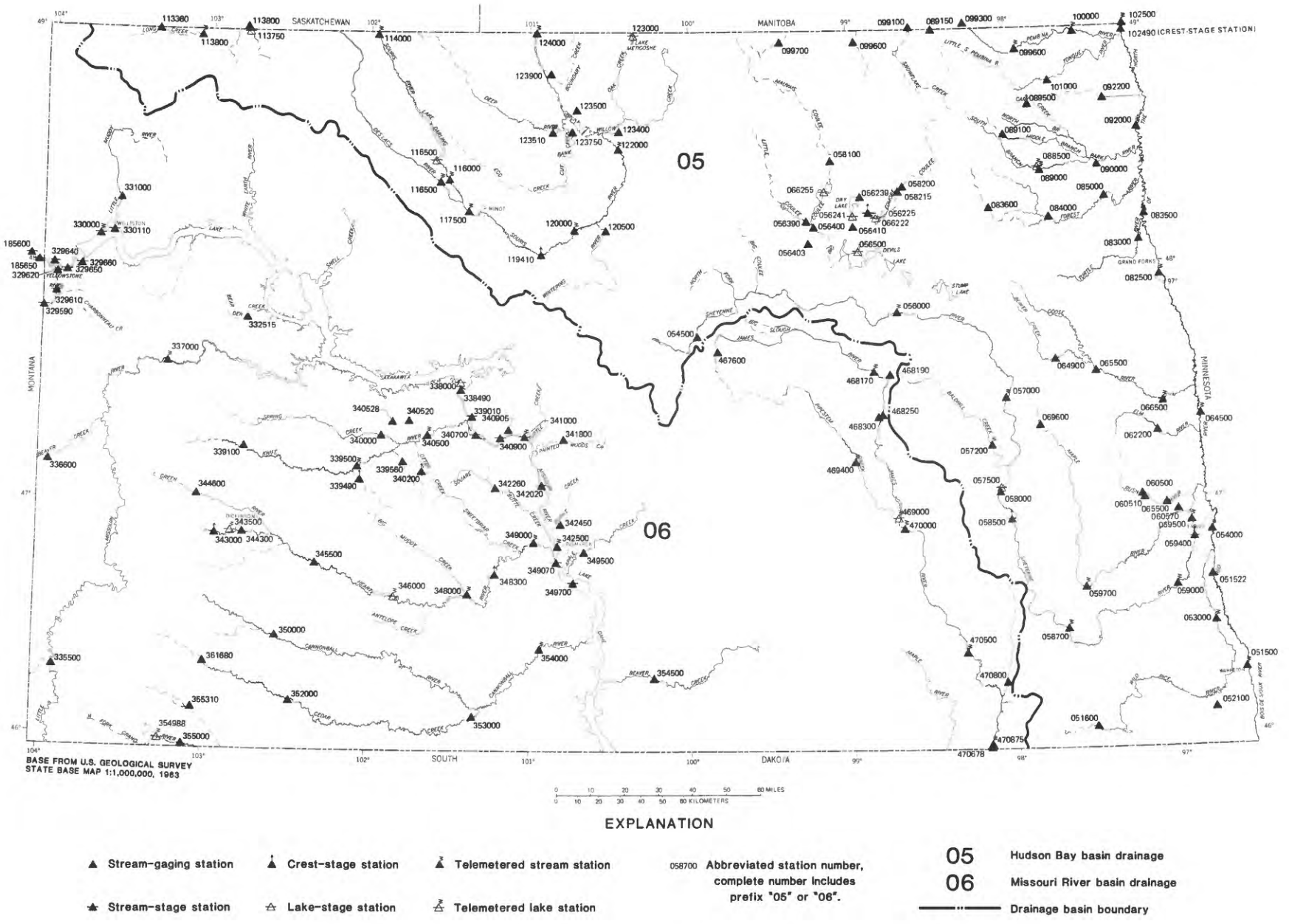


Figure 11.—Locations of lake, crest-stage, and stream-gaging stations in 1986.

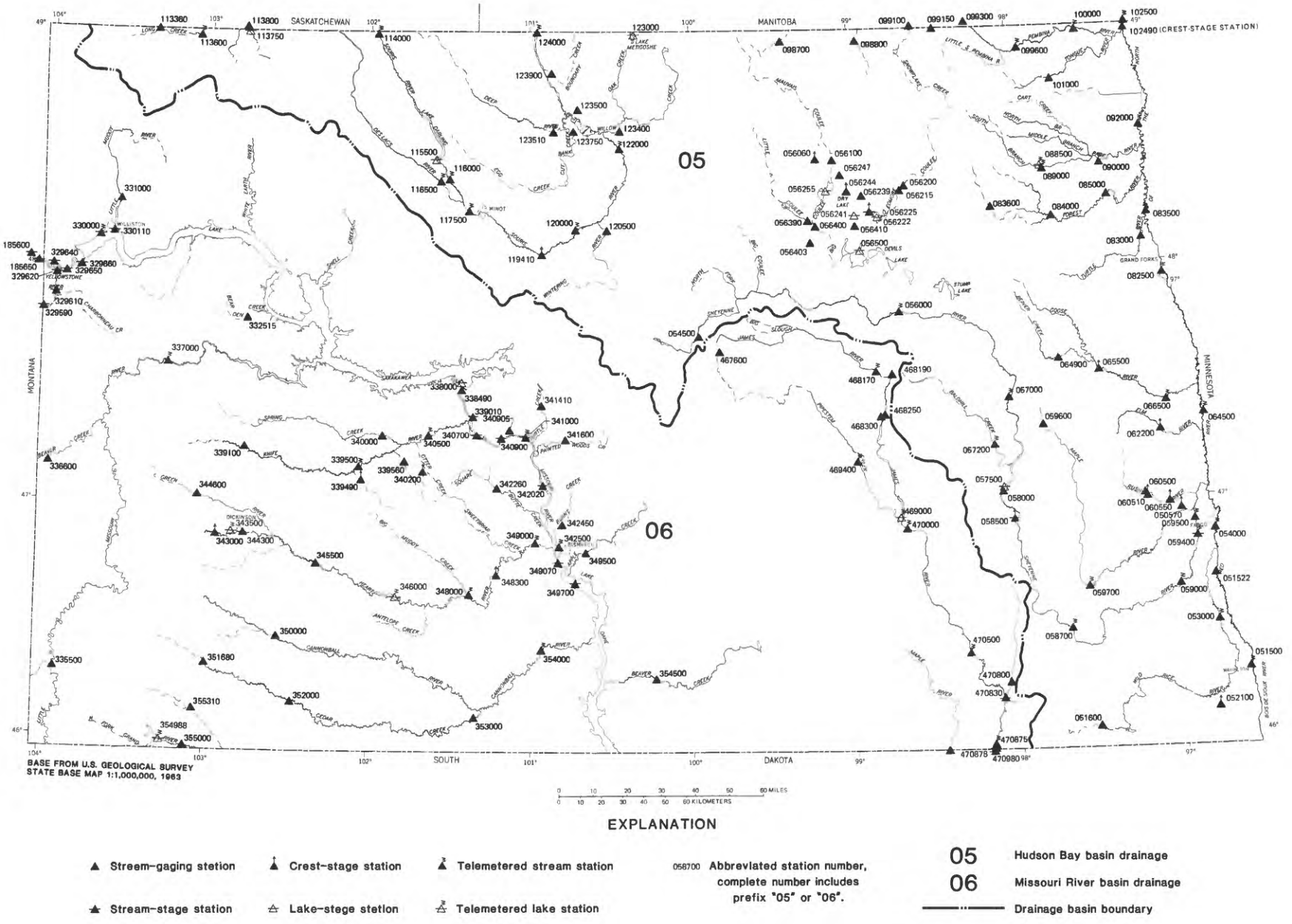


Figure 12.—Locations of lake, crest-stage, and stream-gaging stations in 1987.

Table 3.--*Station-classification summary*

Station classification		Number of stations
Stream stations		147
Continuous record:		
Discharge and stage	84	
Stage only	13	
Stage and peak flow	3	
Partial record:		
Discharge (seasonal)	24	
Stage only (seasonal)	8	
Peak (maximum) flow only	15	
Lake and reservoir stations		13
Stage and contents	10	
Stage only	3	
Total		160

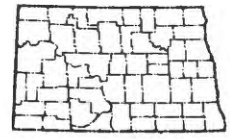
Ground-Water Stations

PROJECT NUMBER: ND 00-002.

LOCATION: Statewide.

PERIOD OF PROJECT: Continuous.

PROJECT CHIEF: Russell E. Harkness.



STATEWIDE

COOPERATING AGENCIES: (1) North Dakota Public Service Commission; (2) North Dakota State Water Commission; and (3) U.S. Department of the Army, Corps of Engineers.

COLLECTING WATER-LEVEL DATA

PROBLEM: Planning for management and development of ground-water resources requires extensive knowledge of the occurrence and availability of ground water and use of and impacts on the ground-water system.

OBJECTIVES: Objectives are twofold. The first is to collect water-level data sufficient to provide a minimum long-term data base. The data base is used for continued observation of the impacts of climatic variation and man's activities on the ground-water system. A statewide data base is essential for efficient resource management. The second objective is to provide a data base against which the short-term records acquired in areal studies can be analyzed.

APPROACH: Evaluation of regional geology allows a general definition of aquifer systems and their boundary conditions. Within this framework and with some knowledge of (1) changes in the ground-water system in time and space and (2) the hydrologic properties of the aquifers, subjective decisions can be made in upgrading the statewide ground-water observation-well network. A network of wells has been established and currently consists of 383 wells that are measured quarterly or more frequently and 433 wells that are measured annually. This network can be refined as data become available and detailed areal studies of the ground-water system better define the aquifers, their properties, and the stresses to which they are subjected.

PROGRESS IN 1986 AND 1987: All network data were collected on schedule. The data were tabulated and stored in District files and in the WATSTORE system. Only the data from a basic network of wells (figs. 13 and 14) were published.

PLANS FOR 1988: Plans are to continue to operate the observation-well network.

REPORT PRODUCTS: U.S. Geological Survey, 1977, Ground-water levels in the United States, 1972-74, north-central states: U.S. Geological Survey Water-Supply Paper 2163, p. 57-61.

Ground-water data for the basic network have been and will continue to be published in the annual report series, "U.S. Geological Survey, Water-resources data, North Dakota."

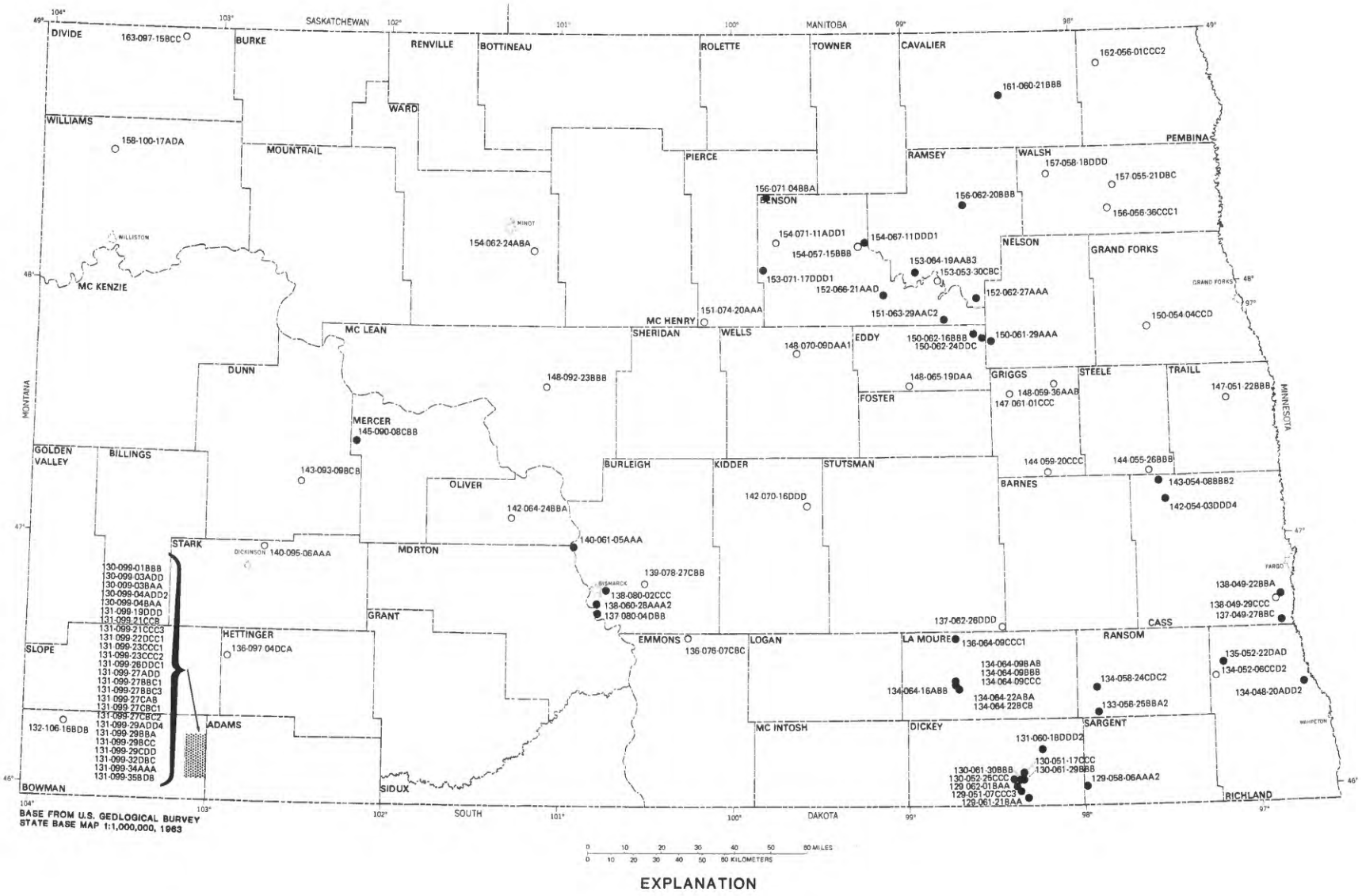


Figure 13.—Locations of ground-water observation wells in basic network in 1986.

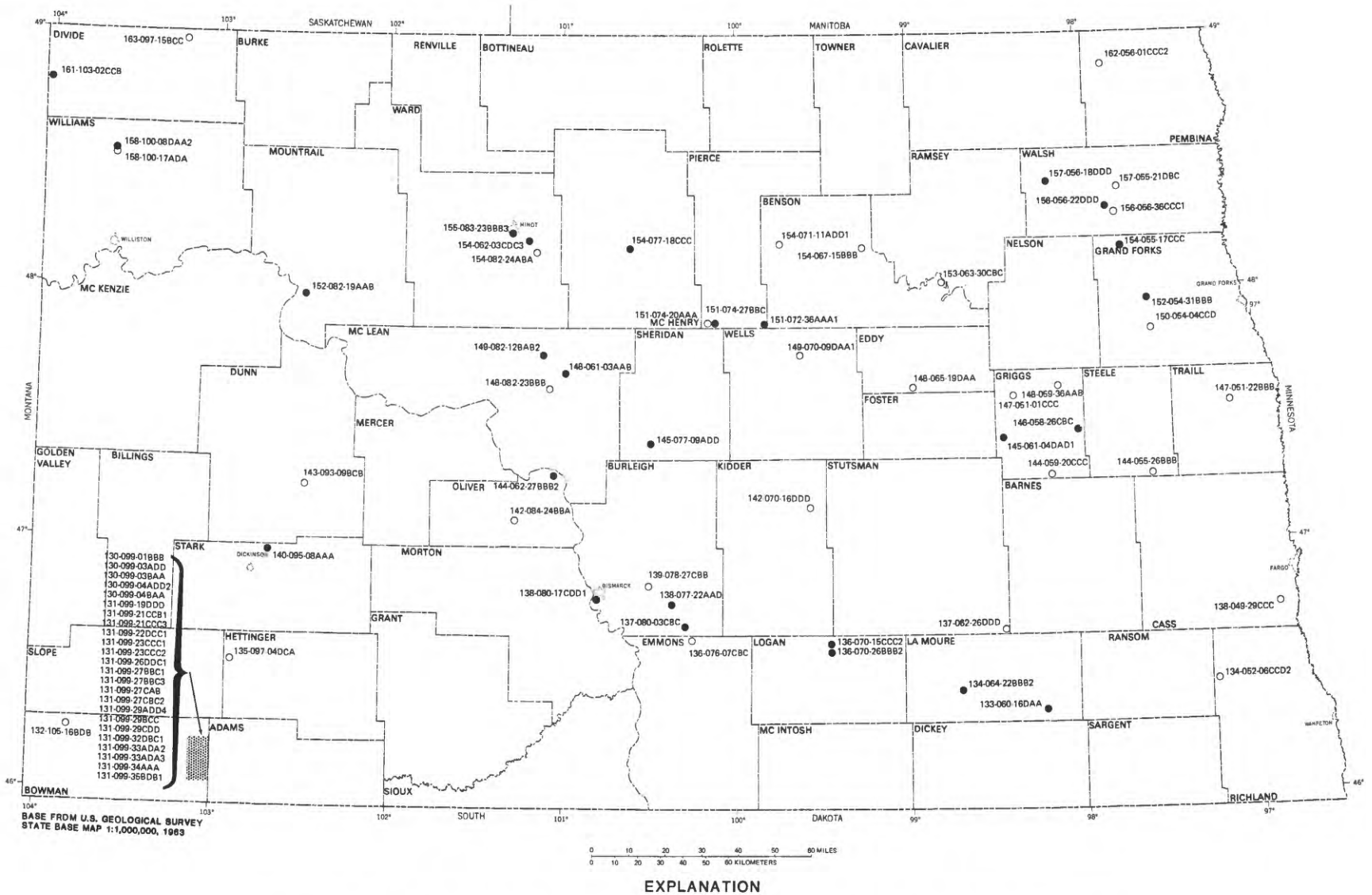


Figure 14.—Locations of ground-water observation wells in basic network in 1987.

