Water-Resources Activities of the U.S. Geological Survey in Minnesota, 1993 Water Year

Compiled by G.L. Amos

U.S. Geological Survey
Open-File Report 94-338

Mounds View, Minnesota
1994

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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FORWARD

Since the U.S.Geological Survey began water-resources activities in Minnesota in 1903, a large amount of hydrologic data has been collected and many areal investigations and research projects have been completed. Over the years, these activities have reflected the need for water-resource information on priority issues of the time. I am gratified by past accomplishments and pleased to be part of the current program. Water issues continue to be a focal point for many environmental concerns. The U.S. Geological Survey continues to collect hydrologic data, make assessments of water resources, provide water-related information to the public, and work cooperatively with other Federal, State and local agencies in Minnesota. The staff of the Minnesota District maintains its commitment to providing timely and accurate information that relates to current priority issues.

George Garklavs
District Chief

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

CONVERSION FACTORS AND DEFINITION OF TERMS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	.3048	meter
foot per mile (ft/mi)	.1894	meter per kilometer
foot per day (ft/d)	.3048	meter per day
foot squared per day (ft^2/d)	.09290	meter squared per day
cubic foot per second (ft^3/s)	2.831	cubic meter per second
acre	.4047	hectacre
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	.06309	liter per second
degrees Fahrenheit (^oF)	5/9 x (^oF-32)	degrees Celsius

A water year begins October 1 and ends September 30 the following year. The water year is named for the calendar year in which it ends. For example, the 1991 water year begins October 1, 1990 and ends September 30, 1991.

Use of brand/firm/trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN MINNESOTA, 1993 WATER YEAR

Compiled by G.L. Amos

INTRODUCTION

The U.S. Geological Survey was established as an agency in the Department of the Interior by an Act of Congress in 1879. The growth of its scientific investigations has paralleled the growth of the United States and has contributed to that development. Initially, the mission of the U.S. Geological Survey was to assess the mineral resources of the United States. However, as need arose, the Survey mission expanded and the organization eventually was divided into several operating Divisions and Offices, each addressing specific aspects of natural resources. As a result of its expanding research and fact-finding role, the U.S. Geological Survey has become the Nation's largest earth-science research agency, the largest civilian-mapmaking agency, the primary source of data on the Nation's surface-water and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs, which serve a diversity of needs and users, 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-resources appraisals 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 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."

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 interpretive water-resources appraisals describing the presence, availability, and the physical, chemical, and biological characteristics of surface water 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 measurements 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 water.

*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.

*Acquiring, developing, and disseminating information on water-related natural hazards such as droughts, floods, landslides, land subsidence, mudflows, and volcanoes.

*Administering the provisions of the Water Resources Research Act of 1984, which include the State Water Resources Research Institutes and the Research Grants and Contracts Programs.

*Supporting the provisions of the National Environmental Policy Act of 1969 and managing the Geological Survey conduct of natural resources surveys in response to the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act) of 1980.

ORGANIZATION OF THE MINNESOTA DISTRICT

Water Resources Division
U.S. Geological Survey
Mounds View, Minnesota
February 1993

A description of the functions of each organizational unit in the Minnesota District is given below. An organizational chart is shown in figure 1.

Office of the District Chief

The long-term and intermediate responsibilities of the Office of the District Chief are to stay abreast of the status, trends, and problems of water resources in the District. The District Chief promotes, develops, and maintains the technical proficiency of the District Office by participation in research and technical investigations with local, State, and Federal agencies. Technical proficiency is maintained by career development and training of personnel, which is encouraged and supported by the District Chief. Maintenance of quality scientific products, which result from research and investigations, are the highest priority of the District Chief.

The Office of the District Chief is comprised of the District Chief and a secretary. The District maintains communication with the Area Hydrologist and the Regional Hydrologist to update them on all phases of water resources in the District. The Office of the District Chief is supported from within the District by Administrative Services Section, Information Management Section, Hydrologic Investigations Sections I & II, National Water-Quality Assessment (NAWQA) Programs, Network Surveillance Section, and one Field Office. Section chiefs advise the District Chief and share in other duties.

Administrative Services Section

The responsibilities of the Administrative Services Section are the financial, human resource, and organizational management of the District. Specific responsibilities of the Administrative Services Section are (1) preparation and maintenance of District program documents such as project proposals, financial management, and joint-funding agreements; (2) processing of personnel actions and other personnel management and administrative matters; (3) managing the controlled property data base, and (4) obtaining office services, supplies, and equipment.

The Administrative Services Section is comprised of an administrative officer, administrative operations assistant, and three administrative technicians. The Administrative Officer makes specific recommendations about all District-wide administrative concerns.

Information Management Section

The responsibility of the Information Management Section is to provide support for the production of high-quality scientific products and to manage informational data bases. Computer support is provided by the Computer Applications Unit. Land-surface information is provided by

Geographic Information Systems Unit. Report publication is provided by the Scientific Publications Unit. These three units work together to produce high-quality scientific products.

Computer Applications Unit

The responsibility of the Computer Applications Unit is computer operations for the District. The Computer Applications Unit services the automatic data-processing needs of the District and its principal cooperators. This is accomplished by (1) maintaining a library of computer programs, (2) aiding in the storage, management, and retrieval of data, (3) staying abreast of procedures to access the U.S. Geological Survey national computer system, and (4) procuring new automatic data-processing equipment.

The Computer Applications Unit is comprised of the Unit Chief, one computer programmer analyst, and one student trainee in computer science. The Unit Chief advises the District on computer applications to hydrologic problems, and serves as a contact for the District's Local Area Network (LAN). The Computer Programmer Analyst develops, debugs, and runs scientific and research programs, manages the District's PRIME mini-computer, and writes specific computer programs to aid in the operation and management of the District.

Geographic Information System Unit

The responsibility of the Geographic Information System (GIS) Unit is maintenance of the District GIS data base. A Geographic Information System is a computer system capable of holding and using data that describe the land surface. The GIS Unit provides support services to the District that include (1) providing guidance on using GIS in a project, (2) building GIS coverages, (3) constructing maps and illustrations, and (4) geographic analysis.

The GIS Unit is comprised of one hydrologist and one cartographic technician. The Unit Chief is the District GIS Specialist and maintains quality control for the District GIS data bases.

Scientific Publications Unit

The responsibility of the Scientific Publications Unit is to process and publish high-quality scientific reports in a timely manner. Authors are assisted through all stages of report production, which include (1) preparation of report outline and illustration plan, (2) review, (3) approval, (4) publication, and (5) distribution of printed reports.

The Scientific Publications Unit is comprised of one scientific illustrator, one cartographic technician, one technical publications editor, and two office automation clerks. The Unit Chief oversees the production of reports by the District.

Hydrologic Investigations Section I & II

The responsibility of the Hydrologic Investigations Sections is to appraise the water resources of specific areas in the State through research and investigations. Emphasis is placed on the collection and interpretation of hydrologic data required for planning, developing, and managing the State's water resources.

Each Hydrologic Investigations Sections is comprised of one supervisory hydrologist, about six hydrologists, and two hydrologic technicians. Hydrologists initiate and conduct research and technical investigations.

Hydraulic Investigations Unit

The responsibility of the Hydraulic Investigations Unit is to conduct complex technical research and investigations in open-channel hydraulics and streamflow characteristics. Research and investigation activities are (1) magnitude and frequency of floods, (2) low-flow frequency and duration, (3) streamflow duration, (4) stream sediment transport, (5) bridge scour, (6) relation of flow to channel and basin characteristics, and (7) streamflow time-of-travel.

The Hydraulic Investigations Unit is comprised of two hydrologists, who serve the District as specialists in surface-water research and investigations.

National Water-Quality Assessment Program—Red River of the North Study Unit

The long-term responsibilities of the NAWQA (National Water-Quality Assessment) program are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. The Red River of the North Basin is 1 of 20 studies that began in 1992. The project team is comprised of specialists from St. Paul, Minnesota and field experts from Grand Forks, North Dakota. The Project Chief and specialists in stream hydrology, data-base management and geographical information systems, chemistry, aquatic biology, hydrogeology, and data collection comprise the St. Paul interdisciplinary team.

Communication and coordination between U.S. Geological Survey personnel and other interested scientists and water-management organizations are critical components of the NAWQA program. The Red River of the North study-unit investigation has a local liaison committee consisting of representatives that have water-resources responsibilities from Federal, State, and local agencies, universities, and the private sector. Activities of the liaison committee include (1) information exchange about water-quality issues of regional and local interest, (2) identification of data and information sources, (3) assistance in design and scope of the project products, and (4) the review of project-planning documents and reports.

Network Surveillance Section

The responsibility of the Network Surveillance Section is to supervise the design and operation of hydrologic-data networks and review hydrologic records and the operations of the Water Quality Unit and the Grand Rapids Field Headquarters. Particular emphasis is placed on collection, verification, and compilation of surface- and ground-water records for publication of the District's annual report.

The Network Surveillance Section is comprised of the Section Chief, two hydrologists, and three hydrologic technicians. The Section Chief monitors the compilation of the District's annual report, and also ensures that adequate technical guidance, supervision and training are provided to the assigned staff. Hydrologists design and manage hydrologic data networks, and review hydrologic records to develop a better understanding of surface water and water quality of the State.

Water Quality Unit

The responsibility of the Water Quality Unit is to provide quality assurance for District water-quality activities. Responsibilities of the Water Quality Unit include (1) ordering supplies for the District laboratory, (2) maintaining the Water-Quality data base, (3) making periodic data retrievals of laboratory data for review and distribution to the Project Chiefs and to the annual report, and (4) maintaining the lab for determination of selected constituents and physical properties.

The Water Quality Unit is comprised of one hydrologist and one hydrologic technician. The hydrologist is responsible for the District Laboratory. The hydrologic technician serves as the Water-Quality Data-Base manager for data retrieval.

Grand Rapids Field Headquarters

The responsibilities of the Grand Rapids Field Headquarters are surface-water, groundwater, and water-quality hydrologic records for the northern region of the District. Specific responsibilities include collection, computation, analysis, review, and assembly of hydrologic records for publication in the District's annual report.

The Grand Rapids Field Headquarters is comprised of the Technician-in-Charge, and four hydrologic technicians. The Supervisory Hydrologic Technician, or Unit Chief, ensures that the data are complete, accurate, and timely. The Grand Rapids Field Headquarters provides support to the Network Surveillance Section in the collection, verification, and compilation of data for the District's annual report.

MINNESOTA DISTRICT

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Chief, Hydraulic Investigations Unit ..... George H. Carlson
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  Red River of the North Study Unit ..... Jeffrey D. Stoner
Chief, Network Surveillance Section ..... Mark R. Have
Chief, Information Management Section ..... Allan D. Arntson
Chief, Geographic Information System Unit ..... Thomas A. Winterstein
Chief, Scientific Publications Unit ..... Rebecca A. Miller
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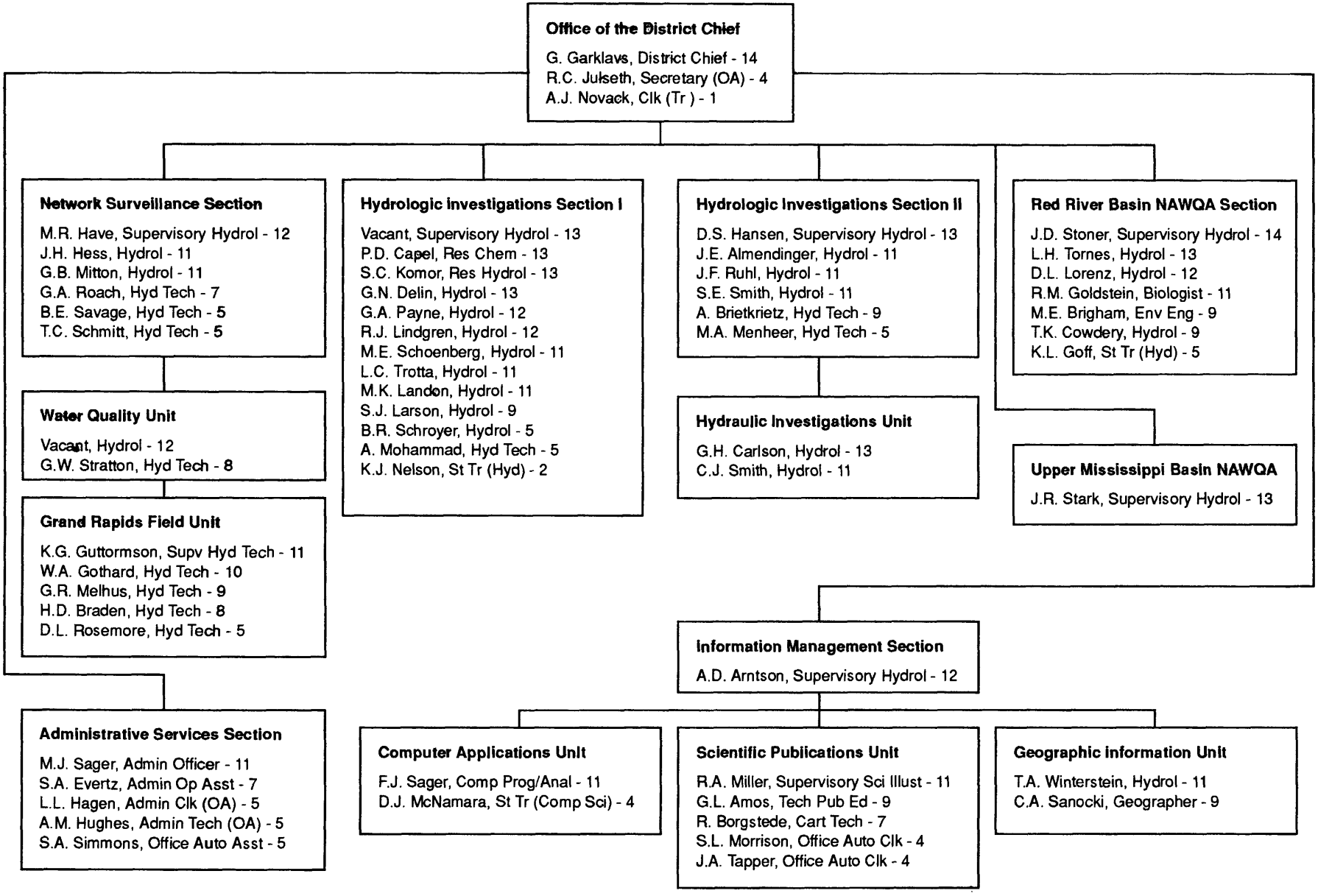


Figure 1.–Organizational chart, Minnesota District, February 1994.