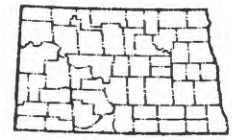
Water-Quality Stations

PROJECT NUMBER: ND 00-003.

LOCATION: Statewide.

PERIOD OF PROJECT: Continuous.

PROJECT CHIEF: Lawrence I. Briel.



STATEWIDE

COOPERATING AGENCIES: (1) North Dakota Public Service Commission; (2) North Dakota State Water Commission; (3) U.S. Department of the Army, Corps of Engineers; (4) U.S. Department of the Interior, Bureau of Reclamation; and (5) U.S. Department of the Interior, Fish and Wildlife Service.

COLLECTING WATER-QUALITY SAMPLES

PROBLEM: Water-resources planning and water-quality assessment require a nationwide base level of relatively standardized information. For proper planning and assessment of the water resources, the chemical and physical qualities of surface water and ground water must be defined and monitored.

OBJECTIVES: Objectives are (1) to provide a national bank of water-quality data for broad Federal and State planning and action programs and (2) to provide data for Federal and State management of interstate and international waters.

APPROACH: A network of water-quality stations will be operated to provide average chemical concentrations, loads, and time trends as required by planning and management agencies.

PROGRESS IN 1986 AND 1987: Water-quality data were obtained at 118 surface-water stations and at 5 other surface-water sites where discharge and stage are not measured routinely. Nine of the stations also are part of a U.S. Geological Survey nationwide network known as the National Stream Quality Accounting Network (NASQAN), data from which are used to define nationwide trends in water quality. The types of data obtained at surface-water stations are given in table 4. Inasmuch as several types of data may be determined at a particular station and not all types of data were determined at each station, the numbers given in table 4 will not equal the total number of stations given earlier. All surface-water stations where water-quality data were collected are shown in figures 15 and 16.

Water-quality data were collected at 68 wells in 1986 and at about the same number of wells in 1987. Physical data collected include water temperature, specific conductance, and pH. Water samples collected are analyzed primarily for inorganic constituents. The number of wells and the locations sampled vary from year to year. Wells and locations sampled in 1986 and 1987 are shown in figures 13 and 14.

On April 4, 1987, an agricultural-chemical warehouse in Minot, N. Dak., burned. Water used to fight the fire became extremely contaminated by pesticides and presented a potential hazard to Souris River plant and animal life. Although State and Federal agencies maintained that the contaminated water had been contained, a short-term pesticide monitoring program was initiated because an actual spill would have international implications. Preliminary results support the contention that the spill had been contained behind earthen dams.

Cleanup operations were almost complete when dams used to contain the spill were breached during a thunderstorm on July 18, 1987. The pesticide monitoring program was reinstituted for August 1987. Results are pending completion of analysis of samples by the Denver Central Laboratory.

Table 4.--*Water-quality data types*

Data type	Number of stations
Physical data:	
Water temperature	123
Specific conductance	123
pH	123
Chemical data:	
Inorganic constituents	123
Organic constituents	3
Pesticides	2
Radiochemical data	6
Microbiological data	11
Precipitation quality	2

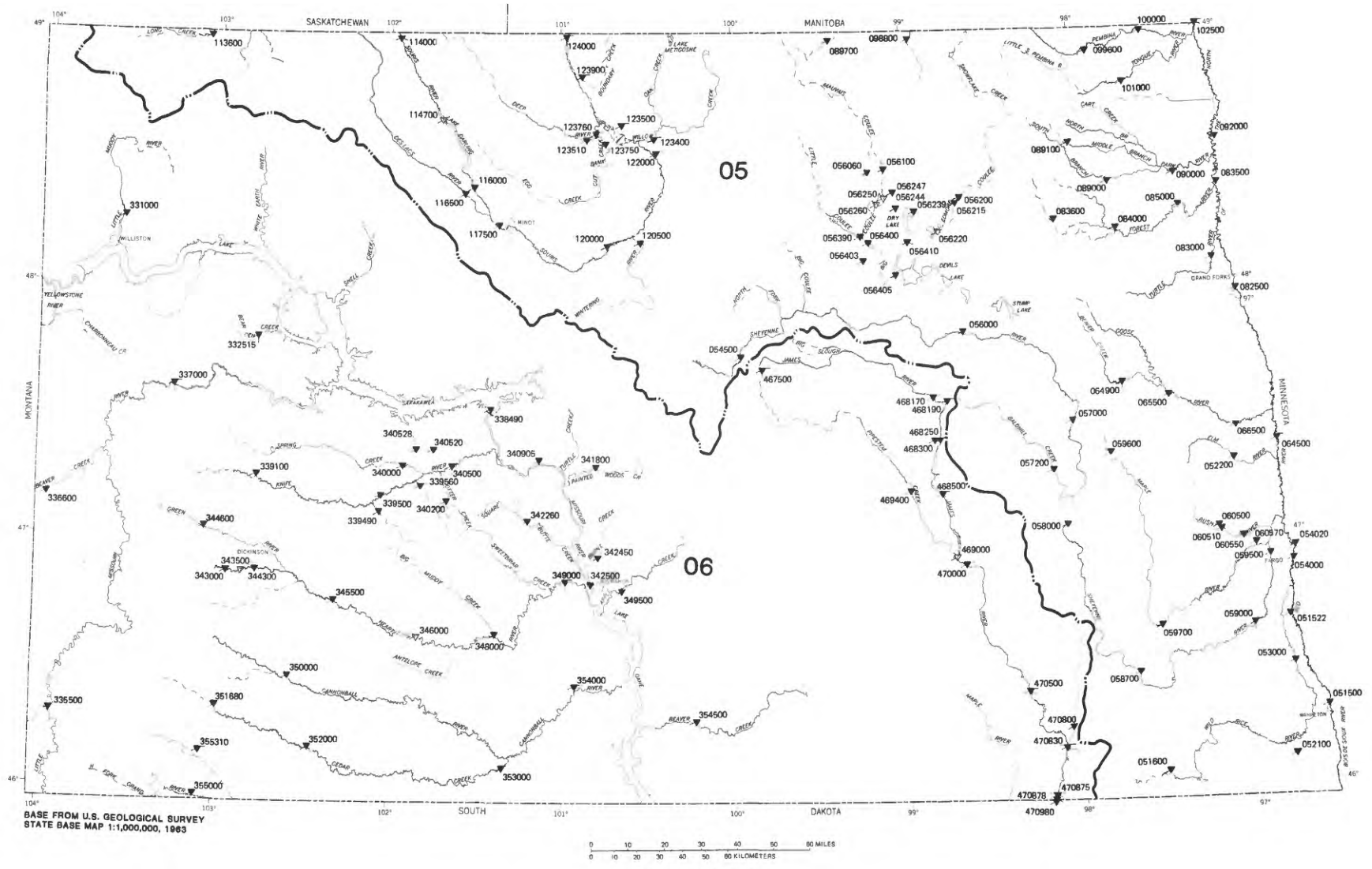


Figure 15.—Locations of surface-water stations where water-quality data were collected in 1986.

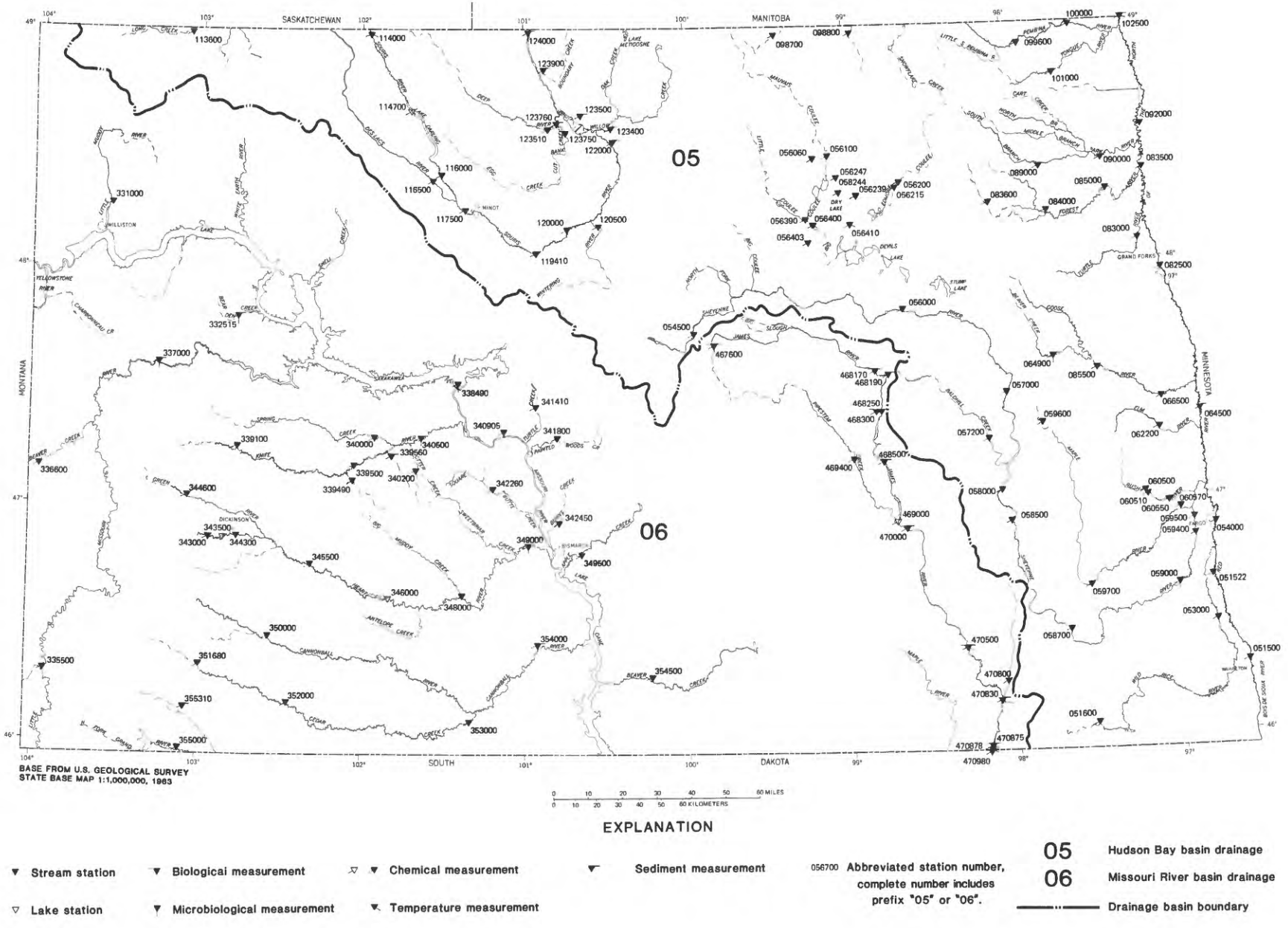


Figure 16.—Locations of surface-water stations where water-quality data were collected in 1987.

PLANS FOR 1988: The network will continue to operate with a few cooperator-requested modifications. Three floating platforms for continuous monitoring of water temperature, specific conductance, pH, and dissolved oxygen will be installed and operated on Arrowwood Lake National Wildlife Refuge. Synoptic sampling will be done on three pools plus on the inflow and outflow of Long Lake, also a national wildlife refuge.

REPORT PRODUCTS: U.S. Geological Survey, 1986, Water-resources data, North Dakota, Water year 1985: U.S. Geological Survey Water-Data Report ND-85-1, 368 p.

U.S. Geological Survey, 1987, Water-resources data, North Dakota, Water year 1986: U.S. Geological Survey Water-Data Report ND-86-1, 388 p.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1987 (planned).

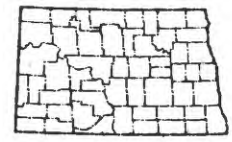
Sediment Stations

PROJECT NUMBER: ND 00-004.

LOCATION: Statewide.

PERIOD OF PROJECT: Continuous.

PROJECT CHIEF: Norman D. Haffield.



STATEWIDE

COOPERATING AGENCIES: (1) North Dakota Public Service Commission; (2) U.S. Department of the Interior, Bureau of Reclamation; (3) U.S. Department of the Interior, Fish and Wildlife Service; and (4) other Federal agencies of the U.S. Department of the Interior for the development of the Missouri River basin.

COLLECTING SEDIMENT SAMPLES

PROBLEM: Water-resources planning for intrastate, as well as interstate, waters requires a standardized data base containing sediment transport information. The information must be accurate, unbiased, and available to the user.

OBJECTIVES: Objectives are (1) to provide a national bank of sediment data for use in broad Federal and State planning and action programs and (2) to provide data for Federal management of interstate and international waters.

APPROACH: A network of sediment stations will be established and operated to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and particle size of sediment being transported by rivers and streams.

PROGRESS IN 1986 AND 1987: Data were collected and analyzed for 28 partial-record stations (figs. 15 and 16). Five new daily concentration sites were started in the Souris River basin as part of a 5-year refuge monitoring program. Five new monthly sites were added in the James River basin. One monthly site was discontinued.

PLANS FOR 1988: Plans are to continue to operate the network. One quarterly sampling site will be discontinued.

REPORT PRODUCTS: U.S. Geological Survey, 1986, Water-resources data, North Dakota, Water year 1985: U.S. Geological Survey Water-Data Report ND-85-1, 368 p.

U.S. Geological Survey, 1987, Water-resources data, North Dakota, Water year 1986: U.S. Geological Survey Water-Data Report ND-86-1, 388 p.

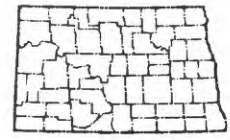
U.S. Geological Survey, Water-resources data, North Dakota, Water year 1987 (planned).

National Trends Network for Atmospheric Deposition

PROJECT NUMBER: ND 00-005.

LOCATION: Statewide.

PERIOD OF PROJECT: Continuous since November 1983.



STATEWIDE

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and Russell E. Harkness (1988).

WETFALL-DRYFALL PRECIPITATION COLLECTOR AND PRECIPITATION GAGE

PROBLEM: In order to determine atmospheric fluxes within the hydrologic system and man's influences on these fluxes, it is necessary to establish and operate a nationwide, long-term monitoring network for atmospheric deposition.

OBJECTIVES: Objectives are (1) to establish and operate a nationwide, long-term monitoring network to detect and measure levels of atmospheric deposition and (2) to determine variations in atmospheric deposition that occurs on a week-to-week basis by collection of wet- and dry-deposition products for analysis of elements and constituents that can contribute to the chemical composition of surface waters.

APPROACH: Monitoring stations were set up at Woodworth and Icelandic State Park as part of the National Trends Network (NTN). Stations will be maintained, on-site measurements made, samples processed, and samples submitted to the analytical laboratory. Data will be stored in the NWIS and verified. Results will be reported to the national program coordinator.

PROGRESS IN 1986 AND 1987: Two atmospheric deposition stations were operated. Records for 1986 precipitation and quality are being published; 1987 data are undergoing prepublication review. Digitally recording rain gages were operated at each station in addition to paper-chart recorders. The digital records were less affected by wind and vibrations.

PLANS FOR 1988: Stations will continue to be monitored. Data will be stored in NWIS files. Event precipitation data will be published in addition to weekly total precipitation. An additional rain gage will be installed at Woodworth to evaluate the relative effectiveness of the Nipher shield in improving snow-capture efficiency.

REPORT PRODUCTS: U.S. Geological Survey, 1986, Water-resources data, North Dakota, Water year 1985: U.S. Geological Survey Water-Data Report ND-85-1, 368 p.

U.S. Geological Survey, 1987, Water-resources data, North Dakota, Water year 1986: U.S. Geological Survey Water-Data Report ND-86-1, 388 p.

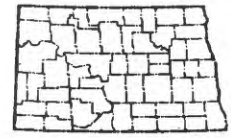
U.S. Geological Survey, Water-resources data, North Dakota, Water year 1987 (planned).

Water-Use Data Acquisition and Dissemination Program

PROJECT NUMBER: ND 00-007.

LOCATION: Statewide.

PERIOD OF PROJECT: Continuous.



STATEWIDE

PROJECT CHIEFS: Edwin A. Wesolowski and Christopher D. Bader (North Dakota State Water Commission).

COOPERATING AGENCY: North Dakota State Water Commission.

WATER WITHDRAWAL FOR IRRIGATION

PROBLEM: The water resources of North Dakota and the Nation are being used more extensively each succeeding year. In North Dakota, competition among users for available water resources in certain areas of the State has increased. In order to manage the development of the resources and to project future trends, planners and managers must be aware of existing patterns and quantity of use.

OBJECTIVES: Specific objectives are (1) to collect site-specific data to provide water-use information for the optimum utilization and management of the State's water resources; (2) to store data collected so they may be retrieved at national, regional, and various local levels; and (3) to disseminate water-use data to complement data on availability and quality of State and national water resources.

APPROACH: As an integral part of the water-permit program, the North Dakota State Water Commission collects site-specific water-withdrawal information from an annual inventory of permitted water users. Information on water withdrawals is stored in the following categories: public supply (includes municipal use and rural water systems), irrigation, and self-supplied commercial and industrial (includes mining and thermoelectric).

The North Dakota State Water Commission and the U.S. Geological Survey entered into a cooperative program to contribute data to the national water-use data base. The North Dakota State Water Commission furnishes annual water-withdrawal information to the U.S. Geological Survey by magnetic tape. After the site-specific data are converted from state water-use categories to national water-use categories, the data are reformatted and stored in the U.S. Geological Survey's State Water Use Data System (SWUDS) and in the National Water Use Data System (NWUDS). As needed, amounts of nonpermitted water withdrawals for rural-domestic use and for agricultural use will be estimated based on human and animal population and per capita use.

PROGRESS IN 1986 AND 1987: The 1985 data for 10 water-use categories plus data on sewage returns and population were compiled by county and four-digit hydrologic unit for the report, "Estimated Use of Water in the United States in 1985 (EUOWITUS 1985)." Withdrawals were divided between surface and ground water. Deliveries from the water-supply category for domestic, commercial, and industrial use and consumptive use for 10 water-use categories were estimated. Irrigation conveyance losses and acres irrigated by sprinklers and flooding also were estimated. The hydrologic unit data that were reaggregated from four-digit to eight-digit units and the county data were stored in the NWUDS. These data were interpreted in terms of water supply and demand and, along with information on the history of water development and water management in North Dakota, will be included in the National Water Summary 1987 report.

PLANS FOR 1988: An open-file report will be written to document in detail the sources of information, procedures used, and computer files created to complete the North Dakota section of EUOWITUS 1985 and to document the problems encountered during report preparation.

The North Dakota State Water Commission plans to publish a report that shows the trends in water use in North Dakota from 1973-85 and the amount of withdrawals and distribution of use from surface water and unconsolidated and bedrock aquifers from 1985.

The North Dakota State Water Commission will continue to annually update site-specific withdrawals and to maintain its water-permit master file. The data for 1987 and 1988 will be entered into the SWUDS and certain categories will be transferred into the NWUDS.

REPORT PRODUCTS: Patch, J.C., and Haffield, N.D., 1982, Estimated use of water for North Dakota, 1982: North Dakota State Water Commission Information Series No. 33 (map).

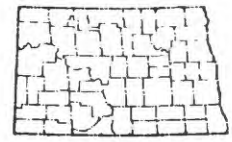
Smith, M.L., and Harkness, R.E., 1982, Water use in North Dakota, 1980: North Dakota State Water Commission Information Series No. 31 (map).

Bader, C.D., and Wesolowski, E.A., Estimated water use in North Dakota in 1985 (in progress).

Documentation of the preparation of the estimated use of water in the United States, 1985, North Dakota section (planned).

Evaluation of the Streamflow Collection Network for North Dakota

PROJECT NUMBER: ND 90093.



STATEWIDE

LOCATION: Statewide.

PERIOD OF PROJECT: October 1983 to September 1986.

PROJECT CHIEF: Gerald L. Ryan.

PROBLEM: Changes in the streamflow data-collection network often are made to satisfy a cooperating agency's needs. Also, changes or cutbacks are necessary because of restraints or reallocation of funds and manpower and increased costs of operation. Collection of selective data to meet immediate needs often does not meet the requirements of a long-term data-collection network.

OBJECTIVES: The purpose of this study is to make a systematic review of the network to determine how best to serve the immediate and long-term Federal and State needs. Objectives are (1) to define the purpose of the data collection at each site, (2) to make a comparative merit evaluation for all sites, (3) to identify alternative means of supplying required data and changes that could be made in the network to effect savings in funds and manpower, and (4) to identify requirements for periodic or continuous network evaluation.

APPROACH: The study will be conducted in two phases. Phase 1 will be to meet objectives 1 and 2. Phase 2 will be to meet objectives 3 and 4. A questionnaire will be prepared and distributed to cooperators and other interested agencies to define interest in individual stations. Data from the questionnaire will be compiled and analyzed to develop a relative merit for each existing station as well as any that might be proposed. Phase 2 will consist of analyzing data-collection activities with varying funding levels and manpower costs, such as the "Kalman Filter Cost Effective Resource Allocation (K-CERA)."

PROGRESS IN 1986 AND 1987: Statistical evaluation of the data operation was completed.

PLANS FOR 1988: Changes that could be made in the network to effect savings in funds and manpower will be identified. Publication of the report containing the results of the second phase of the study is planned.

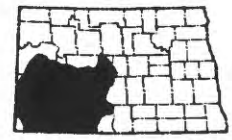
REPORT PRODUCTS: Ryan, G.L., 1985, Data uses and funding of the streamflow-gaging program in North Dakota: U.S. Geological Survey Open-File Report 85-349, 29 p.

Cost effectiveness of the stream-gaging program in North Dakota (planned).

REGIONAL STUDIES

In anticipation of water demands on a scale not limited by political boundaries or local problems, the U.S. Geological Survey is conducting studies of regional hydrologic systems. Some of these studies are in cooperation with other agencies. The studies are directed toward definition of the systems and prediction of the effects of stresses that could be imposed by present and future management plans.

Hydrology of Area 47, Northern Great Plains Coal Province, North Dakota



PROJECT NUMBER: ND 81-098.

LOCATION: Southwestern North Dakota.

PERIOD OF PROJECT: March 1981 to September 1982.

PROJECT CHIEF: Orlo A. Crosby (retired).

COAL-FIRED POWERPLANT

PROBLEM: Because of rapid development of energy resources (i.e., coal and oil), water availability and protection of water resources are significant problems in coal area 47, a subarea of the northern Great Plains coal province. Expected energy development included surface mining, powerplants, and coal conversion plants. Mining companies are required by law to analyze the hydrologic effects of proposed activities and to take appropriate measures to minimize adverse effects. There was, therefore, a need for comprehensive and easily understood information about the water resources in coal area 47.

OBJECTIVES: The purpose of this study was to describe the hydrology of area 47 in a format readily usable by the coal-mining industry, regulatory agencies, interest groups (such as environmental organizations), and the general public. Objectives were to present (1) a description of the area in a hydrologic framework, (2) a quantitative assessment of the occurrence and availability of water, (3) an assessment of the present quality of available water, and (4) an identification of current and planned utilization of water.

APPROACH: Existing data were utilized to establish an information framework for the study area. All available data were used to prepare graphs, maps, and text to fulfill the objectives of the study. The report was prepared in accordance with the Sequential Thematic Organization of Publications (STOP) format.

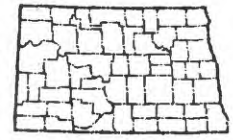
PROGRESS IN 1986 AND 1987: The report has been completed, but publication was delayed during typesetting and printing.

PLANS FOR 1988: Publication of the report is anticipated.

REPORT PRODUCT: Crosby, O.A., and Klausing, R.L., Hydrology of area 47, northern Great Plains and Rocky Mountain coal provinces; North Dakota, South Dakota, and Montana: U.S. Geological Survey Open-File Report 83-221, 150 p. (in press).

Changes in Precipitation Chemistry Resulting from Coal-Fired Energy Conversion Plants in North Dakota

PROJECT NUMBER: ND 82-106/108.



STATEWIDE

LOCATION: Statewide.

PERIOD OF PROJECT: October 1981 to September 1986.

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: North Dakota State Department of Health.

WEATHER STATION

PROBLEM: Little data have been collected on precipitation quality in relatively pristine areas of the country not presently receiving large pollutant loads from the atmosphere. Of the western energy-producing states, North Dakota may be vulnerable to serious environmental damage in the future. The State has experienced an expansion of population, lignite mining, petroleum and synfuel production, and energy production by coal-fired powerplants. With the known energy-development projects proposed for operation within North Dakota by 1985, the total statewide emissions of sulfur and nitrogen oxides are expected to exceed 1,300 tons per day. Considering additional input from increased emissions in upwind regions of Montana and Saskatchewan, the potential also exists for an adverse or episodic acid rain problem on a regional scale in North Dakota.

OBJECTIVES: Detailed geochemical investigations will be made (1) to determine baseline concentrations of certain elements in aerosol, precipitation, soil, and water prior to large-scale development of fuel resources; (2) to examine this baseline data for evidence of current influences by coal-fired generating facilities; (3) to determine the variation in composition of atmospheric precipitation both temporally and spatially; (4) to identify and evaluate mechanisms by which elements transfer within the ecosystem among atmosphere, water, and soil components; and (5) to determine the impact of changes in precipitation chemistry on surface- and ground-water quality. The results of these studies should provide the necessary basis (1) to develop a conceptual model of the processes controlling the composition of atmospheric deposition and (2) to follow with a mathematical model for quantitative predictions of future changes in precipitation quality and network design required to determine long-term changes in the quality of precipitation.

APPROACH: Representative receptor locations will be chosen within and downwind of the energy-development area in western North Dakota. Meteorological data and chemical data for wet and dry deposition collected at each receptor location will be evaluated statistically to determine the covariance of properties measured. Parameters indicative of differing types of energy development will be identified and monitored on an event or weekly basis. Stable isotopes will be monitored periodically to determine the proportion of acidic substances in precipitation contributed by biogenic processes and fossil-fuel combustion. A mass-balance flux-type model will be used to evaluate the effects of changing precipitation composition on the hydrologic system. An atmospheric model developed by the North Dakota State Department of Health may be used to evaluate the effects of powerplant emissions on precipitation quality and to predict future impacts. The composition of streams and lakes in the vicinity of precipitation stations will be monitored to measure the effects of precipitation chemistry on local surface waters. If impacts of degraded atmospheric deposition are recognized in local surface waters, surface- and ground-water quality data collected as part of the statewide network will be evaluated to determine the extent of these impacts regionally.

PROGRESS IN 1986 AND 1987: The quality of water in potholes adjacent to precipitation-collection stations at Canfield Lake and Woodworth and a small-basin headwater stream near Dunn Center was determined monthly in 1986 to determine the hydrologic consequences of changing precipitation chemistry. During snowmelt, these surface-water quality determinations were supplemented by daily samplings and snow cores to identify snowmelt enrichments in the volatile trace metals. An area of apparent acidification in the Turtle Mountains of northern North Dakota also was monitored on a monthly basis. In 1987, this surface-water monitoring was discontinued because of funding constraints.

The U.S. Geological Survey and the North Dakota State Department of Health continued operation on a precipitation-chemistry station at Canfield Lake and established complementary air-quality instrumentation at the site in 1986. Additionally, the North Dakota State Department of Health continued to operate stations at Dunn Center and Woodworth. In 1987, collection was discontinued at these three sites because of unavailability of cooperator funding. This network was supplemented by two NTN stations operated by the U.S. Geological Survey and a third NTN station operated by the U.S. National Park Service, all of which continued operation through 1987.

PLANS FOR 1988: The Canfield Lake precipitation-collection station will be dismantled. Final report products will be prepared.

REPORT PRODUCTS:

Houghton, R.L., 1983, Acidification of North Dakota surface water: Proceedings, Symposium on Acid Rain in Western Canadian Provinces, Regina, Saskatchewan, May 26-27, 1983, p. 16.

Houghton, R.L., 1983, Composition of atmospheric deposition in western North Dakota: Proceedings, 75th Annual Meeting of the North Dakota Academy of Science, Grand Forks, N. Dak., April 28-30, 1983, p. 59.

Houghton, R.L., 1984, Differences in composition of wet fall collected on weekly and event basis in North Dakota: National Atmospheric Deposition Program Technical Committee Meeting, Abstracts of Papers, October 31-November 2, 1984, p. 11-12.

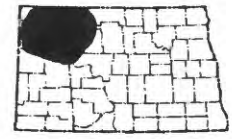
Houghton, R.L., Berger, M.E., Zander, N., and Dutchuk, S.K., 1984, Atmospheric deposition: Sample handling, storage, and analytical procedures for chemical characterization of event-based samples in North Dakota: U.S. Geological Survey Water-Resources Investigations Report 83-4205, 71 p.

Houghton, R.L., and Foss, J.E., 1985, Snowmelt trace-element enrichments in prairie potholes and soils of central North Dakota: National Atmospheric Deposition Program Technical Committee Meeting, Abstracts of Papers, October 8-11, 1985, p. 20.

Houghton, R.L., and Snow, Ray, 1986, Sources of sulfate in wet deposition, North Unit of Theodore Roosevelt National Park, North Dakota: Proceedings, 78th Annual Meeting of the North Dakota Academy of Science, Grand Forks, N. Dak., April 24-26, 1986, p. 94.

Macek-Rowland, K.M., Emerson, D.G., and Houghton, R.L., Meteorologic data for West Branch Antelope Creek stations and Canfield Lake station in west-central North Dakota, May 1982 through September 1986 (in progress).

Hydrology of Area 46, Northern Great Plains Coal Province, North Dakota



PROJECT NUMBER: ND 83-112.

LOCATION: Northwestern North Dakota.

PERIOD OF PROJECT: October 1982 to September 1983.

PROJECT CHIEF: Mack G. Croft (retired).

SPOIL PILES FROM SURFACE MINING OF COAL

PROBLEM: Because of the rapidly developing energy resources (i.e., coal and oil), water availability and protection of water resources are significant problems in coal area 46, a subarea of the northern Great Plains coal province. Expected energy development included surface mining, powerplants, and coal conversion plants. Mining companies are required by law to analyze the hydrologic effects of proposed activities and to take appropriate measures to minimize adverse effects. There was, therefore, a need for comprehensive and easily understood information about the water resources in coal area 46.

OBJECTIVES: The purpose of this study was to describe the hydrology of area 46 in a format readily usable by the coal-mining industry, regulatory agencies, interest groups (such as environmental organizations), and the general public. Objectives were to present (1) a description of the area in a hydrologic framework, (2) a quantitative assessment of the occurrence and availability of water, (3) an assessment of the present quality of available water, and (4) an identification of current and planned utilization of water.

APPROACH: A topic outline was developed and existing data were utilized to establish an information framework for the study area. All available data were used to prepare graphs, maps, and text to fulfill the objectives of the study. The report was prepared in accordance with the STOP format.

PROGRESS IN 1986 AND 1987: The report has been completed, but publication was delayed during typesetting and printing.

PLANS FOR 1988: Publication of the report is anticipated.

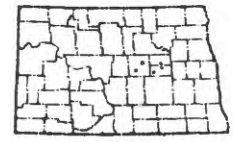
REPORT PRODUCT: Croft, M.G., and Crosby, O.A., Hydrology of area 46, northern Great Plains and Rocky Mountain coal provinces, North Dakota: U.S. Geological Survey Open-File Report 84-467, 135 p. (in press).

SPECIAL STUDIES

Special hydrologic studies often are needed to supplement the ongoing program. These special studies include water-supply problems, drainage problems, ground-water and surface-water relationships, ground-water recharge, water-quality problems, geochemical studies, and water management. The objective of special studies is to assist State and Federal agencies in solving water-resources problems that have both local impact and that are categorized as national concerns.

Hydrologic Drainage-Basin Characteristics Determined Using Digital Elevation Models

PROJECT NUMBER: None.



LOCATION: Eddy, Foster, and Wells Counties, North Dakota.

PERIOD OF PROJECT: June 1985 to December 1986.

PROJECT CHIEF: Gregg J. Wiche.

COOPERATING AGENCIES: (1) U.S. Department of the Interior, Bureau of Reclamation; and (2) U.S. Department of the Interior, Geological Survey, National Mapping Division.

PROBLEM: The U.S. Bureau of Reclamation is evaluating the hydraulic characteristics of the Jamestown Dam and Reservoir under the Safety Evaluation of Existing Dams (SEED) program. The Bureau is charged with the responsibility of estimating the Probable Maximum Flood (PMF) into the reservoir. Key factors needed to compute the PMF are knowledge of whether a drainage area is contributing or noncontributing and knowledge of the hydrologic characteristics of the drainage basin.

OBJECTIVES: The purpose of this study is to document methods developed to delineate drainage basins and compute hydrologic characteristics. Objectives of the study are (1) to apply the methods developed to compute the hydrologic characteristics of five test areas in the James River basin, (2) to test the performance of digital elevation models of various accuracies, and (3) to provide general cost estimates to procure digital elevation models of various accuracies.

APPROACH: National Mapping Division/Mid-Continent Mapping Center personnel contracted for aerial photographs over the test areas and will generate special-product, high-resolution, high-accuracy digital elevation models. Spatial data-processing algorithms and data-interchange software will be used at the EROS Data Center to derive the hydrologic basin characteristics.

PROGRESS IN 1986 AND 1987: Digital elevation models were developed and used to compute drainage-basin characteristics for five test areas in the James River basin. The accuracy of three different digital elevation models was tested.

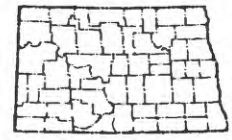
PLANS FOR 1988: Plans are to obtain Director's approval for report publication.

REPORT PRODUCT: Hydrologic drainage-basin characteristics of five test areas in the James River basin determined using digital elevation models (planned).