COOPERATING AGENCIES—1993

The U.S. Geological Survey and local, State, and other Federal agencies have had joint agreements for the systematic collection of water records or for interpretive studies and research since 1903. Organizations that participated through cooperative or interagency agreements with the Survey during 1993 are:

Becker County Soil and Water Conservation District
Beltrami County Soil and Water Conservation District
Dakota County Soil and Water Conservation District
Elm Creek Watershed Management Commission
Grand Portage Band of Chippewa Indians
Hubbard County Soil and Water Conservation District
Leech Lake Reservation Tribal Council
Legislative Commission on Minnesota Resources
Local Road Research Board
Lower Red River Watershed Management Board
Metropolitan Council of the Twin Cities
Mille Lacs Band of Chippewa Indians
Minnesota Department of Health
Minnesota Department of Natural Resources
Minnesota Department of Transportation
Minnesota Geological Survey
Minnesota Pollution Control Agency
Northwestern Minnesota Ground Water Steering Committee
St.Paul Water Utility
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
University of Minnesota
Vadnais Lake Watershed Management Organization

SURFACE-WATER STATIONS

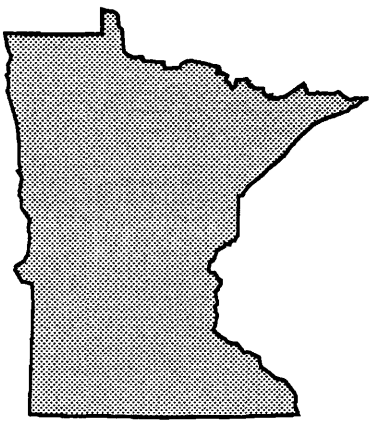
MN001

DATE PROJECT BEGAN: May 1903

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Statewide



PRINCIPAL COOPERATING AGENCIES: Minnesota Department of Natural Resources, Minnesota Department of Transportation, Elm Creek Watershed Management Commission, and Lower Red River Watershed Management Board, Minnesota Pollution Control Agency, and U.S. Army Corps of Engineers.

PROBLEM: Surface-water information is needed for surveillance, planning, design, hazard warning, operation, and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, contamination abatement, flood-plain management, and water-resources development.

OBJECTIVES: Collect data on the surface waters of Minnesota for public needs such as assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and control of contamination, evaluation of water-quality data, compacts and legal requirements, and research or special studies. Collect data for analytical studies, planning, and design that will define statistical properties and trends in the presence of water at any location in Minnesota streams, lakes, reservoirs, and estuaries.

APPROACH: Maintain a statewide network of gaging stations (fig 2). Standard methods of data collection will be used as described in the series, "U.S. Geological Survey Techniques of Water-Resources Investigations." Partial-record gaging will be used instead of complete-record gaging where it better serves the required purpose.

RESULTS LAST YEAR: Surface-water data for 1992 were published in the Water Resources Data—Minnesota Water Year 1992. The surface-water network consisted of the following: 87 continuous-record discharge stations, 84 high-flow partial-record stations, approximately 600 low-flow partial-record stations, 6 continuous-record stage stations on streams, and 13 continuous-record stage stations on lakes. Water year 1993 began with generally normal flow in most of the State except for the southern one-third. This condition persisted until March when flow for the entire State was normal. In April flow in the southern third of the State became excessive. Flooding from rain in the southern part of Minnesota began in May. This flooding was the beginning of flood conditions which continued for most of the summer. The area of excessive flow increased in

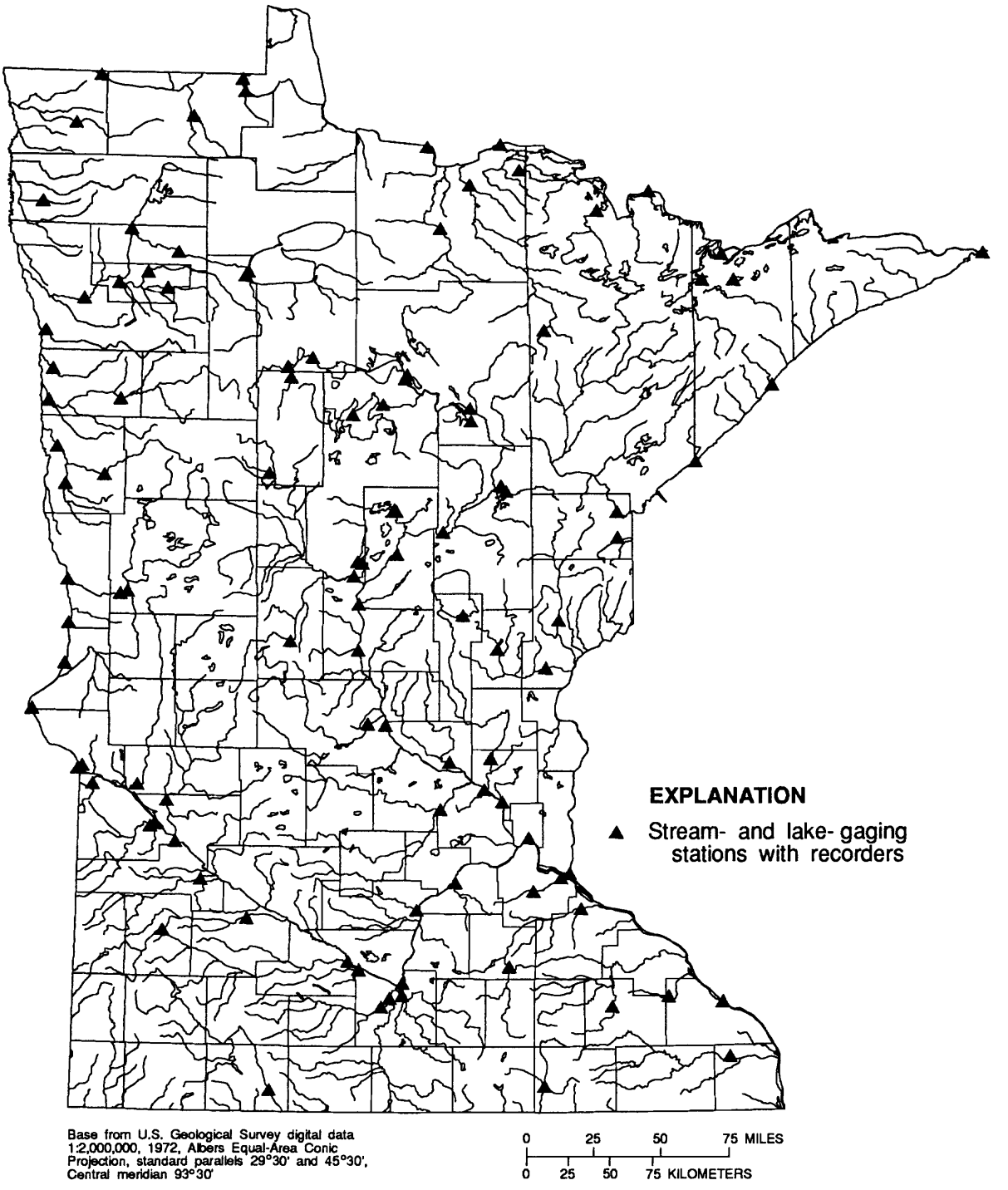


Figure 2.--Surface-water network (MN001) operated during the 1993 water year.

May until the entire State was under excessive flow conditions except for a small part in the north. Several high-flow measurements were made at high-flow partial-record stations, especially in the southern one-third of the State and in the Red River of the North Basin. Baseline data and flood data were collected on several streams for a bridge-scour study.

Preparation of U.S. Geological Survey Open-File Reports presenting maps of drainage basin boundaries and other river-basin characteristics for major tributaries of the Minnesota and Mississippi River was continued. Reports describing the basins of the Pomme de Terre and Lac qui Parle River Basins are being prepared for publication, and preparation of similar reports for the Upper Minnesota, Chippewa, Cottonwood, Middle Minnesota River Basin, and the Lower Minnesota River Basins are being compiled.

PLANS NEXT YEAR: Continue the surface-water program at about the same level as in 1993. Prepare and publish Water Resources Data—Minnesota Water Year 1993, and maintain the data in the U.S. Geological Survey data base (WATSTORE). The low-flow and high-flow programs will be continued as in the previous year. The program of preparing drainage-basin reports will continue.

PUBLISHED REPORTS IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River Basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River Basins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

GROUND-WATER STATIONS

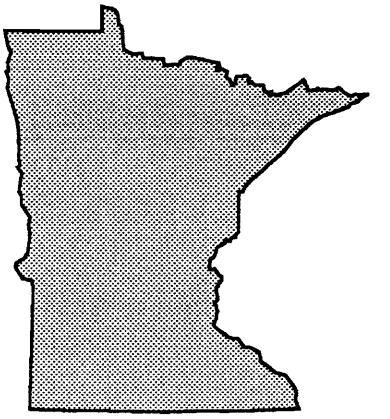
MN002

DATE PROJECT BEGAN: July 1947

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Brietkrietz, Alex

LOCATION: Statewide



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources, Minnesota Department of Health, and Beltrami Soil and Water Conservation District.

PROBLEM: Climatic variations directly affect recharge to and discharge from the 14 principal aquifer systems in Minnesota. Long-term water-level records will provide water-resource managers a data base to aid in assessing the effects of long-term climatic variation on Minnesota's principal aquifers.

OBJECTIVES: Collect and tabulate water-level data from 14 principal aquifers in Minnesota. Provide the data base necessary for effective development and management of ground-water resources.

APPROACH: Measure and maintain a network of observation wells screened in the principal aquifers in Minnesota (fig. 3).

RESULTS LAST YEAR: Ground-water data for water year 1992 were published in the Water Resources Data—Minnesota Water Year 1992. Data for the 1993 water year were transmitted to Minnesota Department of Natural Resources. The observation-well network included 16 wells, of which 14 were equipped with recorders. Water levels for wells screened in surficial aquifers in the northern half of Minnesota were 1 to 2 feet below the monthly average during October through June and 1 foot above the monthly average from July through September 1993 and 1 to 4 feet above the monthly average in the southern half of Minnesota. Water levels in observation wells in the Prairie du Chien-Jordan aquifer in the Minneapolis-St. Paul area rose from October to December 1992, declined from January to July 1993, and rose from August to September 1993. Water levels were 8 feet above the annual average in St. Paul and were 17 feet above the annual average in Minneapolis during September 1993. Water levels in observation wells in the Mount Simon-Hinckley aquifer were 5 feet below the annual average in St. Paul and were 9 feet below the average annual level in Minneapolis.

PLANS NEXT YEAR: Water-level measurements will be maintained on selected wells in the program. Water Resources Data—Minnesota Water Year 1993 will be prepared and published.