Pumping Techniques Bias in Chemistry of Ground-Water Samples

PROJECT NUMBER: ND 81-096.

LOCATION: Statewide.



STATEWIDE

PERIOD OF PROJECT: October 1980 to September 1982.

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: North Dakota State Water Commission.

COLLECTING GROUND-WATER SAMPLES

PROBLEM: One of the most common sources of error in the chemical analysis of ground water is bias introduced by chemical alteration during sampling. The largest source of alteration is believed to result from air entrainment during pumping. Therefore, if the nature and magnitudes of the biases of different common pumping techniques were known, it would be possible to determine which ground-water data currently on file are usable in future studies. Current quantitative studies would not be hampered by historical data of questionable accuracy.

OBJECTIVE: The objective of this study is to determine the nature and magnitudes of chemical biases introduced during the sampling of ground water by several different common pumping methods. Pumps that will be investigated include air-lift, gas-squeeze, gas-driven reciprocating, peristaltic, and submersible centrifugal. Kemmerer-type and conventional bailers also will be investigated. Analyses of ground water sampled by these techniques will provide a basis for evaluating historical ground-water data and determining preferred methods for future sampling.

APPROACH: In phase 1 of the project, only wells of similar construction will be studied, thus minimizing water-quality alteration due to well conditions. During phase 2, randomly selected wells will be sampled without regard to construction design, but only water from wells of similar construction and composition will be considered in each statistical group. To fully assess the affected properties, deep, intermediate, and shallow wells will be included. To assure applicability of the results to all water types, wells yielding sulfate-, bicarbonate-, and chloride-type waters will be studied. Additionally, adjacent wells drilled to the same aquifer depth but cased in different materials will be sampled to evaluate the effect of well construction on apparent ground-water quality.

PROGRESS IN 1986 AND 1987: The draft report remained in the review process. Additional statistical analysis of data was requested.

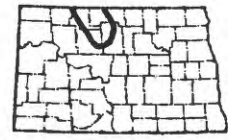
PLANS FOR 1988: Publication of the final report is anticipated.

REPORT PRODUCTS: Houghton, R.L., and Berger, M.E., 1984, Effects of well-casing composition and sampling methods on apparent quality of ground water: Proceedings, Fourth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring, Columbus, Ohio, May 23-25, 1984, National Water Well Association, p. 203-213.

Houghton, R.L., and Berger, M.E., Effect of sampling method on apparent quality of ground water (in progress).

Water-Quality Assessment of the Souris River Within North Dakota

PROJECT NUMBER: ND 82-103.



LOCATION: Souris River within North Dakota.

PERIOD OF PROJECT: October 1981 to September 1985.

PROJECT CHIEF: Edwin A. Wesolowski.

COOPERATING AGENCY: North Dakota State Department of Health.

LOG JAM ON SOURIS RIVER

PROBLEM: Water-quality degradation of the Souris River has resulted in both intrastate dispute and international concern. The source and movement of contaminants are of concern to Saskatchewan and Manitoba, the municipalities and State agencies of North Dakota, and several Federal agencies. The North Dakota State Department of Health and the U.S. International Joint Commission's Souris River Pollution Control Board requested that a study be undertaken to determine the cause of water-quality degradation on the Souris River. Potential sources of water-quality degradation include inadequately treated municipal and industrial wastes, urban and rural runoff, feedlots, and several large wildlife refuges.

OBJECTIVES: Objectives are (1) to define the hydrologic system and existing water-quality problems; (2) to determine time-of-travel, dispersion, and reaeration characteristics; (3) to quantitatively evaluate water-quality processes; and (4) to develop conceptual and digital models to evaluate the waste-load and water-quality relationships and to predict the effect of waste discharges on the river at various flows and at selected reaches of the river.

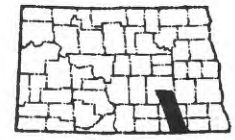
APPROACH: Existing data will be used to identify seasonal water-quality and hydrologic trends and conditions for times when the river is susceptible to degradation. At these critical periods, additional data will be collected to isolate the processes that degrade stream quality. A one-dimensional steady-state water-quality model will evaluate these processes using the new data and field-determined times-of-travel and dispersion and reaeration coefficients.

PROGRESS IN 1986 AND 1987: Colleague and regional reviews were completed for the report, "Low-Flow Traveltime, Longitudinal-Dispersion, and Reaeration Characteristics of the Souris River from Lake Darling Dam to J. Clark Salyer National Wildlife Refuge, North Dakota." Director's approval for publication has been requested. No progress was made on the water-quality modeling part of the study.

PLANS FOR 1988: The report, "Low-Flow Traveltime, Longitudinal-Dispersion, and Reaeration Characteristics of the Souris River from Lake Darling Dam to J. Clark Salyer National Wildlife Refuge, North Dakota," will be published pending Director's approval.

REPORT PRODUCT: Wesolowski, E.A., and Nelson, R.A., Low-flow traveltime, longitudinal-dispersion, and reaeration characteristics of the Souris River from Lake Darling Dam to J. Clark Salyer National Wildlife Refuge, North Dakota (in progress).

Hydrology of the Lower James River Basin in North Dakota



PROJECT NUMBER: ND 82-104.

LOCATION: Southeastern North Dakota.

PERIOD OF PROJECT: October 1981 to September 1984.

PROJECT CHIEFS: Paul K. Christensen (U.S. Bureau of Indian Affairs) and Jeffrey E. Miller (now in Denver, Colo.).

COOPERATING AGENCY: North Dakota State Water Commission.

LOWER JAMES RIVER

PROBLEM: Previous investigators have noted a hydraulic relation among the local glacial-drift aquifers, the terrace aquifers, and the lower James River in North Dakota. Irrigation and other developments in the James River basin are increasing their demands on the ground-water and surface-water system. As development of the water resources of the basin increases, concerns regarding the impact of development or proposed development on low flows and water quality in both the James River and the connected aquifers also increase. Before the North Dakota State Water Commission can begin to allow additional use of the water in the basin, the ground-water and surface-water system needs to be defined so that the effects of further development can be estimated.

OBJECTIVES: Objectives are (1) to define the hydrology of the ground-water and surface-water system and (2) to develop quantitative capabilities for the evaluation of water-use impacts.

APPROACH: The project will be done in a series of stages over a 3-year period. The ground-water and surface-water system will be defined to the extent possible with available data. Based on this definition, a data-collection procedure will be designed so that the system can be further defined. Ground-water levels, flow data, and ground-water and surface-water quality differences will be used to define the system. A preliminary report will be prepared. Additional data needs again will be determined and that data collected before the final system definition is completed. Based on the system and approach, a model will be developed, tested, and described in the final report.

PROGRESS IN 1986 AND 1987: The report describing the hydrologic system was completed and received Director's approval.

PLANS FOR 1988: The report will be revised to include suggested improvements made by reviewers. Publication of the final report is anticipated.

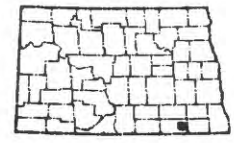
REPORT PRODUCTS: Wald, J.D., and Christensen, P.K., 1986, Water-resources data for the lower James River, Dickey, LaMoure, and Stutsman Counties, North Dakota: North Dakota State Water Commission Water-Resources Investigation 2, 491 p.

Christensen, P.K., and Miller, J.E., Progress report for the cooperator on the ground-water and surface-water system of the lower James River basin, North Dakota (not published).

Christensen, P.K., and Miller, J.E., The hydrologic system of the lower James River, North Dakota (in progress).

Christensen, P.K., Miller, J.E., and Patten, E.P., Spiritwood aquifer and James River system: Synopsis of the system and an evaluation of a management scheme, southeastern Stutsman and north-central LaMoure Counties, North Dakota (in progress).

Application of Unsaturated Zone Monitoring and Modeling Techniques to the Determination of Ground-Water Recharge



PROJECT NUMBER: ND 83-120.

LOCATION: Southeastern North Dakota.

PERIOD OF PROJECT: October 1983 to September 1986.

PROJECT CHIEF: William F. Horak (now in Oklahoma City, Okla.).

COOPERATING AGENCY: North Dakota State Water Commission.

PROBLEM: A review of the hydrologic literature indicated that little precedent is available for direct, quantitative approaches to studying ground-water recharge and evapotranspiration (ET). Most geohydrologic studies have involved either loosely defined water budgets or water-level time-series analyses to estimate ground-water recharge or ET or both. Neither of these approaches is suitable for the intensive management of North Dakota's heavily developed glacial-drift aquifers. Attempts to simulate the effects of additional ground-water withdrawals on these aquifers have been frustrated by the lack of data defining recharge and ET. It is essential to the responsible management of the aquifers, therefore, that reliable estimates of the magnitudes of recharge and ET be made available.

OBJECTIVES: Objectives are (1) to measure the hydraulic properties, including the functional relations of hydraulic conductivity and of matric potential to moisture content, for the major soil groups in the study area; (2) to evaluate the areal variability of those data; (3) to select a physically-based model(s) for simulation of unsaturated or variably saturated flow; (4) to use the model to estimate the sensitivity of the flow system to variations in soil hydraulic properties and assumed boundary conditions; (5) to collect the data required for use of the Penman combination method of estimating potential evapotranspiration (PET); and (6) to make recommendations as to the optimum manner in which to interface the data generated by the recharge and ET process model(s) with the ground-water flow model.

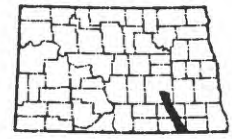
APPROACH: The important emphasis of this study is the field collection of soil hydrologic data. Tensiometers and neutron moisture measurements will be used to define the soil-moisture characteristics for the major soils in the study area. The instantaneous profile method of determining unsaturated hydraulic conductivity also will be used. The acquired soil-moisture, moisture potential, and hydraulic conductivity data will be used with an unsaturated or variably saturated flow model to determine probable rates of ground-water recharge. Estimates of ET from the water table will be derived from the PET, moisture content, and moisture potential data.

PROGRESS IN 1986 AND 1987: The draft report was prepared and is being reviewed.

PLANS FOR 1988: Publication of the final report is anticipated.

REPORT PRODUCT: Horak, W.F., Review of methods for determining recharge for shallow glacial aquifers (in progress).

Evaluation of Streamflow-Gaging Methods for Application to Rivers with Flat Slopes, North Dakota



PROJECT NUMBER: ND 83-121.

LOCATION: Southeastern North Dakota.

PERIOD OF PROJECT: October 1982 to September 1985.

PROJECT CHIEF: Gregg J. Wiche.

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Reclamation.

FLOODING OF JAMES RIVER

PROBLEM: The James River, like many rivers in eastern North Dakota and other Plains states, has a flat slope and, therefore, experiences variable backwater conditions, slow velocities, and reverse flows. These conditions make accurate discharge measurements difficult to obtain and eliminate the usefulness of the standard single-value rating curve for streamflow-gaging applications.

OBJECTIVES: Objectives are (1) to test and compare the feasibility, cost effectiveness, and accuracy of acoustical velocity meters, stage-fall discharge ratings, and unsteady-state flow models for gaging stream discharge and (2) to collect adequate field data to develop streamflow records at a site near Hecla, S. Dak.

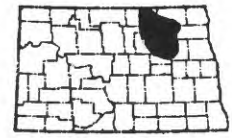
APPROACH: The stage data necessary to drive the unsteady flow model have been collected by constructing and operating three gaging stations. These stage data will be used to develop the unsteady-state flow model for a 4-mile section of the river ending at the downstream site. Discharge will be computed by the flow model at the downstream site. A stage-fall discharge rating will be developed at the downstream site. Discharge also is being collected at the downstream site using an acoustic velocity flow meter. The accuracy, feasibility, and cost effectiveness of the three methods used to collect discharge will be compared. In addition, a stage-discharge relationship has been developed at the upstream site (a low-head dam) and this discharge will be compared with the discharge at the downstream site.

PROGRESS IN 1986 AND 1987: Cross-section data, required as input to the unsteady flow model, were compiled and used to calibrate the model. A comparison of modeled and conventional discharge was made. A draft report was written.

PLANS FOR 1988: Plans are to obtain Director's approval for report publication.

REPORT PRODUCT: Benson, R.D., and Wiche, G.J., Evaluation of streamflow-gaging methods for application to a river with flat slope--James River, North Dakota/South Dakota (in progress).

An Investigation of the Hydrologic and Climatologic Mechanisms Controlling the Water-Surface Elevation of Devils Lake, North Dakota



PROJECT NUMBER: ND 83-124.

LOCATION: Northeastern North Dakota.

PERIOD OF PROJECT: October 1983 to September 1984.

PROJECT CHIEF: Gregg J. Wiche.

COOPERATING AGENCY: U.S. Department of the Army, Corps of Engineers.

CHAIN OF LAKES CONTRIBUTING TO DEVILS LAKE

PROBLEM: The current high water-surface elevations of Devils Lake pose an immediate flood threat to the city of Devils Lake. The U.S. Army Corps of Engineers has developed a draft report detailing a flood-control project at Devils Lake. In this project, four structural and nonstructural flood-control plans have been developed to prevent flooding. Implementation of any of these plans should be based on knowledge of the hydrologic and climatologic relationships of the Devils Lake system.

OBJECTIVES: The purpose of this study is to gain an understanding of the interaction of the hydrologic and climatologic mechanisms controlling the water-surface elevation of Devils Lake. Objectives are (1) to conduct a literature review to determine what previous studies have been completed on other terminal lakes and (2) to conduct a statistical comparability analysis of the Devils Lake basin to other streams and basins.

APPROACH: A literature review will be conducted to see what studies have been undertaken that may provide ideas and methods that can be incorporated in the present study. These findings from previous studies will provide guidelines as to what statistical techniques may show promising results. A statistical analysis of the Devils Lake basin and other streams and basins will be conducted using multiple linear regression. In addition, correlations will be made using the climatological indices of temperature and precipitation.

PROGRESS IN 1986 AND 1987: Data collection continued in the Devils Lake basin in an effort to determine the quantity and magnitude of discharge into the chain of lakes. The draft report, "Hydrology of the Chain of Lakes Tributary to Devils Lake and Water-Level Simulations of Devils Lake, Northeastern North Dakota," began the review process.

PLANS FOR 1988: Plans are to obtain Director's approval for report publication.

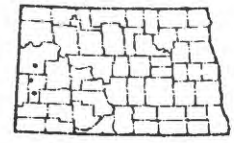
REPORT PRODUCTS: Wiche, G.J., 1986, Hydrologic and climatologic factors affecting water levels of Devils Lake, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 86-4320, 62 p.

Wiche, G.J., Hoetzer, S.M., and Rankl, J.G., 1986, Hydrology of the Devils Lake basin, northeastern North Dakota: North Dakota State Water Commission Water-Resources Investigation 3, 86 p.

Wiche, G.J., Hydrology and water-level fluctuations of Devils Lake, North Dakota: Proceedings of the International Symposium on Flood Frequency and Risk Analysis, Baton Rouge, Louisiana, May 14-17, 1986 (in press).

Ryan, G.L., and Wiche, G.J., Hydrology of the chain of lakes tributary to Devils Lake and water-level simulations of Devils Lake, northeastern North Dakota (in progress).

Flood Analysis Along the Little Missouri River Within and Adjacent to Theodore Roosevelt National Park, North Dakota



PROJECT NUMBER: ND 84-006.

LOCATION: Little Missouri Badlands.

PERIOD OF PROJECT: April 1984 to September 1984.

PROJECT CHIEF: Douglas G. Emerson.

COOPERATING AGENCY: U.S. Department of the Interior, National Park Service.

PROBLEM: The U.S. National Park Service needs information on flood potential as part of a general management plan for the Theodore Roosevelt National Park.

OBJECTIVES: Objectives are (1) to determine water-surface elevations for the 100- and 500-year flood discharges for selected reaches of the Little Missouri River; (2) to determine water-surface elevations for the 100-year flood discharge for the areas near the mouths of Knutson, Paddock, and Squaw Creeks; and (3) to evaluate the effects of ice jams on flood elevations.

APPROACH: Peak-flow frequency analyses described by the U.S. Geological Survey (1982, Guidelines for determining flood flow frequency: Interagency Advisory Committee on Water Data, Office of Water Data Coordination, 28 p.) will be used to determine the flood discharges at the gaging stations, 06336000 and 06337000. The 100- and 500-year flood discharges for the Elkhorn Ranch Site will be determined by using the drainage-area ratio method. The 100-year flood discharges for the mouths of Knutson, Paddock, and Squaw Creeks will be determined by using a regression equation developed to determine flood-peak discharges for small drainage areas in North Dakota. Water-surface elevations will be determined by using step-backwater computations.

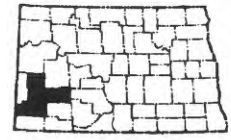
PROGRESS IN 1986 AND 1987: The final report was published, and project activities were terminated.

PLANS FOR 1988: The project is complete; no further activities are planned in 1988.

REPORT PRODUCT: Emerson, D.G., and Macek-Rowland, K.M., 1986, Flood analysis along the Little Missouri River within and adjacent to Theodore Roosevelt National Park, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 86-4090, 36 p.

Hydrogeochemical Controls on the Mobility of Radiogenic Constituents in Uraniferous Lignite and Ash in North Dakota

PROJECT NUMBER: ND 84-125/126.



LOCATION: Billings, Slope, and Stark Counties, North Dakota.

PERIOD OF PROJECT: June 1983 to September 1987.