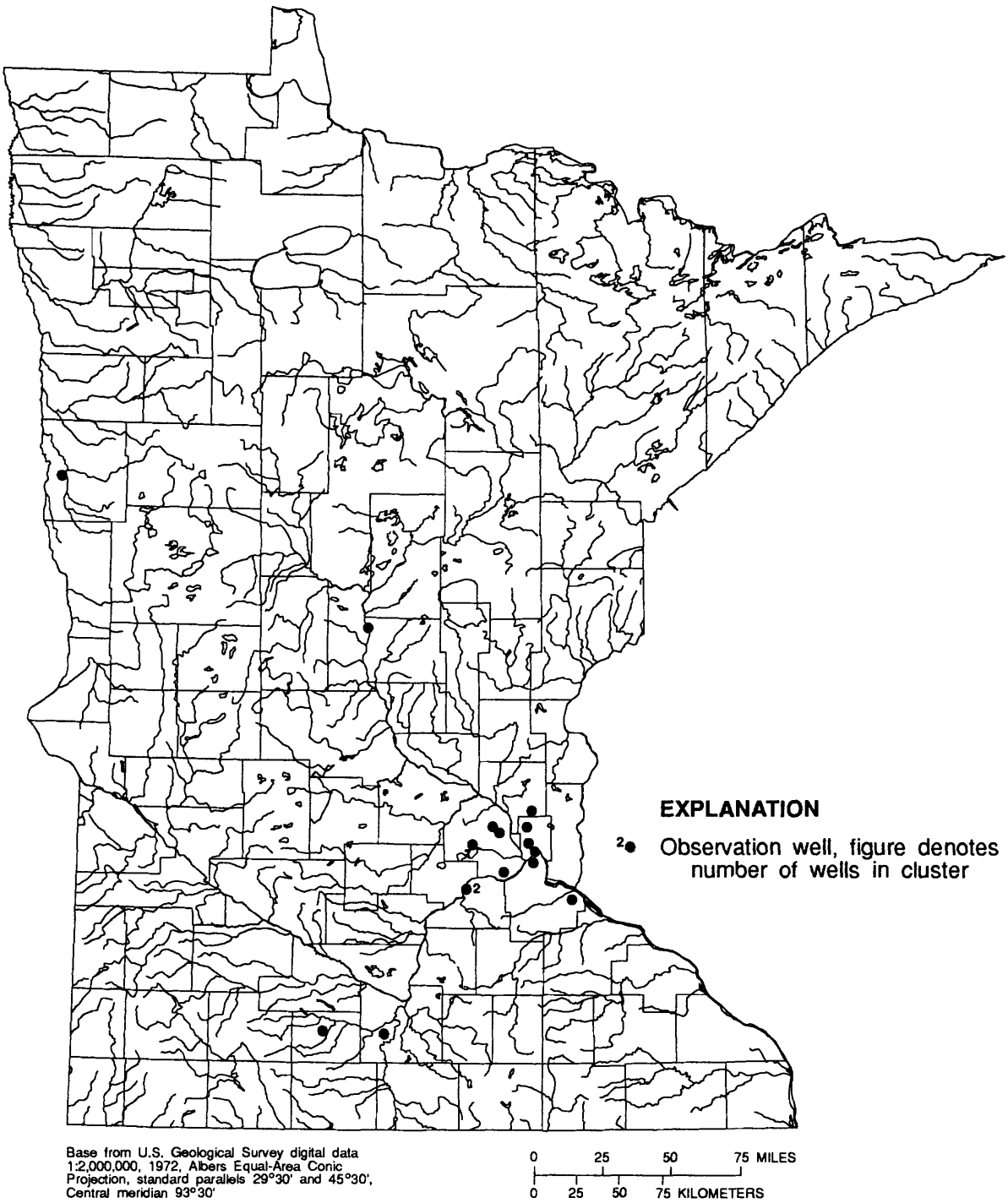


Figure 3.--Observation-well network (MN002) operated during the 1993 water year.

PUBLISHED REPORTS IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River Basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River Basins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

WATER-QUALITY STATIONS

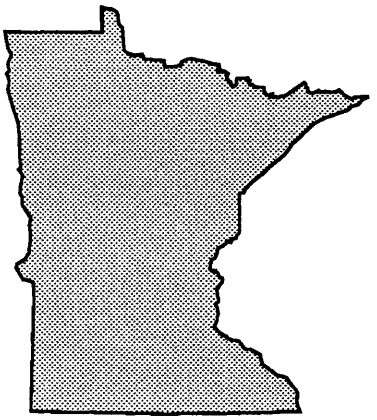
MN003

DATE PROJECT BEGAN: June 1955

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Statewide



PRINCIPAL COOPERATING AGENCIES: Elm Creek Watershed Management Commission.

PROBLEM: Water-quality assessments for water-resources planning and development require a regional and national water-quality data base. To provide this data base, a network of ground-water and surface-water stations must be maintained and additional sites must be selected for synoptic sampling to obtain representative data that describe water-quality conditions at the time of collection.

OBJECTIVE: Provide water-quality data for local, State, and Federal planning and for the management of interstate and intrastate water resources.

APPROACH: Maintain a network of stations to provide water-quality data on both a continuing and synoptic basis, including concentrations, loads, and time trends, for water-resource planning and management (fig. 4).

RESULTS LAST YEAR: Water-quality data for 1992 were published in the Water-Resources Data—Minnesota Water Year 1992. Nitrate-nitrogen concentrations in samples collected in 1992 were near the historical monthly median, for sites at the four National Stream Water Quality Network (NASQAN) stations in the northern part of the state as well as in the Mississippi River near Royalton. Nitrate-nitrogen concentrations were higher than monthly medians in some samples collected at the other three NASQAN stations. Samples for a midcontinent study of herbicides in reservoirs were collected in the 1993 water year at five river sites below reservoirs and at top and bottom points within three of the reservoirs. The three reservoirs that were sampled drain areas that have heavy, moderate, and very little agricultural activity. Lac qui Parle Reservoir in the Minnesota River Basin had the highest average concentrations of atrazine and cyanazine with 0.33 and 1.17 micrograms per liter, respectively. A reconnaissance study was conducted in August 1993 in the Snake River watershed. The purpose was to gather baseline data that would give local governments a definition of the spatial variation in the quality of water in the watershed. Concentrations for fecal *Streptococci* and fecal coliform bacteria showed some high concentrations locally. There were no samples for dissolved ammonia, nitrite plus nitrate nitrogen, or phosphorus that showed concentrations above alert limits. The benchmark

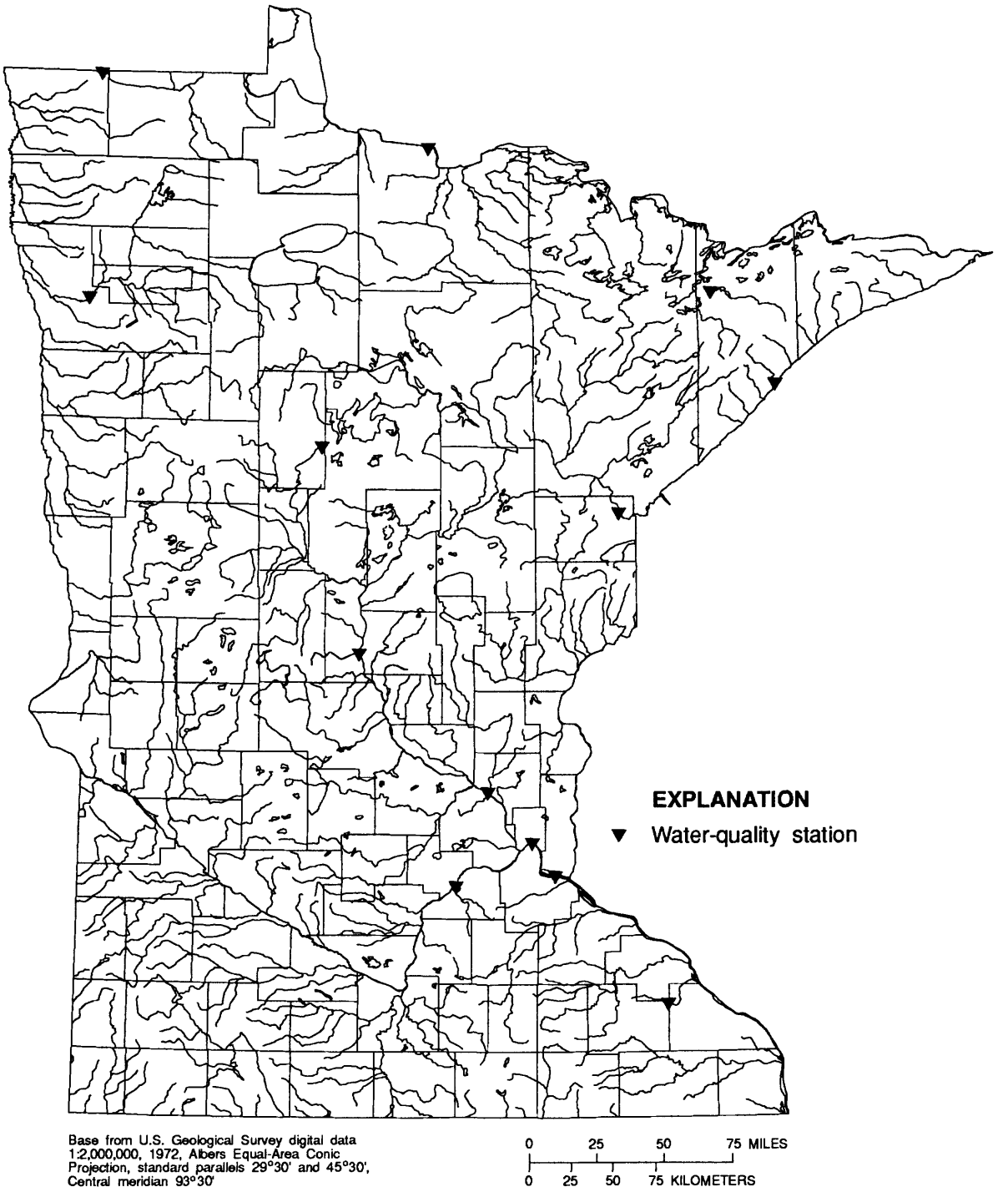


Figure 4.--Water-quality network (MN003) operated during the 1993 water year.

station, North Fork Whitewater River near Elba, and two NASQAN stations (Baptism River near Beaver Bay and Roseau River below State Ditch 51 near Caribou) were discontinued at the end of the 1993 water year.

PLANS NEXT YEAR: Continue the remaining NASQAN and benchmark stations and the station on Elm Creek where an automatic sampler has been sampling storm events. Prepare and publish Water Resources Data—Minnesota Water Year 1993.

PUBLISHED REPORTS IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River Basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River Basins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

SEDIMENT STATIONS

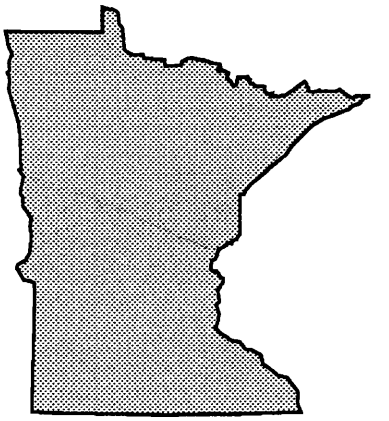
MN004

DATE PROJECT BEGAN: March 1967

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Statewide



PRINCIPAL COOPERATING AGENCY: U.S. Army Corps of Engineers.

PROBLEM: Water-resources planning and development require data on suspended-sediment concentrations, suspended-sediment load, total-sediment load and particle-size distribution of suspended sediment and bed material.

OBJECTIVES: Provide standardized sediment data for broad Federal and State planning and action programs and provide data for Federal management of interstate and international waters.

APPROACH: Maintain a network of sediment stations to determine trends in sediment concentration, discharge, and particle size of sediment transported by selected streams in Minnesota (fig. 5).

RESULTS LAST YEAR: Sediment data for 1992 were published in the Water Resources Data—Minnesota Water Year 1992. Daily records for the Minnesota River at Mankato and the Mississippi River near Anoka were completed for the 1992 water year. A suspended-sediment load of 193,105 tons was transported past the Anoka station in the 1992 water-year. A maximum daily load of 7,200 tons was measured March 9, 1992. A suspended-sediment load of 1,558,791 tons was measured at the Mankato station in 1992. A maximum daily load of 58,700 tons was measured March 3, 1994. Sediment stations operated in 1993 included daily stations on the Minnesota River at Mankato and on the Mississippi River near Anoka and 11 periodic-sediment stations, 10 of which are part of the NASQAN and benchmark programs. Data collected at all stations were mainly suspended-sediment concentrations. Size data for suspended sediment were collected at all stations and size data for bed material were collected at the two daily stations (Minnesota River at Mankato and Mississippi River near Anoka).

PLANS NEXT YEAR: Continue at about the same level. Publish the 1993 data. Prepare and publish Water Resources Data—Minnesota Water Year 1993.