PROJECT CHIEF: Robert L. Houghton (now in Reston, Va.).

COOPERATING AGENCY: North Dakota Public Service Commission.

ABANDONED LIGNITIC URANIUM MINES

PROBLEM: During operation of lignitic uranium mines in western North Dakota, airborne fugitive dust from the ashing of mined lignite was deposited on rangeland surrounding the sites. Adjacent to the kiln sites where the greatest amount of ashing occurred, soil became highly contaminated with radioactive and trace-metal residuals. After the abandonment of North Dakota lignitic uranium mines, most mine pits filled with ground water, providing a potential for mobilization of metals and radioactive components concentrated in ash and unburned lignite remaining in pit bottoms. Aquifers hydrologically connected with mine pits locally are used for domestic and livestock supply.

OBJECTIVES: Objectives are (1) determination of the physiochemical conditions that promote the mobility of radiogenic, select trace metal, and other potentially hazardous chemical constituents from uraniferous lignite and its ash throughout the hydrologic system; (2) prediction of the mobility of these constituents at each of the abandoned mine sites in western North Dakota; (3) comparison of predicted and observed ground-water, pore-water, and surface-water compositions affected by mine-derived solutes; (4) development of reclamation methods that might limit hazardous-waste mobility from the sites; and (5) evaluation of reclamation practices adopted by the North Dakota Public Service Commission to restore the sites to maximum safe usefulness.

APPROACH: The study consists of three phases. Phase 1 is designed to provide the geohydrologic and geohydrochemical data at all eight sites necessary to develop initial reclamation plans. Phase 2 will determine the geochemical processes controlling radiochemical mobility in the hydrologic system. Specifically, one uranium mining and ashing site that intersects the water table, a second uranium mining and ashing site remote from the water table, and a kiln processing site will be selected for extensive study. Phase 3 will determine the transference value of information gathered in phase 2 to the remaining phase 1 sites. Proof of transference is requisite before the simulation can be utilized to help develop standards for reclamation of mine sites.

PROGRESS IN 1986 AND 1987: Reclamation of Palaniuk "A" mine site, undertaken in 1985, was completed. Monitoring wells and radon-emanation sensors were reinstalled at the site to determine the effectiveness of reclamation. Water quality and water levels at the wells were determined on a monthly basis throughout the period. A preliminary report on the reclamation procedure was presented at the 1987 Billings Symposium on Surface Mining and Reclamation in the Great Plains and American Society for Surface Mining and Reclamation.

In 1986, the spoil piles at the Palaniuk "B", "C", and "D"; Frank; and Talkington mine sites were drilled on 50-foot centers and sampled at 20-foot depth intervals. Spoil samples were analyzed for paste pH, specific conductance of soluble salt fraction at saturation, total uranium, total radium-226, and selected associated trace elements. Fence diagrams of these data were used to develop reclamation plans for the Palaniuk sites, and reclamation of the Palaniuk "C" and "D" mine sites was undertaken in 1987.

Ground and pore water in the vicinity of the other mine sites were sampled seasonally for water quality and monthly for water levels. These data were prepared for later release as a data report.

PLANS FOR 1988: Monitoring and water-quality sampling will continue to determine the effectiveness of reclamation efforts. Reports documenting data-collection and reclamation efforts will be completed.

REPORT PRODUCTS: Houghton, R.L., Wald, J.D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents at uraniferous lignite mines in southwestern North Dakota [abs.]: Proceedings, 76th Annual Meeting of the North Dakota Academy of Science, Fargo, N. Dak., v. 38, p. 59.

Houghton, R.L., Wald, J.D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents in mine spoils and uraniferous lignite ash in southwestern North Dakota [abs.]: Proceedings of the 1984 Rocky Mountain Ground-Water Conference, Great Falls, Mont., April 8-11, 1984, Montana Bureau of Mines and Geology Special Publication 91, p. 26-27.

Houghton, R.L., Wald, J.D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents in the coal-bearing Fort Union Formation and in lignite mines in western North Dakota: Proceedings of the 1984 Rocky Mountain Coal Symposium, Bismarck, N. Dak., p. 89-113.

Houghton, R.L., Hall, R.L., Unseth, J.D., Wald, J.D., Anderson, G.S., and Hill, S.R., 1985, Hydrogeochemistry of uranium and associated elements at abandoned uranium mines in western North Dakota: Proceedings of the Second Toxic Waste Ground-Water Contamination Technical Meeting, Cape Cod, October 21-25, 1985, p. 1-3.

Houghton, R.L., Hall, R.L., Unseth, J.D., Wald, J.D., Burgess, J.L., Patrick, D.P., Anderson, G.S., and Hill, S.R., 1986, Reclamation of a uraniferous lignite mine, North Dakota: Proceedings of the Eighth Annual U.S. Department of Energy (DOE) Low-Level Waste Management Forum, Technical Session II--Site Closure, Denver, September 23-25, 1986, p. 55-59.

Houghton, R.L., Anderson, G.S., Hill, S.R., Burgess, J.L., Wald, J.D., Patrick, D.P., Hall, R.L., and Unseth, J.D., 1987, Prevention of ground-water quality degradation during reclamation of a uraniferous lignite mine, North Dakota: Proceedings of the 1987 Billings Symposium on Surface Mining and Reclamation in the Great Plains and American Society for Surface Mining and Reclamation, Billings, March 16-20, 1987, p. G-4-1 to G-4-19.

Distribution and hydrogeochemical mobility of radioactive and associated constituents in the coal-bearing Fort Union Formation of western North Dakota (planned).

Data Development and Analysis for Use in the U.S. Bureau of Reclamation Model on the James River

PROJECT NUMBER: ND 84-128.

LOCATION: Southeastern North Dakota.

PERIOD OF PROJECT: October 1983 to September 1984.

PROJECT CHIEF: Gregg J. Wiche.

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Reclamation.

PROBLEM: The James River planning model that will be developed by the U.S. Bureau of Reclamation will require as input data the nonregulated and regulated discharges at a number of locations along the James River. A combination of water-balance and statistical procedures will be used to synthesize the necessary input data.

OBJECTIVES: The purpose of this study will be to compile and analyze the monthly discharge data needed as input to the planning flow model that will be developed by the U.S. Bureau of Reclamation. Objectives are (1) to compute regulated discharge for 1953-82 at the North Dakota-South Dakota State line, (2) to compute unregulated discharge for six James River locations, (3) to characterize the period of record in terms of the recorded climatological record, and (4) to compute revised drainage-area figures for the James River basin.

APPROACH: Two methods will be used to compute the regulated discharge at the North Dakota-South Dakota State line. The first method of record reconstruction is the drainage-area ratio technique outlined by Hirsch (Hirsch, R.M., 1979, An evaluation of some record reconstruction techniques: Water Resources Research, v. 15, no. 6, p. 1781-1790). The second method will be to develop log-log regression between the monthly flows of James River at LaMoure and the monthly flows of James River at Ludden Dam, which is within a mile of the North Dakota-South Dakota State line. The unregulated flows will be computed by determining the effect of Jamestown and Pipestem Reservoirs and then subtracting or adding the monthly effect to the regulated flows at stations downstream of the reservoirs.

PROGRESS IN 1986 AND 1987: The objectives of the study were completed, and a draft report was written.

PLANS FOR 1988: Plans are to obtain Director's approval for report publication.

REPORT PRODUCT: Wiche, G.J., Emerson, D.G., and Benson, R.D., Measured and synthesized monthly historic discharge and synthesized monthly unregulated discharge at 13 gaging stations on the James River in North Dakota and South Dakota, 1953-82 (in progress).

Hydraulic Characteristics of Aquifers and Confining Units in the Fort Union Formation

PROJECT NUMBER: ND 84-129.

LOCATION: West-central North Dakota and eastern Montana.

PERIOD OF PROJECT: October 1983 to September 1985.

PROJECT CHIEF: Thomas B. Reed.

PROBLEM: Previous studies of the hydrogeology of lignite deposits in North Dakota generally have not provided the areally distributed hydraulic data that are required for use in ground-water flow models. Without this type of data, the areal and temporal distribution of drawdown in the vicinity of a strip mine cannot be projected accurately. Furthermore, without valid, calibrated flow models, solute transport processes cannot be modeled quantitatively.

OBJECTIVES: Objectives are (1) to evaluate the available methodologies appropriate for the *in situ* determination of hydraulic conductivity (or transmissivity), specific storage, and specific yield of fractured rock aquifers and for the determination of vertical hydraulic conductivity and specific storage of confining beds; (2) to establish and execute a systematic procedure for the collection and analysis of data required for the determination of the hydraulic properties of the lignite and sandstone aquifers and confining beds; (3) to examine the data for correlative relationships between lignite hydraulic conductivity and various physical or geologic parameters such as depth of burial or lignite bulk density; and (4) to compare values of aquifer hydraulic conductivity derived from slug testing with those derived from pumping tests to evaluate the validity of the slug test method for fractured rock and granular aquifers.

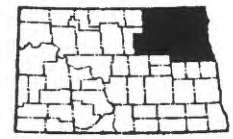
APPROACH: Accomplishment of the study objectives will require a drilling program that will provide the production and observation wells necessary for the pumping and slug tests. Aquifer testing by pumping methods will require production wells to be drilled in several different locations, each fully penetrating the aquifer and each accompanied by several observation wells placed at varying distances and directions from the production well. Each of the wells completed in aquifer zones also will be used for slug testing. Additional wells will be completed in the confining beds.

PROGRESS IN 1986 AND 1987: The draft report was completed and began the review process.

PLANS FOR 1988: Plans are to complete the review process, obtain Director's approval for publication, and publish the final report.

REPORT PRODUCT: Reed, T.B., Hydraulic characteristics of the Harmon lignite aquifer and surrounding units in the Fort Union Formation near Beach, North Dakota (in progress).

Effects of Fallowed Land on Soil Erosion, Northeastern North Dakota



PROJECT NUMBER: ND 85-130.

LOCATION: Northeastern North Dakota.

PERIOD OF PROJECT: July 1983 to September 1986.

PROJECT CHIEF: Robert L. Houghton (now in Reston, Va.).

COOPERATING AGENCY: North Dakota State University.

SOIL EROSION

PROBLEM: Each year, large tracts of agricultural land in North Dakota are left fallowed. Recent Federally-sponsored programs have increased this acreage greatly. Because ground cover commonly is not used or is planted mid-summer, early summer rains have a great potential to cause significant soil erosion. Currently, no easily applicable means of remotely determining the magnitude of this soil erosion are available.

OBJECTIVES: Objectives are (1) to make semiquantitative estimates of soil erosion from farmlands managed with differing agricultural practices, (2) to determine the effect of land laid fallow on the magnitude of soil erosion, and (3) to determine the effect of expected increase in soil erosion on sediment loads in major rivers and their tributaries draining eastern North Dakota.

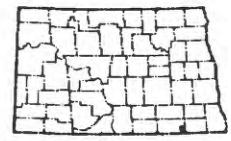
APPROACH: Low-level aerial photography of fallow fields will be employed before and after the major summer rain period. Soil erosion will be estimated from rill patterns on the photographs and calibrated against ground-truth surveys. Calculated soil losses will be compared to suspended-sediment loads at stations in the small basins being investigated.

PROGRESS IN 1986 AND 1987: The principal investigator for the cooperating agency and the project chief both transferred. Cooperator interest in continuing the project was absent, and project activities were terminated.

PLANS FOR 1988: None.

REPORT PRODUCT: Houghton, R.L., and Foss, J.E., 1985, Snowmelt trace-element enrichments in prairie potholes and soils of central North Dakota: National Atmospheric Deposition Program Technical Committee Meeting, Abstracts of Papers, October 8-11, 1985, p. 20.

Heat and Moisture Transfer Model for Seasonally Frozen Soils in North Dakota



PROJECT NUMBER: ND 85-131.

LOCATION: Eastern Dickey County, southeastern North Dakota.

PERIOD OF PROJECT: January 1985 to September 1987.

PROJECT CHIEF: Douglas G. Emerson.

COOPERATING AGENCY: North Dakota State Water Commission.

SOIL-MOISTURE MEASUREMENT

PROBLEM: Snow cover is an important manageable water resource of the northern prairies. To take full advantage of this water resource, an understanding of the processes of runoff and water movement into and through seasonally frozen soils and an operational procedure to quantify these processes are needed.

OBJECTIVES: Objectives are (1) to develop a physically-based model for simulation of flow through seasonally frozen soils, (2) to measure the hydraulic properties of soil types in a study area and collect meteorological and hydrological data for verification of the model, (3) to use the model concurrently with the data-collection process to evaluate the sensitivity of the model to variations in soil hydraulic properties and driving variables, and (4) to couple the model to the U.S. Geological Survey's precipitation-runoff modeling system.

APPROACH: A physically-based heat and water transport model for seasonally frozen soils will be developed. Data collection will consist of measuring the necessary parameters to verify the snow accumulation and melt, soil freezing and thawing, and soil water content.

PROGRESS IN 1986 AND 1987: Data were collected for the winters of 1985-86 and 1986-87. A report that presents the analysis of the 1985-86 data was prepared. A model to simulate heat and moisture transfer for seasonally frozen soils was developed, tested, and verified. The model was coupled to the U.S. Geological Survey's Precipitation-Runoff Modeling System. A report that describes the model and presents the calibrated and verified simulation was prepared.

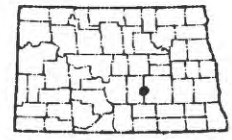
PLANS FOR 1988: Plans are to publish final reports.

REPORT PRODUCTS: Emerson, D.G., 1986, Study plan for heat and water transport in frozen soils, North Dakota, *in* Proceedings of the Symposium Snow Management for Agriculture: Great Plains Agricultural Council Publication No. 120, Swift Current, Saskatchewan, p. 289-298.

Emerson, D.G., Heat and water transfer model for seasonally frozen soils (in progress).

Emerson, D.G., and Sweeney, M.D., Heat and moisture transfer in seasonally frozen soils: An *in-situ* study in south-central North Dakota (in progress).

Ground-Water Flow in the Marstonmoor Aquifer in the Vicinity of Chase Lake, North Dakota



PROJECT NUMBER: ND 85-134.

LOCATION: Kidder and Stutsman Counties, North Dakota.

PERIOD OF PROJECT: April 1985 to September 1986.

PROJECT CHIEF: Thomas B. Reed.

COOPERATING AGENCY: U.S. Department of the Interior, Fish and Wildlife Service.

CHASE LAKE NATIONAL WILDLIFE REFUGE

PROBLEM: Chase Lake National Wildlife Refuge is the sole nesting area for the white pelican. Irrigation wells have been installed near the refuge, and refuge officials fear that pumpage will cause lake-level declines and threaten the nesting area.

OBJECTIVES: The purpose of this study is to determine whether nearby irrigation pumpage can effect a decline in the level of Chase Lake. Objectives are to ascertain ground-water gradients and relative transmissivities adjacent to the lake.

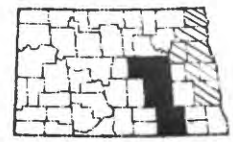
APPROACH: Ground-water wells and meteorological stations will be installed to measure aquifer gradients around the lake and hydrologic impacts to the system. A ground-water flow model will be used to determine whether irrigation pumpage is likely to affect lake levels.

PROGRESS IN 1986 AND 1987: The draft report was completed and began the review process.

PLANS FOR 1988: Plans are to complete the review process, obtain Director's approval for publication, and publish the final report.

REPORT PRODUCT: Reed, T.B., Ground-water flow in the Marstonmoor aquifer in the vicinity of Chase Lake, North Dakota (in progress).

Generation of a Data Base for the James River Salinity Model, North Dakota and South Dakota



PROJECT NUMBER: ND 85-135.

LOCATION: James River basin of eastern North Dakota and South Dakota.

PERIOD OF PROJECT: April 1985 to December 1986.

PROJECT CHIEF: Lawrence I. Briel.

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Reclamation.

PROBLEM: Operation of the Garrison Diversion Unit will bring Missouri River water into the James River basin to augment flows in the James River. The additional flows will permit expanded irrigation and provide a new supply for municipalities and industry. Increased irrigation may increase river-water salinity beyond acceptable limits. Before the U.S. Bureau of Reclamation can predict impacts on river salinity, model inputs must be estimated in a hydrochemically sound manner.

OBJECTIVES: The original objectives of this study were (1) to generate the dissolved-solids loads required by the river-salinity model of the U.S. Bureau of Reclamation in order to evaluate a variety of management options and (2) to index the effect of each option on water quality in the James River basin. The objectives and scope of the project later were expanded to include the generation of similar data bases for carbonate hardness, sulfate, chloride, and sodium loads, and the project area was expanded to include the Sheyenne and Red River basins.

APPROACH: Successive reaches of the river will be defined for purposes of the salinity model. For each reach, input of water-quality and -quantity data is required for modeling surface-water, ground-water, and irrigation return flows. Most information on surface-water contributions will be taken from historical streamflow records. Ungaged surface-water inflows will be estimated from residuals in the flow model and assigned salinities based on historical data. Ground-water data will be estimated from seepage information. Irrigation return flow quality will be estimated from extract or reaction-model data.