REPORTS PUBLISHED IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

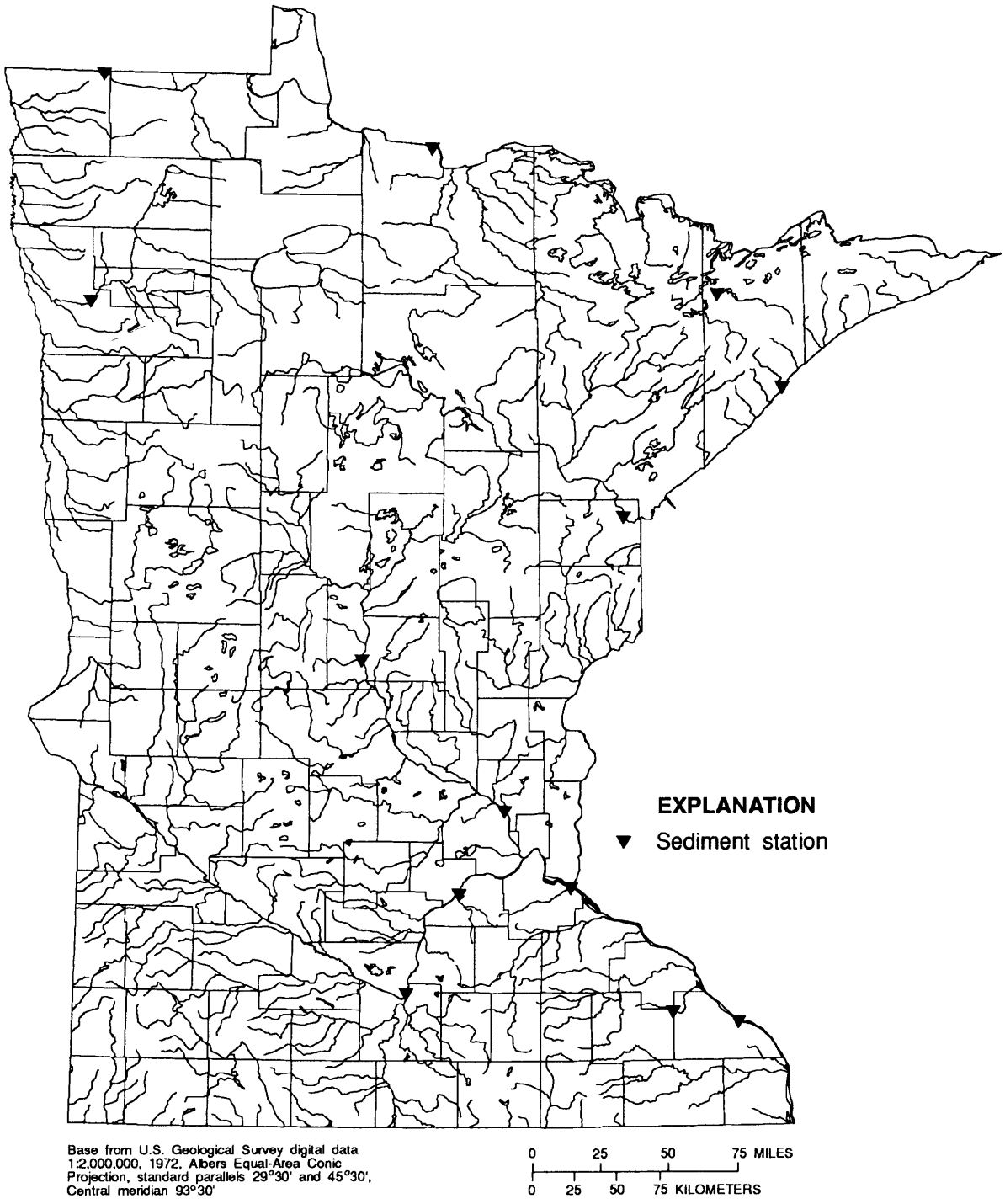


Figure 5.–Suspended-sediment network (MN004) operated during the 1993 water year.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River Basins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

PRECIPITATION STATIONS

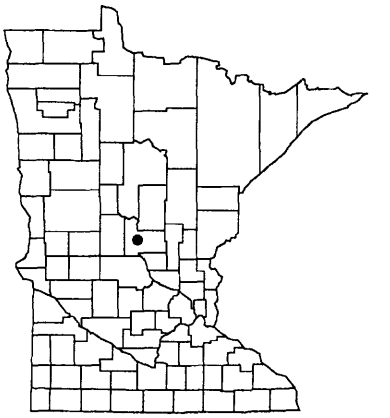
MN005

DATE PROJECT BEGAN: August 1983

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Central Minnesota



PROBLEM: Human activities have greatly increased the abundance of chemical substances dispersed into the atmosphere. These substances can be deposited by precipitation and adversely affect plants, surface water, and ground water. Spatial and temporal trends in the chemical composition of atmospheric deposition require better definition to determine the affects.

OBJECTIVE: Establish a record that allows detection of spatial and temporal trends in the chemical composition of atmospheric deposition. This record will better define the sources, movement, and transformation of materials contributing to or associated with acidic atmospheric deposition in the United States and its effects on the biosphere.

APPROACH: A site at Camp Ripley was constructed as part of about 150 sites nationwide. The site has a wet-fall/dry-fall collector and a recording rain and snow gage. The wet-fall collector is changed and the recording raingage is serviced once a week. The dry-fall collector is changed every 8 weeks. Chemical analyses will be made by the Illinois State Water Survey.

RESULTS LAST YEAR: Analytical results for samples collected during the 1992 water year were published in the Water-Resources Data—Minnesota Water Year 1992. Weekly precipitation in 1992 ranged from 0.0 to 3.48 inches and field pH ranged from 4.1 to 6.1, with a median pH of 5.3. Concentrations of sulfate (as SO_4) ranged from <0.03 to 4.67 milligrams per liter, and nitrate (as NO_3) ranged from 0.05 to 4.6 milligrams per liter.

PLANS NEXT YEAR: Continue operating the site at the same level. Prepare and publish Water Resources Data—Minnesota Water Year 1993.

REPORTS PUBLISHED IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River Basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River Basins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

WATER USE

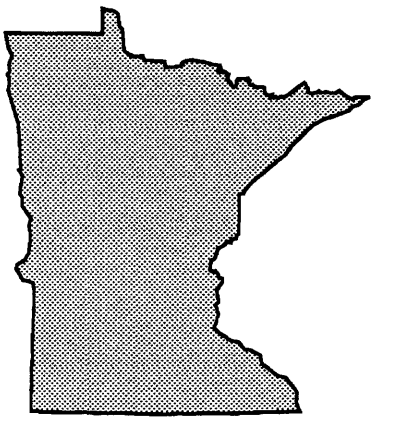
MN007

DATE PROJECT BEGAN: October 1986

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Mitton, Greg B.

LOCATION: Minnesota Statewide



PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources.

PROBLEM: Decisions by water planners and managers depend on accurate, current, systematically collected water-use data.

OBJECTIVE: Maintain a statewide system to collect, store, and disseminate information on water use in Minnesota that is compatible with the U.S Geological Survey's National Water-Use Data System.

APPROACH: Compilation of data is conducted by the Minnesota Department of Natural Resources, Division of Waters, and the U.S. Geological Survey. Direction, management, and development standards will be the responsibility of the U.S. Geological Survey. Acquisition, storage and dissemination of data is the responsibility of the Minnesota Department of Natural Resources. Water-use data is compiled from the files of local, State, and Federal agencies, followed by field inventories and development of a State water-use reporting system.

RESULTS LAST YEAR: A water-use compilation for the Red River of the North National Water Quality Assessment program (NAWQA) study was prepared. This compilation is part of a larger descriptive report of the NAWQA study and includes water-use figures for 1980, 1985, and 1990 to develop trend information. A 1991 water-use summary for the Great Lakes Basin (Minnesota part) was prepared in cooperation with the Minnesota Department of Natural Resources, Division of Waters. This summary is prepared annually for the Great Lakes Commission. A report of water use in east-central Minnesota, developed in conjunction with a study of water resources in the Mille Lacs Indian Reservation, was reviewed.

PLANS NEXT YEAR: Publish a map report of water use in Minnesota based on the 1990 compilation figures. Develop the 1992 water-use summary for the Great Lakes Commission. Examine water-use reporting methods for the six largest public water suppliers in Minnesota.

REPORTS PUBLISHED IN 1993:

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994a, Water Resources Data—Minnesota Water Year 1992, Volume 1. Great Lakes & Souris-Red-Rainy River Basins: U.S. Geological Survey Water-Data Report MN–92–1, 228 p.

Gunard, K.T., Hess, J.H., Zirbel, J.L., and Cornelius, C.E., 1994b, Water Resources Data—Minnesota Water Year 1992, Volume 2. Upper Mississippi and Missouri River asins: U.S. Geological Survey Water-Data Report MN–92–2, 377 p.

APPRAISAL OF THE GROUND-WATER RESOURCES OF THE TWIN CITIES METROPOLITAN AREA, MINNESOTA

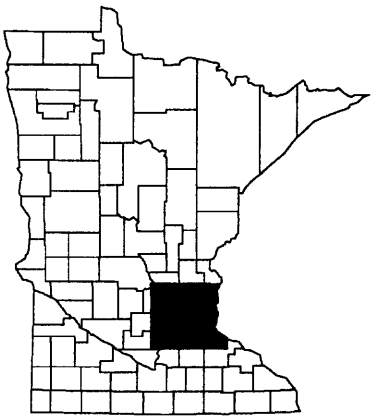
MN063

DATE PROJECT BEGAN: January 1979

DATE PROJECT ENDED: September 1985

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: East-central Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources and the Metropolitan Council of the Twin Cities.

PROBLEM: A study of the aquifer system in the Twin Cities area is needed to provide a detailed understanding of the hydrogeologic system and its response to continued development. This understanding is necessary for management of the aquifer system and protection of the resource.

OBJECTIVE: Developed a detailed understanding of the hydrologic system and geologic framework within which it operates. Applied this detailed understanding, using the U.S. Geological Survey three-dimensional ground-water-flow model, to evaluate the hydrologic effects of continued development of ground-water resources. Provided State and local water managers and planners the information to evaluate alternative development and management of ground-water resources.

APPROACH: Project work was divided into three phases. During the first phase a preliminary ground-water-flow model was constructed. The preliminary ground-water-flow model was used to help set priorities for additional data collection by identifying the types of additional data required and areas where the need was greatest. The second phase focused on the collection of the additional data identified in the first phase. The ground-water-flow model was tested, evaluated, and revised during this phase. The third phase concentrated on using the ground-water-flow model to evaluate the hydrologic effects of various water-management applications proposed by State, regional and local agencies.

RESULTS LAST YEAR: The project is complete.

PLANS NEXT YEAR: The Pinder-Trescott format will be converted to the modular McDonald-Harbough model format.

THERMAL ENERGY IN THE IRONTON-GALESVILLE AQUIFER, ST. PAUL, MINNESOTA

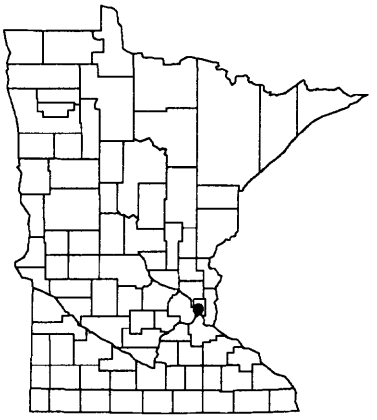
MN077

DATE PROJECT BEGAN: May 1980

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Delin, Geoffrey N.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES:
Minnesota Geological Survey and University of Minnesota.

PROBLEM: Aquifer thermal-energy storage (ATES) is believed to be a cost-effective method of energy conservation because it employs a natural reservoir for storage of waste heat from power plants. However, demonstration projects are needed to prove the feasibility of such systems. A site on the St. Paul Campus of the University of Minnesota was selected by the U.S. Department of Energy and Battelle Pacific Northwest Laboratories for an ATES demonstration. Hydrologic modeling for the aquifer system is needed to aid in the design of field-testing experiments and evaluation of the aquifer-system response to injection and withdrawal of heated water.

OBJECTIVES: Developed a method to evaluate flow and thermal-energy transport during annual variations of injection and withdrawal cycles under real heating loads. Assisted in the collection of hydraulic and thermal data during pilot testing of actual injection/withdrawal cycles and process data for analysis. Determined effects of hot-water injection/withdrawal on hydraulic properties of the Ironton-Galesville aquifer near an injection well.

APPROACH: Constructed three numerical-simulation models of the project area. A three-dimensional flow model, a two-dimensional axially-symmetric radial-flow and thermal-energy-transport model, and a three-dimensional flow and energy-transport model were used. Simulation models were used to accomplish the first three objectives of the study. The results of three other studies in the Twin Cities area that involve simulation models of the aquifer system also were used for model construction and calibration. Simultaneous pressure and temperature data at predetermined time intervals using multi-channel automatic data recorders was recorded. These data were entered into computer storage for retrieval, analysis, and manipulation. These data also were used for testing and calibration of the numerical simulation models.

RESULTS LAST YEAR: The interpretive report documenting the short-term test cycles was approved for publication as a U.S. Geological Survey Open-File Report, pending publication as a U.S. Geological Survey Professional Paper.

PLANS NEXT YEAR: The report documenting modeling of the long-term test cycles will be completed published.

PUBLISHED REPORTS IN 1993:

Miller, R.T., and Delin, G.N., 1993, Field observations, preliminary model analysis, and aquifer thermal efficiency—Cyclic injection, storage, and withdrawal of heated water in a sandstone aquifer at St. Paul, Minnesota: U.S. Geological Survey Professional Paper 1530–A, 55 p.