PROGRESS IN 1986 AND 1987: The historical data base was screened to eliminate questionable data. Equations relating surface-water salinity to flow were developed for each stream reach. Monthly mean data bases were developed for the period of record. Ground-water and irrigation return flow qualities were estimated from available ground-water and extract quality data. Methods used to develop the monthly mean data bases were documented in an interpretative report that currently is in the review process.

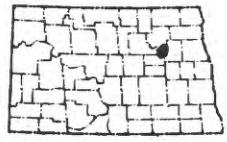
PLANS FOR 1988: Methods used to develop the dissolved solids-streamflow data base for the salinity model were expanded to allow development of data bases for the following conservative water-quality constituents: carbonate hardness, sulfate concentration, chloride concentration, and sodium concentration. Methods used to develop these additional data bases for the James River basin will be documented in the report, "Generation of data bases for four conservative chemical constituents in the James River basin." Methods used to develop five similar data bases for the Sheyenne and Red River of the North basins will be documented in another report, "Generation of data bases for the Sheyenne and Red River of the North basins."

REPORT PRODUCTS: Briel, L.I., Generation of data bases for four conservative chemical constituents in the James River basin (in progress).

Briel, L.I., and Houghton, R.L., Generation of a data base for the James River salinity model, North Dakota and South Dakota (in progress).

Generation of data bases for the Sheyenne and Red River of the North basins (planned).

Ground-Water Flow in the Warwick Aquifer, North Dakota



PROJECT NUMBER: ND 85-136.

LOCATION: Benson, Eddy, and Ramsey Counties, North Dakota.

PERIOD OF PROJECT: April 1985 to December 1986.

PROJECT CHIEF: Thomas B. Reed.

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Indian Affairs.

PROBLEM: It has been proposed to use the Warwick aquifer to irrigate land on the Fort Totten Indian Reservation. However, it is not known if the aquifer can sustain required withdrawals.

OBJECTIVES: The purpose of this study is to augment existing hydrologic knowledge of the Warwick aquifer to determine if the aquifer will sustain planned irrigation withdrawals.

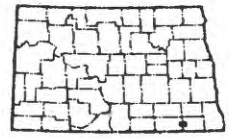
APPROACH: Most hydrologic properties of the aquifer are known. Additional wells will be installed to determine leakage from East Devils Lake into the aquifer and seepage from the aquifer to the Sheyenne River. This information will be sufficient to complete input requirements for a simple ground-water flow model to evaluate irrigation potential.

PROGRESS IN 1986 AND 1987: The draft report was completed and began the review process.

PLANS FOR 1988: Plans are to complete the review process, obtain Director's approval for publication, and publish the final report.

REPORT PRODUCT: Reed, T.B., Ground-water flow in the Warwick aquifer, North Dakota (in progress).

Effects of Irrigation and Ground-Water Recharge Practices on the Quantity and Quality of Shallow Ground Water and on Soil Productivity Along the James River, North Dakota



PROJECT NUMBER: ND 85-137.

LOCATION: Dickey and Sargent Counties, North Dakota.

PERIOD OF PROJECT: May 1985 to September 1988.

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and David M. Sumner (1987-88).

COOPERATING AGENCIES: (1) North Dakota State Water Commission; and (2) U.S. Department of the Interior, Bureau of Reclamation.

COLLECTING CORE SAMPLES

PROBLEM: The Garrison Diversion project includes plans to irrigate about 46,000 acres of land in the Oakes area. To assure sufficient water supply for irrigation, a proposal was made by the 12-member Garrison Diversion Unit Commission to supply irrigation water from the Oakes aquifer and to recharge the aquifer with James River water during peak flows.

OBJECTIVES: The purpose of this study is to provide the means to evaluate effects of an irrigation/ground-water recharge management plan for the Oakes aquifer on ground-water quantity and quality prior to its implementation. Objectives include (1) determination of aquifer thickness and hydraulic properties; (2) development of a regional, two-dimensional ground-water flow model for the Oakes aquifer; (3) development of a three-dimensional ground-water flow model of a single recharge pit; (4) evaluation of the feasibility of other recharge designs; and (5) determination of the effect of the recharge on water quality in the aquifer.

APPROACH: Observation wells will be installed in the Oakes aquifer to provide information on hydraulic heads and water quality. Aquifer tests, core samples, and geophysical logs will be evaluated to determine the hydraulic properties of the aquifer. A two-dimensional ground-water flow model of the aquifer will be developed. Based on design plans for the Garrison Diversion project, a three-dimensional ground-water flow model will be developed to evaluate the operation of a ground-water recharge pit and determine its optimum dimensions. Based on the two models developed, a network of recharge pits necessary to produce the required recharge will be designed by the U.S. Bureau of Reclamation. Effects on the aquifer will be evaluated by another ground-water flow model.

PROGRESS IN 1986 AND 1987: Characterization of the hydraulic properties of the Oakes aquifer was completed, and a draft manuscript detailing the information also was completed. Preliminary evaluation of the effectiveness of recharge pits was completed. A pilot recharge facility was designed and constructed. Recharge experiments were conducted in the fall of 1986 and in the spring and summer of 1987 using water pumped from the James River. Recharge (infiltration) rate; ground-water response; and pond, pore-water, and ground-water quality were monitored throughout the experiments. Principal agents responsible for pit-bottom clogging and slowing of infiltration were identified, and methods of reducing clogging were tested and evaluated.

PLANS FOR 1988: Computer simulation of the infiltration process and of the composite effect of multiple recharge pits on the aquifer will be evaluated. A final report on the recharge experiment will be evaluated.

REPORT PRODUCTS: Shaver, R.B., Hall, R.L., and Houghton, R.L., Feasibility of artificial recharge to the Oakes aquifer, southeastern North Dakota: Part III--Water-quality data for the Oakes aquifer (in progress).

Shaver, R.B., Houghton, R.L., and Schuh, W.M., Feasibility of artificial recharge to the Oakes aquifer, southeastern North Dakota: Part I--Hydrogeology of the Oakes aquifer (in progress).

Shaver, R.B., Schuh, W.M., and Wald, J.D., Feasibility of artificial recharge to the Oakes aquifer, southeastern North Dakota: Part II--Lithostratigraphic and well data for the Oakes aquifer (in progress).

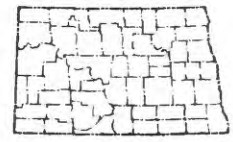
Experimental artificial recharge of the Oakes aquifer--Effects on water quality (planned).

In Situ Monitoring of Organic Contaminants in Ground Water Using a Portable Field Laser Fluorescence Spectrometer

PROJECT NUMBER: ND 86-140.

LOCATION: Statewide to national.

PERIOD OF PROJECT: July 1986 to September 1988.



STATEWIDE

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: North Dakota State University.

PROBLEM: Organic compounds frequently require expensive and individual analytical techniques to identify and quantify. Additionally, many organic compounds are altered in phase or concentration during normal sampling methods. Because most organic compounds on the priority pollution list are fluorescable, most of these compounds could be measured *in situ* by fluorescence spectroscopy if a portable laser fiber-optic spectrometer was available.

OBJECTIVES: The purpose of this study is to design, construct, calibrate, and field test a portable laser fluorescence spectrometer capable of determining the concentrations of many fluorescable organic compounds in ground water without sampling or additional pretreatment.

APPROACH: A portable laser fluorescence spectrometer will be constructed using laser and fiber-optic technologies. The spectrometer will be calibrated to determine its detection limits, optimal excitation and emission wavelengths, and interferences for organic compounds of interest. Finally, the spectrometer will be tested under actual field conditions at sites of groundwater contamination.

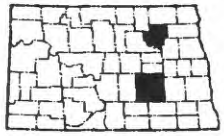
PROGRESS IN 1986 AND 1987: A portable laser fluorescence spectrometer utilizing remote fiber-optic excitation and detection systems was designed. Each element was constructed separately and evaluated independently. Redesign was undertaken based on this evaluation. A new yttrium-aluminum-garnet (YAG) laser system was ordered to replace a previous system that failed. Preliminary chemical-specific identification systems and spectra libraries were initiated.

PLANS FOR 1988: Plans are to complete construction of the portable system by assembling tested elements. Instrumentation will be field tested against standard laboratory analytical methods at a hazardous waste site.

REPORT PRODUCT: Design and use of a portable laser fluorescence spectrometer to determine organic compounds in ground water (planned).

Trace-Element Distributions in Flow-Through Prairie-Pothole Wetlands in North Dakota

PROJECT NUMBER: ND 87-141.



LOCATION: Stutsman and Ramsey Counties, North Dakota.

PERIOD OF PROJECT: March 1987 to September 1989.

PROJECT CHIEFS: Robert L. Houghton (1987; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCIES: (1) North Dakota State University, and (2) North Dakota Geological Survey.

FLOW-THROUGH PRAIRIE POTHOLE WETLANDS

PROBLEM: Prairie-pothole wetlands occupy more than 2,471,000 acres in central and eastern North Dakota, representing an important hydrologic and ecologic resource to the State and the Nation. Potholes directly influence the quantity and quality of much of the State's surface water and surficial ground water. Yet many of these potholes continue to be drained to increase agricultural acreages. Studies of prairie soils (such as ND86-138) indicated that soils receiving large fluxes of water can concentrate relatively small concentrations of trace elements to undesirable environmental levels when concentrating mechanisms occur. These conditions are particularly prevalent in flow-through prairie potholes. If these processes are occurring in North Dakota wetlands, important wildlife habitat could be endangered. Existence of these processes also could argue against agricultural drainage as the land also would be unsuitable for subsequent agricultural use.

OBJECTIVES: The purpose of this study is to determine geochemical controls on trace-element concentrations in flow-through wetlands and the effect of drainage on the mobility of these concentrations. Specific objectives are (1) to determine trace-element concentrations in water, soil, and vegetation in selected flow-through and drained wetlands in common settings; (2) to determine trace-element concentrations in water, soil, and vegetation before, during, and after drainage of a flow-through wetland in a well-documented, calibrated watershed; and (3) to determine the geochemical processes responsible for concentration of trace elements in the soils of flow-through wetlands and how these processes change in response to drainage.

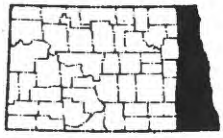
APPROACH: Three paired drained and undrained flow-through potholes in Ramsey County and one additional pair in Stutsman County will be studied. Trace-element concentrations and the concentrations of other chemicals and properties that might control trace-element concentrations in soil, water, and vegetation in each of the six principal ecological zones of the wetlands will be determined. The results will be evaluated in a statistically valid manner and distributed using a three-dimensional krige program.

PROGRESS IN 1986 AND 1987: Study sites were selected and sampling was initiated. Preliminary electromagnetic conductivity surveys of the study sites were undertaken.

PLANS FOR 1988: Plans are to complete laboratory analysis of site samples, begin statistical analysis of the data, and start a drainage project of an existing flow-through wetland.

REPORT PRODUCT: Mechanisms of trace-element concentrations in flow-through prairie-pothole wetlands (planned).

Trace-Element Contributions to the Environment from Mesozoic Rocks of North Dakota



PROJECT NUMBER: ND 87-142.

LOCATION: Eastern North Dakota.

PERIOD OF PROJECT: July 1987 to September 1988.

PROJECT CHIEFS: Robert L. Houghton (1987; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: North Dakota Geological Survey.

DRILL RIG USED TO COLLECT ROCK SAMPLES

PROBLEM: Numerous investigators have suggested that Mesozoic rocks are the most important sources of arsenic, selenium, and associated heavy metals in the northern Great Plains. A large area of arsenic enrichments in glacial aquifers overlying Mesozoic bedrock in southeastern North Dakota and areas of selenium enrichments in glacial aquifers of the Lake Agassiz plain also have been identified. Elevated concentrations of such trace elements can have important health, environmental, and agricultural implications, especially in regard to resource utilization. Presently, there is a serious lack of information on both the regional and local distribution and variability of these trace elements in the North Dakota part of the Mesozoic section. Additionally, little is known about the manner in which these rocks can yield trace elements to the ground-water system.

OBJECTIVES: The purpose of this study is to determine the concentration, phase-specific distribution, and availability of trace elements in Mesozoic rocks of eastern North Dakota.

APPROACH: Initially, 40 fresh samples of Mesozoic rock from the University of North Dakota core library will be analyzed for total and phase-specific concentrations of arsenic and selenium. Data will be evaluated to determine the conditions under which these trace elements might be mobilized. Once these conditions are identified, ground-water concentrations in areas possessing these conditions will be evaluated. Rock samples from other areas believed to have these conditions will be included in an additional round of analyses.

PROGRESS IN 1986 AND 1987: Mesozoic rock samples for initial analysis were selected. Analyses of total trace-element concentrations were completed. Phase-specific extractions were initiated.

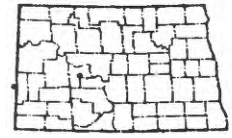
PLANS FOR 1988: Phase-specific extractions will be completed and the data evaluated. Additional sample requirements will be evaluated.

REPORT PRODUCT: Trace-element distributions in Mesozoic rocks of eastern North Dakota (planned).

ENERGY-RELATED STUDIES

Expanding domestic energy demand has resulted in increased coal production and associated development in North Dakota. To meet the requirements for coal leasing and environmental protection, the U.S. Geological Survey is conducting studies to evaluate the water resources in areas of current and planned development. These studies are effected through the cooperation of interested agencies and the U.S. Geological Survey.

Evaluation Through Modeling of Probable Surface-Water Hydrologic Effects of Future Lignite Mining and Reclamation Activities in the Antelope Creek Area, Mercer County, North Dakota, and the Wibaux-Beach Deposit Area, Wibaux County, Montana, and Golden Valley County, North Dakota



PROJECT NUMBER: ND 80-087.

LOCATION: Mercer County, North Dakota, and Wibaux County, Montana.

PERIOD OF PROJECT: October 1979 to September 1982.

PROJECT CHIEF: Douglas G. Emerson.

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Land Management.

WEST BRANCH ANTELOPE CREEK

PROBLEM: The U.S. Bureau of Land Management has the responsibility of evaluating leasing applications for mining of Federal coal. Their evaluations must address environmental impacts, which include those of hydrology. A basic problem to be addressed in this study is the assessment of impacts of surface mining on the surface-water hydrology of mined and adjacent unmined areas.

OBJECTIVES: Objectives are (1) to determine premining hydrologic conditions in a small representative drainage basin, (2) to provide historical data with which to compare the magnitude of change with mining, and (3) to develop the capability of making reasonably accurate projections of hydrologic effects resulting from the various land treatments imposed by surface mining.

APPROACH: This will be a comprehensive study of two small representative watersheds. A surface-water model will be developed through coupling of snowmelt-rainfall runoff models. A modular-design program will be used with each element of the hydrologic system being defined by a subroutine. This program has the capability of combining subroutines to best fit a particular problem. A distribution-parameter approach is being used by having the basin partitioned into subunits based on slope, aspect, vegetation type, soil type, and snow distribution. Each subunit will be considered homogeneous with respect to these parameters. Partitioning into subunits will help define the temporal and spatial variations of the hydrologic characteristics, climatic variables, and overall system response.

PROGRESS IN 1986 AND 1987: The analysis report was revised after colleague review.

PLANS FOR 1988: Publication of the analysis report is anticipated.

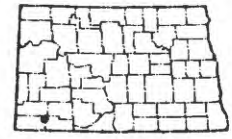
REPORT PRODUCTS: Emerson, D.G., 1981, Progress report on the effects of surface mining on the surface-water hydrology of selected basins in the Fort Union coal region, North Dakota and Montana: U.S. Geological Survey Open-File Report 81-678, 28 p.

Emerson, D.G., 1982, Hydrologic analysis of high flow from snowmelt on small basins in the Fort Union coal region: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., April 22-24, 1982, v. 36, p. 42.

Emerson, D.G., Norbeck, S.W., and Boespflug, K.L., 1983, Data from the surface-water hydrologic investigations of the Hay Creek study area, Montana, and the West Branch Antelope Creek study area, North Dakota, October 1976 through April 1982: U.S. Geological Survey Open-File Report 83-136, 273 p.

Emerson, D.G., Hydrologic analyses of Hay Creek, Montana, and West Branch Antelope Creek, North Dakota (in progress).

Geochemistry of the Upper Fort Union Group as Related to Impacts of Strip Mining of Lignite in the Gascoyne Area, North Dakota



PROJECT NUMBER: ND 80-089.

LOCATION: Southwestern North Dakota.

PERIOD OF PROJECT: October 1979 to September 1985.

PROJECT CHIEF: Robert L. Houghton (now in Reston, Va.).

COOPERATING AGENCIES: (1) North Dakota Geological Survey (1980-83); (2) North Dakota Public Service Commission (1983-85); (3) U.S. Department of the Interior, Bureau of Land Management (1980-82); and (4) U.S. Environmental Protection Agency (1981-82).

MINING OF LIGNITE IN GASCOYNE AREA

PROBLEM: Simultaneous demands for expanded surface-mining activity, agricultural production, and urban development are placing ever-increasing strains on the land and water resources of the region. Studies of the environmental effects of surface mining have begun to provide the data base required to make these land-use decisions, but failure to understand the geochemistry of water-rock interactions may seriously limit the options for future coal development in the Fort Union coal region. Definition of these reaction mechanisms and rate-controlling factors could lead to the recognition of critical parameters governing probable water-rock interactions at other and projected mine sites within the Fort Union lignite region.