CRUDE-OIL CONTAMINATION OF GROUND WATER NEAR BEMIDJI, MINNESOTA

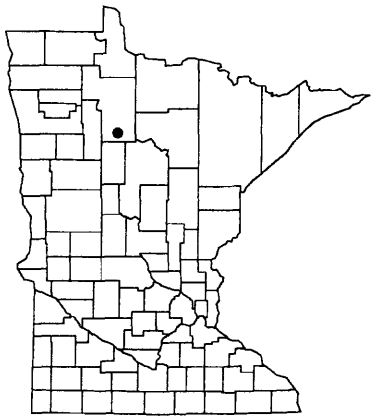
MN095

DATE PROJECT BEGAN: March 1983

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Hansen, Donald S.

LOCATION: North-central Minnesota



PROBLEM: About 10,000 barrels of crude petroleum spilled from a broken pipeline near Bemidji on August 20, 1979. Although regulatory and remedial actions have been completed, as much as 4 ft of crude petroleum is floating on the water table in the outwash aquifer. Ground water is dissolving the oil, and residual organic compounds in the unsaturated zone are being leached downward.

OBJECTIVE: Understand the mobilization, transport, and fate of petroleum derivatives in the subsurface and use this understanding to develop predictive models of contaminant behavior in the ground-water system.

APPROACH: The project required a comprehensive interdisciplinary approach coordinated between the District, National Research Program, and university groups involved in specialized research. The District described the geologic, hydrologic, and natural-geochemical framework, developed and maintained hydrologic monitoring networks, and provided logistical support for separately funded research by the staff of the National Research Program. Although conventional techniques may have been adequate for many purposes, new field, laboratory, and modeling techniques needed to be developed and applied.

RESULTS LAST YEAR: Cores obtained during field work allowed researchers to define more completely the underside of the anoxic plume down the hydraulic gradient from the oil body. Distinct iron precipitation zones were observed in cores taken below the water table. Definition of the hydrocarbon plume down the hydraulic gradient from the oil pool by geochemical analysis and through modeling of the advective, dispersive, and degrative movement of hydrocarbons in ground water showed a similar plume distribution pattern in the aquifer. An estimation of the range for microbial population was calculated based on sediment samples obtained during July 1993. The report, "Hydrogeologic data collected from a crude-oil spill site near Bemidji, Minnesota, 1983–91," by Smith and Hult, was published. Researchers and coordinators of the many projects at the site met in September 1993 to discuss the preparation of individual chapters of the U.S. Geological Survey Water-Supply Paper that will present components of the many projects at the site. A draft of the chapter discussing hydrogeology of the site was completed. A bibliography of research at the site is being published

PLANS NEXT YEAR: The District will continue to support outside researchers with needed drilling at the site, and water-quality collection assistance, and will provide required equipment for other projects. Work will continue on individual chapters of a U.S. Geological Survey Water-Supply Paper.

PUBLISHED REPORTS IN 1993:

Smith, S.E., and Hult, M.F., 1993, Hydrogeologic data collected from a crude-oil spill site near Bemidji, Minnesota: U.S. Geological Survey Open-File Report 93–496, 158p.

IMPACT OF AGRICULTURE AND RURAL–RESIDENTIAL DEVELOPMENT ON GROUND-WATER QUALITY IN THE ANOKA SAND PLAIN, EASTERN MINNESOTA

MN096

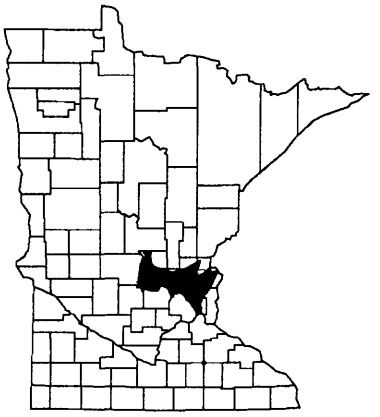
DATE PROJECT BEGAN: July 1983

DATE PROJECT ENDED: September 1986

PROJECT CHIEF: Stark, James R.

LOCATION: East-central Minnesota

PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources



PROBLEM: Degradation of ground-water quality in the Anoka Sand Plain by non-point-source contamination is of concern to residents and to local and State agencies. Potential sources of ground-water contamination in the Anoka Sand Plain are agricultural chemicals, manure produced in feedlots, lawn fertilizer, and septic-system effluent in residential areas. Current data were inadequate to evaluate the effects of these contaminants historically, seasonally, or areally.

OBJECTIVES: Assessed areal and seasonal water-quality variations in the Anoka Sand Plain aquifer in relation to hydrogeologic and climatic conditions, and land use. Determined the degree of horizontal and vertical mixing of water in the aquifer. Determined long-term trends in water quality and effects due to land-use practices. Provided baseline water-quality data. Established a regional network of wells in each aquifer that may be incorporated into a statewide water-quality-monitoring network.

APPROACH: About 100 wells at 75 sites were selected for sampling based on ground-water flow and land use. At 25 of the 75 sites, shallow and deep pairs of wells were installed to determine stratification of water quality. All wells were sampled for baseline quality during May 1984. The wells were resampled the following winter for indicator constituents. Constituents measured were sulfate, chloride, nitrate, and ammonia. In May 1985, 40 to 50 selected wells were sampled again for sulfate, chloride, nitrate, and ammonia. Constituent concentrations were evaluated for relations with land use, seasonal change, and long-term trends. This project also included annual sampling for indicator constituents from about 20 wells in networks established as part of two previous similar projects.

RESULTS LAST YEAR: The report was published

REPORTS PUBLISHED IN 1993:

Anderson, H. W., Jr., 1993, Effects of agricultural and residential land use on ground-water quality, Anoka Sand Plain aquifer, east-central Minnesota: U.S. Geological Survey Water-Resources Investigations Report 93–4074, 62 p.

GROUND-WATER AND SURFACE-WATER RELATIONS IN THE VICINITY OF VADNAIS LAKE, RAMSEY COUNTY, MINNESOTA

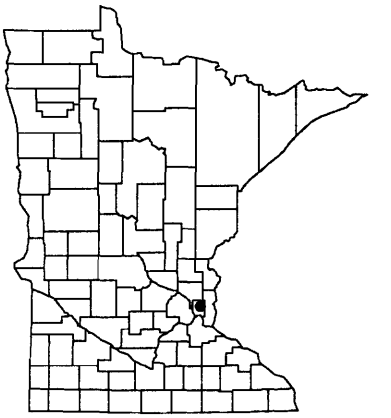
MN101

DATE PROJECT BEGAN: April 1984

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Ruhl, James F.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES: St. Paul Water Utility and Vadnais Lake Watershed Management Organization.

PROBLEM: The St. Paul Water Utility withdraws water from a series of lakes for the city's water supply. Water taken from Vadnais Lake during the summer has had an undesirable taste and odor caused by factors related to eutrophication of the lakes, which is caused by nutrient discharge from tributary streams. Transport of nutrients from ground water to the lake is not well understood.

OBJECTIVES: Determined the quality of water in the surficial aquifer in the vicinity of Vadnais Lake and in Lamberts Creek watershed. Estimated ground-water seepage into Vadnais Lake. Determined the potential for transport of nutrients from the surficial aquifer into Vadnais Lake.

APPROACH: Monitoring wells were installed to complete a network of about 25 wells in the surficial sand-and-gravel aquifer. Water levels in these wells were measured to determine the potentiometric surface. Ten of these wells were sampled quarterly to determine concentrations of major nutrients and annually to determine concentrations of major ions.

RESULTS LAST YEAR: The ground-water component of the hydrologic budget of Vadnais Lake was small compared to the other components.

PLANS NEXT YEAR: The report will be published.

GROUND-WATER RESOURCES OF LEECH LAKE INDIAN RESERVATION, MINNESOTA

MN109

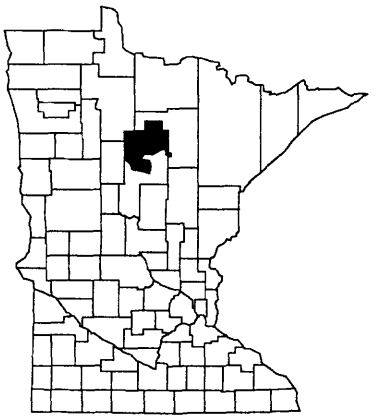
DATE PROJECT BEGAN: July 1987

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: North-central Minnesota

PRINCIPAL COOPERATING AGENCY: Leech Lake Indian Reservation Tribal Council



PROBLEM: Tribal officials need water resource information to manage the water resources of the reservation and to plan future development. The U.S. Geological Survey, in cooperation with the Leech Lake Indian Reservation Tribal Council, conducted a study to provide the data and analyses needed to define the presence, availability, and quality of ground-water resources on the Reservation.

OBJECTIVES: Described the availability of water from unconfined and confined aquifers in the glacial drift. Defined baseline quality of ground water. Related ground-water quality to major land uses.

APPROACH: The hydrogeology of the glacial-drift aquifers in the study area was defined on the basis of drillers' logs, test drilling, and numerical modeling. Hydraulic properties of aquifers were estimated using well-log data and pumping tests. Water-level data were collected from a network of observation wells, and used to describe potentiometric surfaces and flow directions in the aquifers. Recharge and discharge areas were located by comparing potentiometric-surface maps, analyzing stream base-flow data, and conducting mini-piezometer surveys in major lakes. Water quality was evaluated on the basis of existing data and of analyses of samples collected from ground-water sources. Ground-water and land-use relations were studied by analyzing water samples for chemical species indicative of land-use practices.

RESULTS LAST YEAR: The interpretive report on the ground-water resources of the Reservation was complete.

PLANS NEXT YEAR: The report will be published.

GROUND-WATER FLOW IN THE ST. PETER–PLATTEVILLE AND DRIFT AQUIFER SYSTEM RELATED TO CONTAMINATION BY COAL–TAR DERIVATIVES, ST. LOUIS PARK, MINNESOTA

MN112

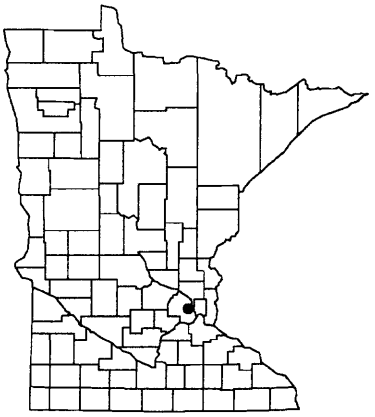
DATE PROJECT BEGAN: April 1987

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: Twin Cities Metropolitan Area

PRINCIPAL COOPERATING AGENCY: U.S. Environmental Protection Agency



PROBLEM: Ground-water contaminants from a coal-tar distillation and wood-preserving plant that operated from 1918–72 have degraded the quality of water in several aquifers in the vicinity of St. Louis Park, Minnesota. The upper aquifers in the glacial drift and the Platteville Limestone and the St. Peter Sandstone have been contaminated by coal-tar compounds that percolated to the water table from ponds and wetlands that received runoff and process water from the plant. Gradient-control and water-treatment measures currently are being implemented in the Prairie du Chien-Jordan aquifer. An appraisal is needed to evaluate gradient-control measures and previous simulations of gradient-control measures in the Prairie du Chien-Jordan aquifer and to provide information for regulators to design gradient-control measures for the drift and Platteville and St. Peter aquifers.

OBJECTIVES: Determined the direction and rate of movement of ground water in the St. Peter aquifer under past and current pumping conditions and under proposed gradient-control conditions. Obtained an understanding of the hydrogeology and ground-water flow in the drift and Platteville aquifer system.

APPROACH: Models from previous studies were refined and used to simulate the effects of past pumping conditions on the movement of contamination in the St. Peter aquifer, including the effects of multi-aquifer wells. The models were used to evaluate effectiveness of several proposed gradient-control options in the St. Peter aquifer. Logs of wells and test holes in the area were used to determine the hydrology, ground-water movement, and stratigraphic framework of the drift and Platteville aquifer in the vicinity of the former plant site. A three-dimensional, ground-water-flow model of the drift and Platteville aquifer was constructed to evaluate options for controlling hydraulic gradients in the aquifer. The effectiveness of gradient-control measures in the Prairie du Chien-Jordan aquifer was evaluated. Results from previous model simulations of proposed gradient-control scheme were compared to evaluate the accuracy of predictions beyond 1990.

RESULTS LAST YEAR: The interpretive report on the hydrogeology of the drift and Platteville aquifer system was completed. The report was processed through editorial and colleague reviews.

PLANS NEXT YEAR: The report will be published.

EFFECTS OF GROUND-WATER WITHDRAWALS ON THE TEMPERATURE AND QUALITY OF THE STRAIGHT RIVER, MINNESOTA

MN114

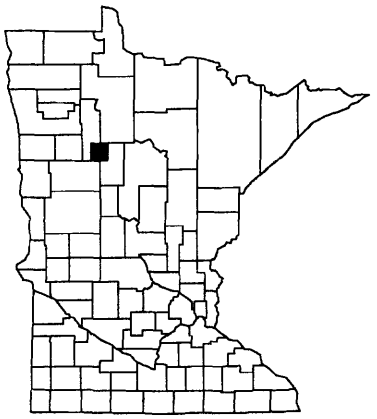
DATE PROJECT BEGAN: January 1988

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Stark, James R.

LOCATION: North-central Minnesota

PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources



PROBLEM: Trout require cold, high-quality water as habitat. Agricultural land-use changes reduce trout habitat by degradation of stream-water quality and quantity. Recreation managers are concerned that contamination from nutrients, pesticides, and reduced oxygen-carrying capacity caused by higher stream-water temperatures will reduce trout habitat. These factors may affect the ability of the river to maintain a stable population of trout. The Straight River is a designated trout stream, having clear, cold water in an area where trout streams are not common. Irrigation development has increased during the last decade and about 1.5 billion gallons of ground water was withdrawn in 1984 from wells screened in glacial-drift aquifers. Intensive use of agricultural chemicals and the subsequent degradation of ground- and surface-water quality because of irrigation has not been clearly established. An understanding of the fate and movement of pesticides, particularly as related to changes in stream quality, needs to be established.

OBJECTIVES: Evaluated the effect of ground-water withdrawals on water temperatures and water quality of a trout stream. Explored the feasibility of water-use-management techniques to balance the need for ground-water use with the need to maintain river and ground-water quality.

APPROACH: A three-year project, conducted in cooperation with the Minnesota Department of Natural Resources accomplished the following objectives: describe the hydrogeologic framework of the aquifer system and bottom sediments of the trout stream; measure baseflow of the stream and pumping for irrigation to determine seasonal change and areal distribution of outflow from the aquifer system; measure the temperature of water in the stream, streambed, and aquifer to determine seasonal and diurnal fluctuations and temperature distribution as related to aquifer-stream flux; sample stream and ground waters for constituents that could indicate seasonal loading effects from the local agricultural practices; construct a preliminary three-dimensional ground-water-flow model to determine which parameters and properties require additional data collection to understand the aquifer-stream system; and use results of the calibrated-flow model to build a model to test concepts of heat transport through the hydrologic system.

RESULTS LAST YEAR: The interpretive report of the effects of ground-water withdrawals on

stream temperature in the Straight River was published.St

REPORTS PUBLISHED IN 1994:

Stark, J.R., Armstrong, D.S., and Zwilling, D.R., 1994, Stream-aquifer interactions in the Straight River area, Becker and Hubbard Counties, Minnesota: U.S. Geological Survey Water-Resources Investigations Report 94-4009, 83 p.

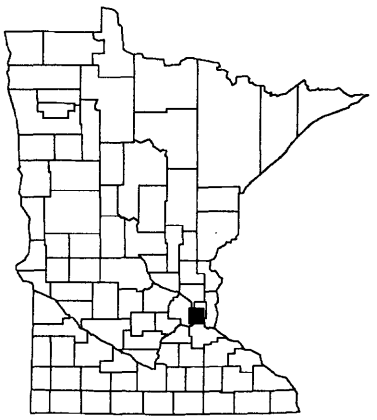
GROUND-WATER FLOW AT THREE AREAS NEAR THE MISSISSIPPI AND MINNESOTA RIVERS, TWIN CITIES METROPOLITAN AREA, MINNESOTA
MN115

DATE PROJECT BEGAN: October 1987

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Schoenberg, Michael E.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES:
Legislative Commission on Minnesota Resources and Minnesota Department of Natural Resources.

PROBLEM: The rate of flow and degree of hydraulic connection between aquifers and rivers in the Twin Cities Metropolitan area is not well defined. This information was needed to manage and estimate the availability of ground water flowing into surface waters.

OBJECTIVES: Determined the spatial and hydraulic properties of the valley-fill deposits along selected transects through deep and shallow buried valleys. Determined the vertical and horizontal hydraulic connections between aquifers and valley fill along the transects.

APPROACH: The distribution and hydraulic properties of the valley-fill deposits in the Mississippi and Minnesota River valleys were determined along three transects by the compilation of hydraulic data, the construction of test holes and observation wells, the collection of geologic samples for laboratory analysis, conducting aquifer tests to determine the hydraulic properties of valley fill, and using geophysical surveys. Ground-water-flow models at one transect were used to simulate ground-water flow and to obtain an understanding of the relation between aquifers and the river.

RESULTS LAST YEAR: The interpretive report of the ground-water flow between aquifers and the Mississippi and Minnesota Rivers was completed.

PLANS NEXT YEAR: The report will be published.

GROUND-WATER FLOW IN THE KARST AREA OF SOUTHEASTERN MINNESOTA
MN116

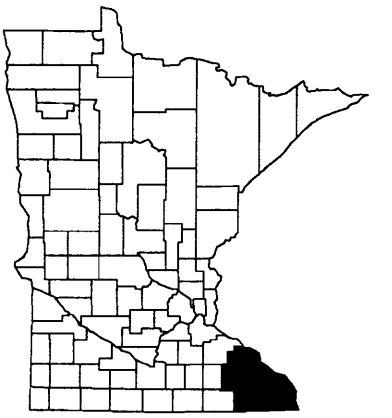
DATE PROJECT BEGAN: October 1987

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Ruhl, James F.

LOCATION: Karst area of southeastern Minnesota

PRINCIPAL COOPERATING AGENCY:
Minnesota Department of Natural Resources



PROBLEM: Contamination of ground water from point sources such as landfills, feedlots, and septic systems, and non-point sources such as agricultural chemicals is a problem in the karst area of southeastern Minnesota. Rate of contaminant movement is dependent on size, orientation, and degree of interconnection between fractures and solution channels in the carbonate rocks on which karst terrain has developed. A better understanding of flow is needed that incorporates data on fracture and solution-channel occurrence and orientation with other hydrogeologic conditions in the karst area.

OBJECTIVES: Determined if the fractures and solution channels in the Prairie du Chien Group of carbonate rocks in southeastern Minnesota are aligned along principal and minor axes of orientation. Evaluated the effect of the fractures and solution channels on ground-water flow.

APPROACH: Surface lineaments were mapped using aerial photographs. The lineament maps were compared with known orientation of fractures determined from previous and ongoing studies. The joint systems were analyzed to determine if they correlated with base-flow characteristics.

RESULTS LAST YEAR: The interpretive report of the ground-water flow of the karst area was completed.

PLANS NEXT YEAR: The report will be published.

SOURCES AND TRANSPORT OF SEDIMENT, NUTRIENTS, AND OXYGEN-DEMANDING SUBSTANCES IN THE MINNESOTA RIVER

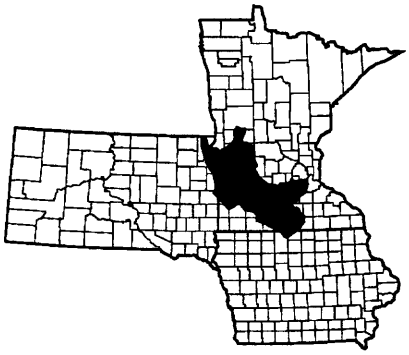
MN120

DATE PROJECT BEGAN: July 1989

DATE PROJECT ENDS: September 1993

PROJECT CHIEF: Payne, Gregory A.

LOCATION: Southwestern Minnesota and parts of North Dakota and South Dakota



PRINCIPAL COOPERATING AGENCY:
Minnesota Pollution Control Agency

PROBLEM: The Minnesota River is affected by point-source and non-point-source contaminants. The extent of contamination by these sources and how water quality will change as point sources are controlled or as agricultural practices change is not known. Point-source discharges have been identified, but interest now is being directed towards controlling non-point sources that could substantially improve the quality of the river and enhance its resources. The sources, transport, and fate of non-point-source contaminants need to be understood so that management practices can be implemented.

OBJECTIVES: Determined the sources and loading of suspended sediment, nutrients, biochemical oxygen demand (BOD), and organic carbon in selected reaches and tributaries of the Minnesota River and ground water. Determined the effects of specific sources on river-water quality. Determined the relation between suspended sediment and nutrients, BOD, and organic carbon. Identified areas of bank erosion and sediment deposition to determine if in-stream loading could have a more adverse effect on river quality than non-point off-stream loading.

APPROACH: This study encompassed most of the Minnesota River drainage basin in Minnesota, North Dakota, and South Dakota, focusing primarily on the mainstem and several major tributaries. Water-quality samples were collected at 12 mainstem, 10 tributary, and 15 seep sites. Two sites were sampled monthly, supplemented by weekly sampling March through July 1990–92. Daily suspended sediment samples were collected at two sites. Water samples were analyzed to determine concentrations of nitrogen, phosphorus, suspended sediment, chemical oxygen demand (COD), BOD, bacteria, and chlorophyll. Bottom material also was sampled. Stream discharges were measured and sediment and chemical loads were calculated. The relation between suspended sediment concentration and concentrations of other constituents were determined. Transport between segments of the main stem was assessed on the basis of differences in load.

RESULTS LAST YEAR: Suspended-sediment and stream-discharge data collected from the

Redwood River during a 4-day runoff period showed a 3,900-ton increase in sediment load within a 5.2-mile study reach. A first-order tributary, Judicial Ditch 5, delivered 170 tons of sediment during the same 4-day period. Suspended-sediment yields for the 4-day period ranged from 9.52 tons/mi^2 for the Redwood River to 19.5 tons/mi^2 for Judicial Ditch 5. Particle-size analyses showed that 99 percent of the suspended sediment in Judicial Ditch 5 was comprised of silt- and clay-sized particles. Suspended sediment in the Redwood River was comprised of sand-sized particles in addition to silt- and clay-sized material. The sediment load and particle-size information were used to characterize the type and amount of sediment from upland, as well as in-stream, sources. The Blue Earth River delivered 69 percent of the nitrate load in the Minnesota River at Mankato from April through July 1991. These results, along with results from nine other tributary streams indicate that tributaries in the eastern part of the Minnesota River Basin have higher nitrite plus nitrate nitrogen yields than tributaries in the western part. The high yields reflect both higher nitrate concentrations and higher annual stream discharge in the eastern part of the basin.

PLANS NEXT YEAR: An interpretive report will be published as part of one volume of a State of Minnesota report series on the findings of the Minnesota River Assessment Project. New field investigations will begin during the spring of 1994. These efforts will be focused on quantifying concentrations and loads of nitrogen, phosphorus, sediment, and oxygen demand in a variety of stream watersheds, including urban as well as agricultural environments. The purpose of these investigations is to characterize the type and quantity of nonpoint-source substances that are derived from various land-management practices in the Minnesota River Basin.

PUBLISHED REPORTS IN 1993:

Winterstein, T.A., Payne, G.A., Miller, R.A., and Stark, J.R., 1993, Selected basin characteristics and water-quality data of the Minnesota River Basin: U.S. Geological Survey Open-File Report 93–164, 100 p.

HYDROGEOLOGIC SENSITIVITY OF THE PRAIRIE DU CHIEN–JORDAN AQUIFER, MINNESOTA

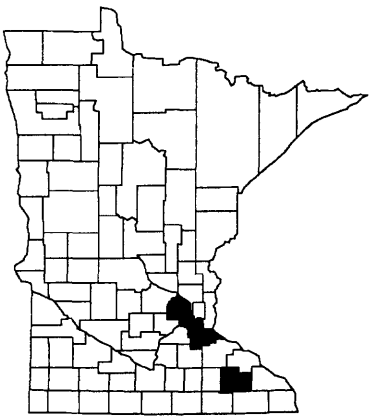
MN122

DATE PROJECT BEGAN: October 1989

DATE PROJECT ENDS: September 1992

PROJECT CHIEF: Smith, Shannon E.

LOCATION: Southeastern Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources and the Legislative Commission on Minnesota Resources.

PROBLEM: The Prairie du Chien-Jordan is a principal aquifer over large parts of southeastern Minnesota and is the principal source of ground water in the Minneapolis-St. Paul Metropolitan Area. The aquifer is comprised of a fractured and solution-channeled dolomite underlain by quartz sandstone. Both stratigraphic units yield significant quantities of water to wells. Vertical differences in natural ground-water quality and contamination between the Prairie du Chien Group and the Jordan Sandstone have been measured. Contamination of the Prairie du Chien by various industrial and agricultural contaminants is widespread; however, the extent of mixing between the two units of the aquifer is not known. The factors that cause water-quality variation in the aquifer and in the degree of contamination must be better defined to allow evaluation of the sensitivity of the aquifer to contamination and to effectively manage large-scale withdrawals of water from this aquifer.

OBJECTIVES: Described the susceptibility of the Jordan Sandstone to contamination by land-use practices. Characterized water-quality variations between the Prairie Du Chien Group and the Jordan Sandstone of the Prairie du Chien-Jordan aquifer. Determined the hydrogeologic factors that could cause water-quality variations.

APPROACH: A 2 1/2-year study was conducted to evaluate ground-water chemistry and hydraulics along flow paths in the Prairie du Chien-Jordan aquifer. Hydrologic, geologic, and chemical data were reviewed to select ground-water flow paths in Olmsted, Dakota, and Hennepin Counties. Six study areas were selected to represent a broad spectrum of land use, water use, and hydrogeologic conditions. Aquifer hydraulic properties and existing water levels were compiled for each study area. Information relative to areas of confinement, areas of fractures, lithology, thickness, and stratigraphy of the Prairie du Chien-Jordan aquifer and overlying units also were compiled. Hydrologic and land-use data were compiled from data available from files of the U.S. Geological Survey, the Minnesota Geological Survey, the State Planning Agency, and local agencies. Water samples were collected from 139 wells for analysis.The data were used to deter-

mine the relation between water quality and hydrologic and geologic conditions in each area.