OBJECTIVES: The purpose of this study is to quantitatively describe major controls on the movement of critical solutes in local and regional ground-water systems within the Fort Union Group affected by surface mining of lignite in western North Dakota. Objectives at the Gascoyne site are to define the hydrogeologic and hydrogeochemical character of the shallow ground-water system in the area and to ascertain the source of observed anomalous sulfate concentrations. The effects of discharge of mine-impacted ground water on the surface-water system in the area also are of concern.

APPROACH: The first phase will be to establish a clear and complete understanding of the hydrologic regime. Next, the mineralogy and mineral chemistry of the Fort Union Group will be determined. Thirdly, formation cation-exchange rates and constants will be determined. Fourth, oxidation-reduction reactions will be defined for important species pairs. Finally, the solute flux from mine to locations of water use must be defined as mining expands.

PROGRESS IN 1986 AND 1987: Continued monitoring of 25 ground-water wells and one surface-water station on a tributary of Buffalo Creek draining the mine area provided additional data on temporal hydrochemical changes in the vicinity of the Gascoyne mine. Review of the data base to identify which chemical parameters in ground and surface water best indicate mine impact was continued.

PLANS FOR 1988: Monitoring at the surface-water station on Buffalo Creek Tributary No. 2 will be discontinued. Monitoring of the ground-water wells will continue with three to four new spoils wells. A summary of the existing hydrochemical data will be developed.

REPORT PRODUCTS: Fisher, D.W., Thorstenson, D.C., Croft, M.G., and Houghton, R.L., 1985, Geochemical processes in the Gascoyne lignite mining area, Bowman County, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 84-4192, 80 p.

Houghton, R.L., 1982, Hydrochemistry of shallow ground water from the Fort Union Group near the Peerless lignite strip mine, Gascoyne, southwestern North Dakota [abs.]: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., p. 40.

Houghton, R.L., 1982, Hydrogeochemical consequences of strip mining in the Fort Union Group of southwestern North Dakota: Proceedings of the 1982 National Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation, Lexington, Ky., December 6-10, 1982, p. 79-86.

Houghton, R.L., 1982, Trace-element enrichments in waters associated with strip mining of lignite in the Fort Union Group of southwestern North Dakota [abs.], *in* Gough, L.P., and Severson, R.C., eds., Trace-element mobilization in western energy regions: Colorado School of Mines Research Institute, Golden, Colo., p. 46.

Houghton, R.L., 1982, Weathering of coal scoria--a source for diagenetic silica cements? [abs.]: Proceedings of the U.S. Geological Survey Workshop on Diagenesis, Denver, Colo., March 1982, p. 36.

Houghton, R.L., and Davison, D., 1982, Stratigraphy and paleoenvironment of the Paleocene Fort Union Group of the Williston basin near Gascoyne, southwestern North Dakota [abs.]: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., p. 15.

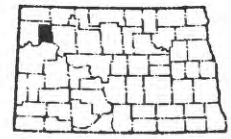
Houghton, R.L., Thorstenson, D.C., Fisher, D.W., and Groenewold, G.H., 1984, Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota: U.S. Geological Survey Open-File Report 84-131, 184 p.

Houghton, R.L., 1985, Inverse modeling of solute transport in shallow ground water, With an example of sulfate movement around a lignite mine in southwestern North Dakota: Proceedings, 77th Annual Meeting of the North Dakota Academy of Science, Minot, N. Dak., v. 39, p. 53.

Houghton, R.L., 1987, Probable and observed hydrologic consequences of lignite strip mining in the Fort Union Group near Gascoyne in southwestern North Dakota--Ground-water study 9, *in* Richards, D.B., ed., Ground-water information manual--Coal mine permit applications, volume II: U.S. Office of Surface Mining Reclamation and Enforcement, p. 299-335.

Houghton, R.L., Thorstenson, D.C., Fisher, D.W., and Groenewold, G.H., 1987, Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota: U.S. Geological Survey Professional Paper 1340, 104 p.

Evaluation of Probable Hydrologic Effects of Future Lignite Mining and Subsequent Reclamation Activities in the M & M Deposit, Williams County, North Dakota



PROJECT NUMBER: ND 81-091.

LOCATION: Northwestern North Dakota.

PERIOD OF PROJECT: October 1980 to September 1983.

PROJECT CHIEFS: William F. Horak, Jr. (1980-83; now in Oklahoma City, Okla.), Clarence A. Armstrong (1984-85; retired), and Robert L. Houghton (1986-87; now in Reston, Va.).

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Land Management.

ABANDONED LIGNITE MINES

PROBLEM: There is a lack of reliable and detailed geologic and hydrologic data for the assessment of the hydrologic effects of strip mining the lignite coal in North Dakota. The mining will, in some areas, affect the availability of water from shallow wells. The quality of water will be changed through displacement and mixing of overburdened materials. Sediment yields from the areas will be changed. The ground-water interrelationship with surface water will be altered. None of these effects can be evaluated without a thorough knowledge of present hydrologic conditions.

OBJECTIVES: Objectives are (1) to define the hydrologic regime in the greatest possible detail consistent with the duration of the study and funding, including assessment of the ground-water flow system and its chemical characteristics, determination of flow frequencies and magnitude, chemical quality, and sediment concentration and load of the larger streams; (2) to establish a historical data base; and (3) to develop the capability for projecting the hydrologic effect of physical treatments imposed by surface mining.

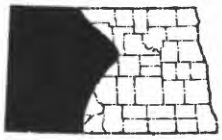
APPROACH: Data will be assembled and collected for use in conjunction with digital models to define the ground-water flow system. The surface-water system will be defined through available records, data collection, and regionalized equations. Quality of water will be defined through an intensive sampling program. Methods for estimating the hydrologic effects of various land treatments imposed by mining will be developed.

PROGRESS IN 1986 AND 1987: The draft report proceeded through review and was approved for publication.

PLANS FOR 1988: Plans are to publish the final report.

REPORT PRODUCT: Armstrong, C.A., Crosby, O.A., Horak, W.F., and Houghton, R.L., Hydrologic system and probable hydrologic consequences of mining in the M & M lignite area, southeast Williams County, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 87-4134, 48 p. (in press).

Surface-Water Resources, Fort Union Coal Region of Western North Dakota



PROJECT NUMBER: ND 82-107.

LOCATION: West-central North Dakota.

PERIOD OF PROJECT: October 1977 to September 1982.

PROJECT CHIEFS: Norman D. Haffield (1977-86), Rowland L. Hall (1987), and George Garklavs (1988).

COOPERATING AGENCIES: Other Federal agencies.

COAL MINE IN FORT UNION COAL REGION

PROBLEM: Because of increasing demands for energy, coal resources in the Fort Union coal region of western North Dakota have been undergoing extensive development. Mining and associated activities will put a demand on the water resources and could alter the chemical quality and flow characteristics of local streams. Because it will be necessary for resource developers to make decisions in order to use and protect the available water resources, there is a need for a comprehensive and easily understood source of data that describes the existing hydrologic system.

OBJECTIVES: The purpose of this study is to describe the surface-water resources of the Fort Union coal region of western North Dakota in a readily usable format. Objectives are (1) to determine the streamflow and water-quality characteristics for the streams located in the region and (2) to describe seasonal and areal variations that occur within the various stream systems.

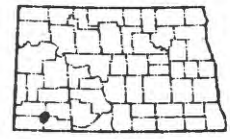
APPROACH: All existing data will be condensed and analyzed in order to define the characteristics of the various components of the streamflow systems that are located within the region.

PROGRESS IN 1986 AND 1987: Statistical analysis of the data was completed, a draft report prepared, and report review initiated.

PLANS FOR 1988: Plans are to complete the review process and publish the final report.

REPORT PRODUCT: Hall, R.L., Surface-water resources of the North Dakota coal region (in progress).

Evaluation of the Hydrologic System in the New England-Mott Coal Area, Adams and Hettinger Counties, North Dakota



PROJECT NUMBER: ND 83-110.

LOCATION: Southwestern North Dakota.

PERIOD OF PROJECT: October 1982 to December 1983.

PROJECT CHIEFS: Mack G. Croft (1982-85; retired) and George Garklavs (1986).

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Land Management.

NEW ENGLAND-MOTT COAL AREA

PROBLEM: The need for the proposed study came about as a response to the Interior Department's request for hydrologic information concerning Federal coal lands leased and eligible for lease within the New England-Mott lignite deposit. Probably the most obvious effect of coal development in the study area will be the disruption of aquifers existing in the lignite beds and overburden material. The majority of farmsteads in the area (virtually all rely on ground water for their water supply) draw water from wells 400 feet or less in depth. Depending on the hydraulic properties and the areal continuity of the lignite and adjacent aquifer, many of these water supplies could be diminished or obliterated. Any coal-development-induced diminuation of streamflow, increase in dissolved chemical constituents, or increase in sediment load could have an effect on the usability of water in Thirty Mile Creek and the Cannonball River.

OBJECTIVES: The primary objective will be to define the hydrologic regime in the greatest possible detail consistent with the project duration and funding. This includes assessment of the ground-water flow system and chemical characteristics and determination of surface-water flow magnitudes, chemical quality, sediment concentration, and sediment load. By defining the hydrologic regime of the study area, a second objective will be satisfied--the establishment of a historical data base with which to monitor changes in the system as mining proceeds.

APPROACH: Existing geologic and hydrologic data will be assembled and used to establish an information framework of the study area. Limited surface-runoff, water-level, and quality-of-water information will be collected in the field. Where possible, regionalized information will be used to define the hydrology. The final report will assess the available information and make recommendations as to whether further study is needed for leasing purposes.

PROGRESS IN 1986 AND 1987: A detailed project proposal and work plan was prepared. A limited canvass of wells and collection of additional water samples was completed in the area. Data were assembled and illustrations and text prepared. The report is being revised to include additional information on ground-water quality.

PLANS FOR 1988: Plans are to process reviews and obtain Director's approval for publication.

REPORT PRODUCTS: Wald, J.D., and Norbeck, S.W., 1983, Ground-water data for selected coal areas in western North Dakota: U.S. Geological Survey Open-File Report 83-219, 229 p.

Croft, M.G., Hydrology of New England-Mott coal area, North Dakota (in progress).

Hydrochemical Impacts of Surface Mining of Lignite--The Sulfur Cycle

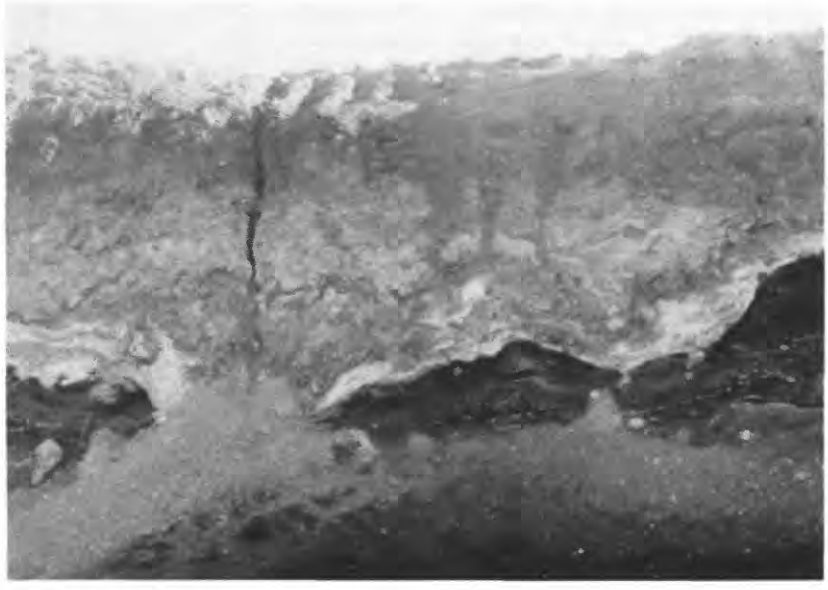
PROJECT NUMBER: ND 83-113/114.

LOCATION: Fort Union coal region, North Dakota.

PERIOD OF PROJECT: October 1983 to September 1984.

PROJECT CHIEFS: Robert L. Houghton (1983-87; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: North Dakota Geological Survey.



LIGNITE SURFACE MINE

PROBLEM: Hydrogeochemical studies of the impacts of surface mining of lignite in recharge areas of the northern Great Plains have not unambiguously defined the sulfur cycle. As sulfate is the principal cause of ground-water deterioration in the vicinity of mines, it is vital that the sulfur cycle be defined so that appropriate reclamation procedures may be developed to mitigate sulfate generation.

OBJECTIVES: Detailed geochemical investigations will be made to quantitatively describe the sulfur sources that contribute to ground-water sulfate in strip mines situated in recharge zones and to determine the hydrogeochemical processes that control the sulfur path to the ground water. Isotopic studies will be employed (1) to trace sulfur transformations among solid and aqueous species present throughout the sulfur cycle, (2) to quantify the relative magnitude of each transformation as a contributor to ground-water sulfate concentrations, and (3) to determine which transformations are affected by biological activity.

APPROACH: Cores and ground- and pore-water samples will be obtained from two active strip mines and one potential mine site. Sulfur species present at various depths will be identified and the sulfur isotopic ratios will be used to determine transformation paths. Samples also will be obtained with minimal contamination for determination of the presence and activity of sulfur-metabolizing microorganisms. Comparison of organism distributions and isotopic ratios will be used to determine the stages at which biological activity affects the sulfur cycle. Observations will be simulated in the laboratory as a control check.

PROGRESS IN 1986 AND 1987: Preliminary drafts of final reports were initiated.

PLANS FOR 1988: Final reports will continue to be processed toward publication.

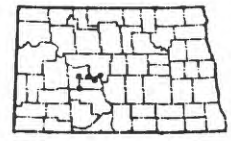
REPORT PRODUCTS: Houghton, R.L., Koob, R.D., and Groenewold, G.H., 1985, Progress report on the geochemistry of the sulfur cycle in northern Great Plains coal mines: U.S. Geological Survey Water-Resources Investigations Report 85-4016, 70 p.

Houghton, R.L., Koob, R.D., and Groenewold, G.H., 1985, Sulfur cycle in western coal mines, *in* Hitchon, Brian, and Wallick, E.I., eds., Proceedings of the First Canadian/American Conference on Hydrogeology--Practical Applications of Ground-Water Geochemistry, Banff, Alberta, Canada, June 22-26, 1984: Worthington, Ohio, National Water Well Association, p. 306-314.

Houghton, R.L., Koob, R.D., Groenewold, G.H., and Brekke, Dave, Geochemistry and microbiology of sulfur in shallow ground-water systems associated with lignite deposits, North Dakota (in progress).

Evaluation of Effects of Ongoing and Future Mining and Reclamation Activities in Western North Dakota

PROJECT NUMBER: ND 83-115.



LOCATION: Western North Dakota.

PERIOD OF PROJECT: October 1982 to September 1985.

PROJECT CHIEF: Douglas G. Emerson.

COOPERATING AGENCY: North Dakota Public Service Commission.

WESTERN NORTH DAKOTA

PROBLEM: The State of North Dakota and the Department of the Interior have signed a cooperative agreement whereby the State will regulate surface coal mining and reclamation operations on Federal lands in North Dakota. The North Dakota Public Service Commission serves as the State regulatory authority to administer this agreement as well as the regulations for State- and privately-owned lands. Although the obligation for hydrologic monitoring to determine the effects of mining falls to the mining company, the North Dakota Public Service Commission needs unbiased information to effectively assure adherence to the regulations.

OBJECTIVES: The purpose of this study is to provide the capability to assess and predict the effects of mining and energy development on the hydrologic system. Objectives are (1) to monitor the variations in the quantity and quality of surface water below active energy-development sites, (2) to use the data collected to augment and refine predictive models presently available, and (3) to verify the transferability of a calibrated watershed model.

APPROACH: The study includes the operation of five stream-gaging and water-quality sites, one complete weather station, and three precipitation sites. The U.S. Geological Survey's Precipitation-Runoff Modeling System has been selected as the predictive model. The model has not been completely calibrated for the site where the model was developed, but this site is one of the five to be operated under this project. Plans are to collect enough data at the sites to check verification of the model. The present plans are to collect data for 3 years depending on runoff conditions.

PROGRESS IN 1986 AND 1987: Streamflow data were collected on a continuing basis and were published in the annual water-resources data report. A data report that contains meteorological data was prepared.

PLANS FOR 1988: Plans are to publish the data report.

REPORT PRODUCT: Macek-Rowland, K.M., Emerson, D.G., and Houghton, R.L., Meteorologic data for West Branch Antelope Creek stations and Canfield Lake station in west-central North Dakota, May 1982 through September 1986 (in progress).

Hydrogeologic and Geochemical Data Base for Coal Areas in North Dakota

PROJECT NUMBER: ND 85-132/133.

LOCATION: Fort Union coal region, North Dakota.

PERIOD OF PROJECT: October 1984 to September 1986.

PROJECT CHIEF: Lawrence I. Briel.

COOPERATING AGENCIES: (1) U.S. Department of the Interior, Bureau of Land Management; and (2) North Dakota Public Service Commission (preproject).

COLLECTING CORE SAMPLES

PROBLEM: Models of the principal geochemical processes controlling water quality in North Dakota and the effects of mining on these processes have been developed during other investigations. Chemical characteristics are determined routinely on overburden and spoils both prior to and during mining as part of the permitting requirements and also have been collected during scientific investigations of the hydrochemical consequences of mining. Accordingly, a large and growing body of data exists for use as input to chemical models. However, data collected by the various industry and government groups are not readily accessible.