RESULTS LAST YEAR: Analysis of the relations between the distribution of water-quality constituents in the aquifer and several hydrogeologic and well-construction factors was completed. A statistically significant relation was found when high concentrations of nitrite plus nitrate nitrogen, chloride, and tritium were compared to the presence of well grout, well depth, and presence of the overlying Decorah Shale. A draft of the report was completed. The report is currently under review and revision.

PLANS NEXT YEAR: The report will be published.

HYDROLOGY AND RELATION OF WATER QUALITY TO SELECTED PHYSICAL FACTORS IN DAKOTA COUNTY, MINNESOTA, 1990–91

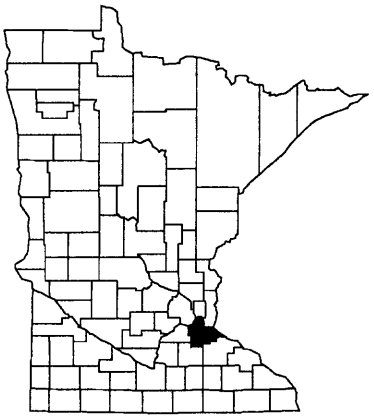
MN123

DATE PROJECT BEGAN: November 1989

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Almendinger, James E.

LOCATION: Southeastern Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources, Legislative Commission on Minnesota Resources, and Dakota County Soil and Water Conservation District

PROBLEM: The headwaters area of the Vermillion River Basin in Dakota County is undergoing rapid urbanization while other areas of the basin are used for agriculture. Information is needed on how the water resources are affected by urbanization, agriculture, water-table depth, and soil type. The Prairie du Chien-Jordan aquifer underlies the glacial drift in Dakota County and is susceptible to contamination from land-use practices where the water table is at or near land surface.

OBJECTIVES: Described surface- and ground-water quality in Dakota County as related to land use, surficial geology, bedrock geology, depth to water table, and soil type. Compared regional depth-to-water mapping methods that are used to assess ground-water susceptibility to surface contamination.

APPROACH: Five combination surface- and ground-water sites for water-quality sampling were established in the Vermillion River Basin. Streamflow data also were collected at these sites. Water-quality sampling was done from January 1990 through June 1991 and samples were analyzed for specific conductance, pH, water temperature, dissolved oxygen, major cations and anions, bacteria, nutrients, organics, U.S. Environmental Protection Agency priority pollutants, and triazines. Twenty domestic wells also were sampled twice during 1990–91. The hydrologic data were correlated with selected physical factors to determine causes for differences in the water-quality data. Geographic Information Systems software were used to determine well locations mapping.

RESULTS LAST YEAR: The draft interpretive report of the hydrology and relation of ground water to selected physical characteristics was completed.

PLANS NEXT YEAR: The project is complete except the report, which is in review.

SPATIAL AND TEMPORAL VARIABILITY OF BASE FLOW OF A PERENNIAL STREAM, STRAIGHT RIVER, MINNESOTA

MN124

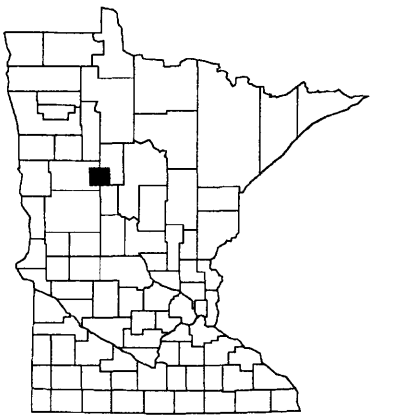
DATE PROJECT BEGAN: December 1989

DATE PROJECT ENDS: September 1992

PROJECT CHIEF: Stark, James R.

LOCATION: North-central Minnesota

PRINCIPAL COOPERATING AGENCY:
Minnesota Department of Natural Resources.



PROBLEM: Spatial and temporal variability in ground-water discharge to streams is complex. The distribution of ground-water flow to streams and the interaction between streams and aquifers need to be studied. Streamflow cannot be routinely and efficiently measured with sufficient detail and frequency to accurately determine the ground-water component of discharge to streams.

OBJECTIVES: Categorized valley reaches of similar geomorphic features (slope, sinuosity, and streambed and alluvial materials) and zones of similar hydraulic gradient between the stream and the aquifer. Determined the affect of these geomorphic features on base flow.

APPROACH: Two principal hypotheses were tested during the study. The first hypothesis was that a correlation exists between geomorphic characteristics of a stream valley or channel (slope and sinuosity), and the spatial distribution of alluvial materials that resist ground-water flow between an underlying alluvial aquifer and a stream. The second hypothesis was that a correlation exists between these same geomorphic characteristics and base flow in the stream. This study developed general conceptual models and conducted field experiments at regional and local scales to determine factors controlling spatial and temporal variability of base flow from glacial aquifers to a perennial stream. The field approach to this study was to compare the base-flow changes between selected reaches of the river. Stream reaches of 4,000 to 7,000 feet were selected for analysis of base flow. Each test reach had different geomorphic characteristics. For each reach, physical factors were mapped into zones of relative base-flow potential. Base-flow gain was measured when aquifer head and stream stage were not changing, and correlated to factors that varied within and among the reaches. Changes in base-flow gain through time caused by changes in hydraulic gradient across the streambed were measured. A conceptual model of streambed and ground-water gradients along the Straight River were developed and used to test stream-ground-water interactions observed during field investigations.

RESULTS LAST YEAR: The project is complete except the report.

PLANS NEXT YEAR: The report will be written.

AVAILABILITY AND QUALITY OF WATER FROM DRIFT AQUIFERS IN MARSHALL, PENNINGTON, POLK, AND RED LAKE COUNTIES, NORTHWESTERN MINNESOTA

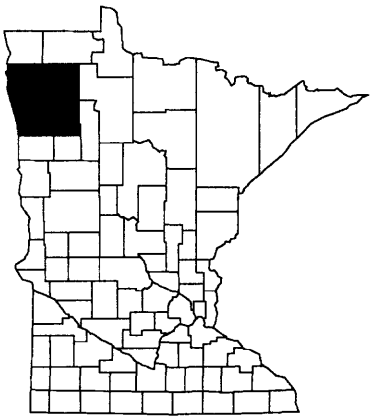
MN125

DATE PROJECT BEGAN: December 1989

DATE PROJECT ENDS: September 1993

ROJECT CHIEF: Lindgren, Richard J.

LOCATION: Northwestern Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources and the Northwestern Minnesota Ground Water Steering Committee.

PROBLEM: Ground-water withdrawals are increasing in Marshall, Pennington, Polk, and Red Lake Counties where surficial aquifers are limited to scattered beach deposits formed by the ancient glacial Lake Agassiz and surface water is not a reliable source of drinking water. The glacial drift ranges from 200 to 300 feet in thickness, but little is known about the presence and availability of water from confined aquifers interbedded within the drift. The surficial (beach-ridge) aquifers, which are susceptible to land-surface contamination, could be significant areas of recharge for the underlying confined sand-and-gravel aquifers. High-salinity water from underlying Paleozoic and Cretaceous sedimentary rocks is believed to have migrated into the drift aquifers, resulting in some water-quality problems. The U.S. Geological Survey, in cooperation with the Minnesota Department of Natural Resources and a local ground-water steering committee made up of county, city, water and soil district representatives, studied water-supply potential and water quality of the sand-and-gravel aquifers in the four counties to help manage the increasingly scarce ground-water resources.

OBJECTIVES: Described the areal extent, thickness, and water-bearing characteristics of confined-drift aquifers. Estimated the water-supply potential from the surficial and uppermost confined-drift aquifers. Described trends in water quality along regional ground-water flow paths from areas of recharge to discharge.

APPROACH: The 3 1/2-year study was conducted under two overlapping phases. Phase I concentrated on regional mapping and description of the confined sand-and-gravel aquifers in Marshall, Pennington, Polk, and Red Lake Counties. Phase II involved a more detailed study of water-resource potential of the surficial aquifers (especially the beach-ridge deposits), the interaction between the surficial and confined aquifers, and ground-water quality in an area smaller than the area for phase I of the study. Data from water-well logs, field inventory of wells, and subsequent test drilling were used to map the distribution of the uppermost confined-drift aquifers and to estimate the direction of flow in the aquifer system. Seismic-geophysical data collected by the Min-

nesota Department of Natural Resources was used to refine estimates of aquifer distribution and depth to bedrock. A mathematical model was constructed to test concepts of ground-water flow and recharge to the aquifer system and to guide additional data collection. Water-use data were compiled to describe the distribution and intensity of ground-water withdrawals. Aquifer tests determined transmissivity, storage coefficients, and the effects of aquifer boundaries to water-supply potential. Water levels were measured continuously in unconfined and confined aquifers to estimate seasonal recharge, relative hydraulic connection between aquifers, and the effects of ground-water withdrawals. Water samples were collected from wells and analyzed for major inorganic constituents to establish baseline water-quality conditions and to define water-quality trends along flow paths. Water samples also were collected from surficial aquifers and analyzed for U.S. Environmental Protection Agency priority pollutants that might be related to local land-surface activities. Specific conductance measurements of well water were made to estimate the depth to saline ground water, especially near the Red River of the North.

RESULTS LAST YEAR: Water levels were measured periodically in 61 observation wells. Estimated recharge to unconfined-drift aquifers ranged from 2.2 to 10.6 inches during 1993, based on hydrograph analysis. Data from 25 slug tests and the 9 single-well recovery aquifer tests were analyzed. Areal maps showing the extent, thickness, transmissivity, and theoretical maximum well yield of confined-drift aquifers were completed. The aquifers were grouped and mapped based on the depth from land surface to the top of the aquifer. The composite aquifers were designated the shallow, intermediate, deep, and basal aquifers. Depths to the top of these aquifers are less than 100 feet, 100–199 feet, 200–299 feet, and greater than 299 feet, respectively. Construction and calibration of numerical models of steady-state ground-water flow in two beach-ridge aquifer systems were completed. Sensitivity analyses and simulations with hypothetical ground-water withdrawals were completed. Water-quality data for water samples from 60 wells were analyzed to establish baseline water-quality conditions. The predominant ions in water from both the unconfined-drift and shallow confined-drift aquifers are generally calcium and bicarbonate. Water from the intermediate confined-drift aquifers consists of a variety of water types, including calcium bicarbonate, calcium sulfate, mixed calcium-sodium bicarbonate, and sodium chloride type waters. The predominant water types for water from the deep confined-drift aquifers are calcium bicarbonate, mixed calcium-sodium bicarbonate, and sodium chloride. Laboratory results for 17 water samples from wells screened in unconfined-drift aquifers indicated that pesticide concentrations were below or only slightly above detection limits for a broad spectrum of pesticides. The first draft of the interpretive report was completed.

PLANS NEXT YEAR: The report will be published.

INFLUENCE OF FOCUSED RECHARGE ON THE MIGRATION OF AGRICULTURAL CHEMICALS TO GROUND WATER

MN126

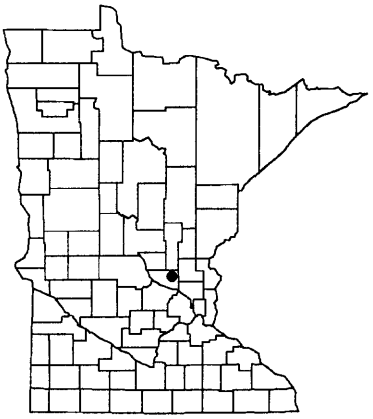
DATE PROJECT BEGAN: October 1989

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Delin, Geoffrey N.

LOCATION: East-central Minnesota

COOPERATOR: University of Minnesota



PROBLEM: Agricultural chemicals are applied most frequently in light soils with low organic content, that are commonly underlain by surficial sand-and-gravel aquifers. These aquifers are hydrogeologically vulnerable because they have hydraulic conductivities greater than till. There is a need to better understand the fate and transport of agricultural chemicals through the surficial sand-and-gravel aquifers.

OBJECTIVES: Determine the fate and mobilization of agricultural chemicals in sand-plain aquifers, specifically at the Princeton, Minnesota, Management System Evaluation Area (MSEA) in collaboration with the University of Minnesota Soil Science Department and the U.S. Department of Agriculture, Agricultural Research Service.

APPROACH: Concentrations of agricultural chemicals and their metabolites will be quantified temporally upgradient, in the middle, and downgradient of the research plots. Research activities by U.S. Geological Survey and U.S. Environmental Protection Agency researchers at the MSEA will be coordinated and logistical support will be provided. Hydrologic and chemical data of common interest to participating scientists will be collected and entered into a data base. The hydrology and water quality at the research farm will be described.