OBJECTIVES: The purpose of this study is to develop a geochemical data base storing data required as input to the model that has been developed to predict the hydrochemical consequences of mining. Objectives include (1) designing a data base for storage of overburden geochemical data required to run models to predict the hydrochemical consequences of mining, (2) initiating data transfer from other data files to this data base, and (3) providing access to the data base by all participating industries and agencies while protecting the propriety of provisional data.

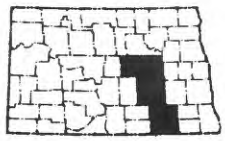
APPROACH: Design of the data base will be undertaken in a tiered fashion. Individual samples will be identified uniquely by geographic location, depth, date and time of collection, and medium type. Numerical parameter codes will be used to identify individual sample constituents or properties, analytical methods, and collecting and analyzing agencies for which data values are stored. To facilitate rapid development of the data base and ease of use by others, the data base will be designed around the existing U.S. Geological Survey WATSTORE data base. The WATSTORE control code will be modified to extend sample identification to include the depth parameter.

PROGRESS IN 1986 AND 1987: Most of the necessary software has been written and tested, and the data base has been populated.

PLANS FOR 1988: A user manual and documentation of the data base will be prepared.

REPORT PRODUCT: User manual and documentation for hydrogeologic and geochemical data base management system (planned).

Evaluation of the Potential for Toxic-Element Consequences Due to the Garrison Diversion Unit, North Dakota and South Dakota



PROJECT NUMBER: ND 86-138.

LOCATION: James River basin, North Dakota and South Dakota.

PERIOD OF PROJECT: March 1986 to September 1987.

PROJECT CHIEFS: Robert L. Houghton (1986-87; now in Reston, Va.) and Lawrence I. Briel (1988).

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Reclamation.

PROBLEM: Arid to semiarid conditions and the common occurrence of fine-grained, frequently organic-rich, marine sediments and their erosion products in western North America provide a potential source of a variety of toxic elements. Changes in environmental conditions, such as those accompanying irrigation and associated water projects, may provide for enhanced concentration or remobilization of these elements, potentially limiting water and soil use and affecting the ecological system dependent upon the resources. Proposed expansion of irrigation in the James River basin as part of the Garrison Diversion Unit could produce such consequences. Because the need to be concerned about these processes was recognized only recently, the expertise necessary to evaluate the potential consequences of Garrison is not available in any single agency and the procedures required to assess the potential are not fully developed.

OBJECTIVES: The purpose of this study is to evaluate the potential effects of expanded irrigation within the Garrison Diversion Unit on the mobility and availability of potentially toxic trace elements. Objectives include identification of the concentration, distribution, speciation, and mobility of potentially toxic trace elements in areas of proposed irrigation development within the Garrison Diversion Unit.

APPROACH: The U.S. Geological Survey, Water Resources Division, North Dakota District, is coordinating investigations by the Water Resources Division and the Geologic Division, according to the expertise of each. The study will be conducted in two phases: (1) A preliminary phase designed to provide a reasonable assessment of the potential consequences of Garrison Diversion Unit development on the availability of potentially toxic trace elements in time to be included in the final Environmental Impact Statement and (2) a research phase that will expand on the confidence level of preliminary studies and permit development of Garrison Diversion Unit management practices that may be expected to limit or prevent concentration or remobilization of potentially toxic trace elements.

PROGRESS IN 1986 AND 1987: An auger was used to obtain soil borings at 18 potentially irrigable areas representing 13 soil-classification series. Eighty soil samples from these borings were frozen and analyzed for total trace-element contents and soluble and phase-specific trace-element contents of arsenic, mercury, and selenium. Contents for any single trace element varied widely, and contents were not correlable with other soil parameters known on a geographic basis. Accordingly, trace-element data could not be geographically distributed, and mass-balance drainage-quality models could not be developed. In an effort to find a means of geographically distributing the data, an additional 150 soil samples from about 35 gridded sites in a single irrigation area near Oakes were analyzed as before. Statistical, kriging, and topologic methods were used to attempt to distribute the data. Preliminary analysis indicated the data could not be directly distributed. Accordingly, Fourier analysis was employed to develop multiple component correlations for distribution. Evaluation of this approach will be complete by the end of 1987.

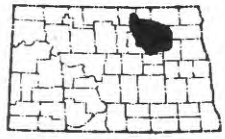
PLANS FOR 1988: Once the Fourier analyses are complete, statistical, kriging, and topologic distributions will be repeated. The selected distribution will be used as input for a mass-balance drainage-quality model of the Oakes irrigation area. Prediction of the minimum number of samples required to geographically distribute the data will be made.

REPORT PRODUCTS: Houghton, R.L., and Briel, L.I., 1987, Arsenic and selenium in irrigable soils of eastern North Dakota: Proceedings of the North Dakota Academy of Science, v. 41, p. 64.

Toxic-element distribution and availability in soils within the Garrison Diversion unit, James River basin, North Dakota (planned).

Evaporation and Ground-Water Interaction of Devils Lake, North Dakota

PROJECT NUMBER: ND 86-139.



LOCATION: Devils Lake basin, northeastern North Dakota.

PERIOD OF PROJECT: April 1986 to September 1988.

PROJECT CHIEF: Gregg J. Wiche.

COOPERATING AGENCY: North Dakota State Water Commission.

INSTALLATION OF METEOROLOGIC INSTRUMENTATION

PROBLEM: The Devils Lake basin in northeastern North Dakota is a 3,800-square-mile closed basin in the drainage of the Red River of the North. About 3,310 square miles of the total 3,800 square miles is tributary to Devils Lake; the remaining 490 square miles is tributary to Stump Lake. High water levels of Devils Lake (and other terminal lakes) in recent years have threatened highways, agricultural land, recreational cabins, and communities located near the lake. Although high water levels have been the main hydrologic problem in the past 10 years, from 1880 to 1930 water levels declined. As water levels declined, lake salinity increased and the fish population declined. By 1940, Devils Lake consisted of a shallow brackish body of water.

State government, local government, and water-resources management groups are concerned about protecting (1) their property, (2) the multimillion dollar fishing and tourist-trade industry, and (3) water for future development. Governmental groups have expressed additional concern about the effect of water-level and associated water-quality fluctuations of Devils Lake on leaching of nutrients and trace elements from bottom material enriched in such constituents from prior low-water stands. Wetland-drainage and agricultural practices also appear to be altering the availability of nutrients, pesticides, and sediment to the lake, and eutrophication recently has become a problem. Expanding irrigation in the area poses a threat of mobilizing selenium and other potentially toxic trace elements and accelerating the concentration mechanisms active in all closed basins. Potential quantity and quality impacts in the Devils Lake basin in the next decade are numerous. Furthermore, because most of the lakes are connected hydraulically to shallow glacial aquifers that are the major water sources in the area, contamination of the surface-water system may have far-reaching consequences.

To assist water management in the basin, a water-accounting model has been developed. However, uncertainties in some controlling input parameters made the model unsuitable for predictive use. Principal uncertainties exist for evaporation data and surface-water/ground-water interactions. Because these data are poorly known throughout eastern North Dakota, methods of investigation developed to refine these data and data determined for Devils Lake might improve our understanding of the hydrologic system throughout the eastern part of the State.

OBJECTIVES: The purpose of this study is to measure the principal hydrologic components that cause water-level fluctuations of Devils Lake. The major emphasis will be to measure evaporation from Devils Lake and estimate the direction and magnitude of the ground-water flux component because these components are the least known. The accuracy of measurements of direct inflow will be improved with the installation of gages in currently ungaged tributaries. Precipitation will be measured by a network of observers throughout the basin.

APPROACH: Evaporation will be computed using the energy-budget technique. Data that will be collected are incoming and reflected shortwave and longwave radiation, air temperature, dewpoint, temperature of discharge of inlet streams, temperature and quantity of ground-water seepage, lake-surface temperature, and periodic temperature surveys of the entire water body to measure changes in stored heat.

The ground-water flux will be estimated by installing a series of shallow water-table wells around Devils Lake in transects extending from the shoreline to the topographic divide. Water-level measurements, conductivity, and temperature will be determined. Near-shore measurements of temperature and conductivity profiles will be made along transects across parts of the lake intersected by shallow aquifers. These profiles will be accompanied by *in situ* measurements of flow rate and direction in lake-bottom sediments using temporary piezometers.

Measurements of precipitation falling on the lake will be refined by employing an observer network distributed around the lake. Additional gages will be installed to improve measurement of inflow to the lake.

PROGRESS IN 1986 AND 1987: Meteorologic instrumentation was installed to compute evaporation. About 65 shallow water-table wells were drilled. Evaporation from the lake surface and inflow to Devils Lake have been computed for 1986. Initial ground-water table contour maps have been drafted.

PLANS FOR 1988: Data collection will continue at the established stations and will be supplemented by thermal surveys of the lake to be conducted on a quarterly basis. Preliminary data evaluation will be used to plan next year's activities.

REPORT PRODUCT: Evaporation and ground-water interaction of Devils Lake, North Dakota (planned).

BOARDS AND COMMISSIONS

PROJECT NUMBER: ND 73-064.

LOCATION: Bismarck, North Dakota.

PERIOD OF PROJECT: Continuous.

PROJECT CHIEF: L. Grady Moore.

COOPERATING AGENCIES: Other Federal agencies.

PROBLEM: To coordinate water-resources activities with International, other Federal, State, and local agencies, District personnel must participate actively on numerous boards and commissions. Participation frequently includes compilation, publication, and dissemination of meeting minutes or researching special concerns of participating agencies.

OBJECTIVES: Primary objectives are (1) to assure impartial Federal representation on the International Souris River Board of Control (International Joint Commission) and the Yellowstone River Compact Commission and (2) to supply accurate, unbiased information to boards and commissions.

APPROACH: Chair the meetings and provide administrative support to the Yellowstone River Compact Commission. Serve as member for the United States to the International Souris River Board of Control. Furnish information requested by members of the International Souris-Red River Engineering Board.

PROGRESS IN 1986 AND 1987: The 1985 and 1986 Annual Reports of the International Souris River Board of Control were printed and distributed. Meetings of the Board were held January 30, 1986, in Moose Jaw, Saskatchewan; May 21, 1986, in Boissevain, Manitoba; February 3, 1987, in Bismarck, N. Dak.; and May 21, 1987, at the Upper Souris National Wildlife Refuge in Foxholm, N. Dak. Information was routinely furnished to parties concerned with Souris River streamflow.

The 1986 Annual Report of the Yellowstone River Compact Commission was printed and distributed. The Commission met via telephone conference call on December 16, 1986.

PLANS FOR 1988: All meetings of the International Souris River Board of Control will be attended. The Annual Report for 1987 will be prepared and distributed.

All meetings of the Yellowstone River Compact Commission and the Administration Committee will be attended. The Annual Report for 1987 will be prepared and distributed.

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	Data uses and funding of the streamflow-gaging program in North Dakota	Ryan	Open File 85-349	29	Available
1985	Evaluation of the hydrologic system and potential effects of mining in the Dickinson lignite area, eastern Slope and western Stark and Hettinger Counties, North Dakota	Armstrong	Water-Resources Investigations 84-4194	35	Available
1985	Geochemical processes in the Gascoyne lignite mining area, Bowman County, North Dakota	Fisher, Thorstenson, Croft, and Houghton	Water-Resources Investigations 84-4192	80	Available
1985	Geohydrologic reconnaissance of the Avoca lignite deposit area near Williston, northwestern North Dakota	Horak and Crosby	Water-Resources Investigations 85-4024	22	Available
1985	Ground-water data for McKenzie County, North Dakota	Croft	North Dakota Geological Survey Bulletin 80	455	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey, North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	Ground-water resources of McKenzie County, North Dakota	Croft	North Dakota Geological Survey Bulletin 80	57	Available
1985	Hydrogeochemistry of uranium and associated elements at abandoned uranium mines in western North Dakota	Houghton, Hall, Unseth, Wald, Anderson, and Hill	Second Toxic Waste Ground-Water Contamination Technical Meeting, Proceedings	3	Available
1985	Hydrologic effects of withdrawal of ground water on the West Fargo aquifer system, eastern Cass County, North Dakota	Armstrong	Water-Resources Investigations 83-4279	28	Available
1985	Inverse modeling of solute transport in shallow ground water, With an example of sulfate movement around a lignite mine in southwestern North Dakota	Houghton	North Dakota Academy of Science, Proceedings	1	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	National Water Summary 1984--North Dakota ground-water resources	Crosby	Water-Supply Paper 2275	6	Available
1985	Progress report on the geochemistry of the sulfur cycle in northern Great Plains coal mines	Houghton, Koob, and Groenewold	Water-Resources Investigations 85-4016	70	Available
1985	Small-area snow surveys on the northern plains of North Dakota	Emerson, Carroll, and Steppuhn	Water-Resources Investigations 85-4026	22	Available
1985	Snowmelt trace-element enrichments in prairie potholes and soils of central North Dakota	Houghton and Foss	National Atmospheric Deposition Program Technical Committee Meeting, Abstract	1	Available
1985	Sulfur cycle in western coal mines	Houghton, Koob, and Groenewold	National Water Well Association	9	Available
1985	Supplement to inventory and analyses of information for flood plain management in North Dakota	Emerson and Wald	Open File 85-700	80	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	Use of chemical test papers to semiquantitatively determine mercury-vapor concentrations	Houghton	Water-Resources Investigations 85-4012	15	Available
1985	Volatile trace-element concentrations in snowmelt contributions to streams monitored by hydrologic bench-mark network stations in the conterminous United States where average snowfall exceeds 12 inches	Houghton and Schimke	Water-Resources Investigations 85-4104	19	Available
1985	Water-resources activities of the U.S. Geological Survey in North Dakota, Fiscal year 1985	Martin	Open File 85-558	124	Available
1986	Flood analysis along the Little Missouri River within and adjacent to Theodore Roosevelt National Park, North Dakota	Emerson and Macek-Rowland	Water-Resources Investigations 86-4090	36	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1986	The geohydrologic system and probable effects of mining in the Sand Creek-Hanks lignite area, Williams County, North Dakota	Armstrong	Water-Resources Investigations 85-4089	38	Available
1986	Hydrologic and climatologic factors affecting water levels of Devils Lake, North Dakota	Wiche	Water-Resources Investigations 86-4320	62	Available
1986	Hydrology of the Devils Lake basin, northeastern North Dakota	Wiche, Hoetzer, and Rankl	North Dakota State Water Commission Water-Resources Investigation 3	86	Available
1986	Reclamation of a uraniferous lignite mine, North Dakota	Houghton, Hall, Unseth, Wald, Burgess, Patrick, Anderson, and Hill	Eighth Annual U.S. Department of Energy (DOE) Low-Level Waste Management Forum, Proceedings	5	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1986	Sources of sulfate in wet deposition, North Unit of Theodore Roosevelt National Park, North Dakota	Houghton and Snow	North Dakota Academy of Science, Proceedings	1	Available
1986	Study plan for heat and water transport in frozen soils, North Dakota	Emerson	Snow Management for Agriculture Symposium, Proceedings	10	Available
1986	Water-resources data for the lower James River, Dickey, LaMoure, and Stutsman Counties, North Dakota	Wald and Christensen	North Dakota State Water Commission Water-Resources Investigation 2	491	Available
1987	Arsenic and selenium in irrigable soils of eastern North Dakota	Houghton and Briel	North Dakota Academy of Science, Proceedings	1	Available
1987	Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota	Houghton, Thorstenson, Fisher, and Groenewold	Professional Paper 1340	104	Available

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
1987	Prevention of ground-water quality degradation during reclamation of a uraniferous lignite mine, North Dakota	Houghton, Anderson, Hill, Burgess, Wald, Patrick, Hall, and Unseth	1987 Billings Symposium on Surface Mining and Reclamation in the Great Plains and American Society for Surface Mining and Reclamation, Proceedings	19	Available
1987	Probable and observed hydrologic consequences of lignite strip mining in the Fort Union Group near Gascoyne in southwestern North Dakota--Ground-Water Study 9	Houghton	U.S. Office of Surface Mining Reclamation and Enforcement	37	Available
--	Hydrologic system and probable hydrologic consequences of mining in the M & M lignite area, southeast Williams County, North Dakota	Armstrong, Crosby, Horak, and Houghton	Water-Resources Investigations 87-4134	48	In press

Supplement 1.--Publications by personnel of the U.S. Geological Survey,

North Dakota District, for 1985, 1986, and 1987--Continued

Date published	Report title	Author	Publication media	Number of pages	Report availability
--	Hydrology of area 46, northern Great Plains and Rocky Mountain coal provinces, North Dakota	Croft and Crosby	Open File 84-467	135	In press
--	Hydrology of area 47, northern Great Plains and Rocky Mountain coal provinces; North Dakota, South Dakota, and Montana	Crosby and Klausing	Open File 83-221	150	In press
--	Hydrology and water-level fluctuations of Devils Lake, North Dakota	Wiche	International Symposium on Flood Frequency and Risk Analysis, Proceedings	--	In press
--	U.S. Geological Survey surface-water project activities related to energy development in North Dakota	Moore	Reclamation-Research Conference Speech	--	--
--	Water-resources activities of the U.S. Geological Survey in North Dakota, fiscal year 1986	Martin	Open File 87-530	100	In press