RESULTS LAST YEAR: Interpretation of data collected during 1991 and 1992 indicates that there are sharp vertical gradients in the concentrations of chloride, nitrate nitrogen (nitrate-N), dissolved oxygen, pH, alkalinity, calcium, magnesium, and sulfate in the upper 2 meters of the saturated zone. The shape of the vertical profiles varied spatially and temporally. There were consistent decreases with depth in the concentrations of chloride, nitrate-N, and dissolved oxygen, and increases in pH, alkalinity, calcium, magnesium, and sulfate. Atrazine was detected above the quantitative reporting limit of 0.04 micrograms per liter (µg/L) in 21 percent of the 322 samples collected during May 1991 through April 1992. De-ethylatrazine (DEA) was the most frequently detected herbicide or herbicide metabolite during 1991–92. DEA was detected above the quantitative reporting limit of 0.06 µg/L in 62 percent of the 322 samples collected. These detections of atrazine and DEA likely are unrelated to the MSEA farming systems.

Concentrations of nitrate-N and chloride in the ground water increased above background concentrations following relatively small amounts of recharge (2.5 to 6.5 centimeters (cm)) that occurred during fall 1991 and spring 1992. Concentrations of these chemicals in the upper 0.5 m of the saturated zone were less than concentrations deeper in the saturated zone during 1991, likely as a result of dilution by a large amount of recharge (12.5 to 20 cm). Vertical mixing within the upper part of the saturated zone likely occurred at the MSEA by April 1992, which allowed newly recharged water and agricultural chemicals to move rapidly to at least 2 m below the water table.

Results of the focused recharge study indicate that small differences in topography (1.4 m vertically over an 80 m horizontal distance) results in focused recharge at lowland sites. Even when recharge occurred at both the upland and lowland sites during 1992, recharge was greater at the lowland site.

PLANS NEXT YEAR: Observation wells, multiport wells, Battle Brook, and the irrigation well will be sampled quarterly. A synoptic measurement of water levels in all observation wells will be completed monthly. Data from the data loggers will be downloaded monthly. Interpretation of the water-quality results will continue. In addition to quarterly sampling of all observation wells and multiport wells, water samples will be collected monthly from multiport wells located in the upland and lowland areas, immediately downgradient of the recharge research plot, and along a transect of wells extending into the wetland. Selected samples will be analyzed for anions, cations, herbicides, isotopes, chlorofluorocarbons, dissolved gases, and tritium. A controlled recharge experiment will be conducted. About 2 to 8 inches of irrigation water will be applied to upland and lowland sites. Water samples will be collected from the irrigation, suction samplers in zones of preferential and retarded flow, and the water table. The samples will be analyzed for concentrations of herbicides and inorganic constituents. Laboratory tracer tests will be conducted on soil cores taken from the upland and lowland sites. A first draft of the site characterization report will be completed and a U.S. Geological Survey Water Fact Sheet summarizing preliminary water-quality results for 1992 at the MSEA will be written. Project personnel will present preliminary research results at selected conferences.

REPORTS PUBLISHED IN 1993:

Anderson, J.L., Dowdy, R.H., Lamb, J.A., Delin, G.N., Knighton, R., Clay, D., and Lowery, B., 1993, Northern cornbelt sand plains Management Systems Evaluation Area: Agricultural Research to Protect Water Quality Conference Proceedings, Minneapolis, Minnesota, February 21–24, 1993, p. 39–47.

Delin, G.N., and Landon, M.K., 1993a, Effects of focused recharge on the transport of agricultural chemicals at the Princeton, Minnesota Management Systems Evaluation Area: U.S. Geological Survey Open-File Report 93–42, 8 p.

Delin, G.N., and Landon, M.K., 1993b, Effects of focused recharge on the transport of agricultural chemicals at the Princeton, Minnesota Management Systems Evaluation Area—Preliminary results: Agricultural Research to Protect Water Quality Conference Proceedings, Minneapolis, Minnesota, February 21–24, 1993, p. 210–214.

Delin, G.N., and Landon, M.K., 1993c, Effects of recharge on the transport of agricultural chemicals at the Princeton, Minnesota Management Systems Evaluation Area, 1991-92: U.S. Geological Survey Open-File Report 93–79, 2 p.

Delin, G.N., and Landon, M.K., 1993d, Effects of topography on the transport of agricultural chemicals near Princeton, Minnesota, 1992: *in* Morganwalp, D.W., and Aronson, D.A. eds. U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the technical meeting, Colorado Springs, Colorado, September 20–24, 1993: U.S. Geological Survey Water-Resources Investigations Report 93–4014, 14 p.

Delin, G.N., Landon, M.K., Anderson, J.L., Lamb, J.A., and Dowdy, R.H., 1993, The Minnesota Management Systems Evaluation Area (MSEA) Project [abs.]:Minnesota Water Resources Conference, St. Paul, Minnesota, October 26–27, 1993, 1 p.

Delin, G.N., Landon, M.K., Healy, R.W., and Olsen, H.W., 1993, Spatial variability of unsaturated zone properties in relation to topography in a sand-plain setting near Princeton, Minnesota: *in* Morganwalp, D.W., and Aronson, D.A., eds. U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the technical meeting, Colorado Springs, Colorado, September 20–24, 1993: U.S. Geological Survey Water-Resources Investigations Report 93–4014, 14 p.

Landon, M.K., Delin. G.N., Lamb, J.A. and Guo, L., 1993a, Ground-water quality at the Management Systems Evaluation Area (MSEA) near Princeton, Minnesota, 1991: U.S. Geological Survey Open-File Report 93–43, 8 p.

Landon, M.K., Delin, G.N., Lamb, J. A., and Guo, L., 1993b, Ground-water quality at the Management Systems Evaluation Area near Princeton, Minnesota, 1991: U.S. Geological Survey Open-File Report 93–80, 2 p.

Landon, M.K., Delin, G.N., Lamb, J.A., Dowdy, R.H., and Anderson, J.L., 1993, Effects of farming systems on ground-water quality at the Princeton, Minnesota Management Systems Evaluation Area, 1991: *in* Morganwalp, D.W., and Aronson, D.A., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the technical meeting, Colorado Springs, Colorado, September 20–24, 1993: U.S. Geological Survey Water-Resources Investigations Report 93–4014, 14 p.

Wanty, R.B., Tuttle, M.L., Landon, M.K., Delin, G.N., and Böhlke, J.K., 1993, Geochemistry of nitrogen in a farmed watershed near Princeton, Minnesota: *in* Morganwalp, D.W., and Aronson, D.A., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the technical meeting, Colorado Springs, Colorado, September 20–24, 1993: U.S. Geological Survey Water-Resources Investigations Report 93–4014, 14 p.

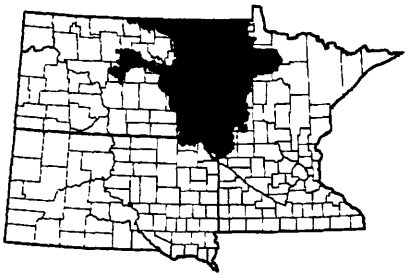
NATIONAL WATER-QUALITY ASSESSMENT—RED RIVER OF THE NORTH BASIN
MN127

DATE PROJECT BEGAN: December 1990

PROJECT ENDS: September 1996

PROJECT CHIEF: Stoner, Jeffrey D.

LOCATION: Northwestern Minnesota and eastern North Dakota.



PROBLEM: Federal, State, and local governments and industry have made significant commitments to the protection of water quality over the past two decades. Large financial investments have been made for water-quality management and protection over the past 20 years and future expenditures are anticipated to abate and control water contamination. Nationally consistent information is needed to make valid regional comparisons and national statements about current water-quality conditions and about changes in these conditions. The U.S. Geological Survey began implementing a full-scale National Water-Quality Assessment (NAWQA) program in 1990 to address this need for national water-quality information. Because it would be impractical to assess water quality in every area of the Nation, major activities of the NAWQA program will take place within a set of hydrologic systems called study units. The Red River of the North basin was selected as 1 of 60 study units because the basin represents an important hydrologic region where good-quality water is a valued resource vital to the region's economy. The quality of the Red River of the North, which flows north into Manitoba, Canada, is of international concern; the basin represents a significant agricultural area and provides opportunities to study sediment, nutrients, and pesticides through the national-assessment part of NAWQA. The northern location and potential interaction of surface and ground water in the Red River of the North Basin are essential physical factors necessary for a complete national assessment of water quality.

OBJECTIVES: Describe the status and trends in the quality of a large, representative part of the basin surface- and ground-water and provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. Identify the regional physical, chemical, and biological constituents of water quality (target constituents) that are of concern in the Red River of the North study unit. Estimate the distribution and annual stream load of selected nutrients, sediment, and pesticides in the basin. Describe the relation of water quality to regional land-use practices in surficial and confined aquifers within the glacial drift and major streams. Identify the predominant natural and human factors that affect the load and concentration of target constituents measured in water and aquatic animals. Describe seasonal variability of selected target constituents in major streams from agricultural runoff and from natural sources. Describe the

long-term regional and subregional trends of target constituents in surface water and ground water. Design procedures for sampling surface water, ground water, and aquatic animals to effectively monitor for long-term trends in water quality.

APPROACH: Project activities will be cyclic to accomplish the water-quality status and trend components of the study. The first two years will focus on planning and analysis of available data. Years 3 through 5 will emphasize data collection and analysis followed by the 6th year for report preparation. A lower level of data collection will continue for the subsequent 5 to 6 years to evaluate long-term trends in water quality after which the more intensive data-collection cycle will be repeated. Project planning will be coordinated through a liaison committee made up of local, State, and other Federal agencies, and some Canadian agencies and private industries that will help identify key water-quality issues of the basin and sources of data, and will assist with the project design. Available water-quality and ancillary data will be compiled into computer data bases, including geographical information systems, for spatial comparisons and statistical analysis. Information from the available data will be used to design data collection networks needed to accomplish a comprehensive assessment of the basin water quality. Water will be sampled from networks of time-series and synoptic stream stations and wells, and analyzed for target constituents. Suspended and bottom sediments will be collected from major streams and analyzed for grain-size distribution and selected chemical constituents. Algae and tissues of fish and macroinvertebrates will be sampled and analyzed for selected target constituents.

RESULTS LAST YEAR: Nutrient, sediment, and pesticide data collected from the Red River of the North Basin by several agencies during 1970–90 were reviewed to determine water quality in the basin. Average nutrient concentrations generally were larger in the Red River of the North than in tributary streams. Tributary streams, especially the Pembina River, had large ranges in nutrient concentrations. Nitrate-nitrogen concentrations in surface water and ground water were slightly above 1 milligram per liter in local areas, but rarely exceeded the 10 milligrams per liter maximum contaminant level for drinking water. The majority of pesticide analyses for the Red River of the North Basin show no concentrations above reporting limits. Pesticide concentrations found above reportable limits usually were below maximum-contaminant levels.

Beginning in March 1993, water samples were collected from four stream sites on a weekly basis to determine the temporal variation in the concentration of pesticides, nutrients, sediment, and major ions in streams during various seasonal and runoff conditions of the 1993 crop-growing season. Samples also were collected monthly at ten other stream sites. These sites were selected to determine the presence and seasonal variation in the concentration of nutrients, common ions, suspended sediment, and organic carbon from representative physiographic and ecological subregions of the Red River of the North Basin. Some stream sites were selected to estimate the integration of runoff from a combination of land uses in the Red River of the North Basinasin. Ecological surveys, which include habitat descriptions and biological-community surveys of fish, invertebrates, and algae, were started after spring runoff at six stream-reach sites located within four major ecological regions. Four of these sites are collocated with four of the intensive water-chemistry sampling sites. High streamflows from an unseasonably wet and cool summer affected the original objectives for basin wide biota sampling and data comparisons. Computer records of water wells were consolidated into a single project data base and reviewed to select wells for water sampling. Wells were installed and completed just below the water table of the Sheyenne Delta aquifer in southeastern North Dakota at 22 randomly selected locations

downgradient from cropping patterns of small grains and corn. Water samples were collected from these and eight existing wells and analyzed for pesticides, nutrients, major ions, selected radionuclides, and volatile-organic compounds to determine land-use effects on shallow ground-water quality. Wells were installed along ground-water-flow paths to evaluate in more detail the distribution of ground-water quality beneath principal land uses and near discharge to streams. Sites were selected and well installation begun for land-use and flow-path studies in a surficial sand-and-gravel aquifer within the upper Otter Tail River Basin in Minnesota, an area of intensively irrigated corn, potatoes, edible beans, and alfalfa.

Ancillary data, such as cropping patterns in intensively studied subbasins, were field verified and updated in the geographical information data base. A number of meetings were held among project team members and state, federal, and Canadian agency representatives to collaborate and coordinate field activities within respective agency programs. The environmental setting and its implications for a water-quality report was sent to the American Water-Resources Association for approval as a journal series publication with four other Central United States NAWQA studies.

A report that describes the distribution of nutrients, sediment, and pesticides in surface and ground water based on available data was drafted and processed through technical reviews.

PLANS NEXT YEAR: Data collected on water chemistry, sediment, and aquatic biota will be analyzed and compared to natural and human factors. These analyses will be used to refine specific approaches and sampling networks to collect additional water-quality data from streams and ground water. Network stream sites will be resampled for chemical constituents, suspended sediment, and aquatic biota to determine annual variability of target constituents. Synoptic surveys of stream chemistry will be conducted on selected watersheds where more data on the spatial distribution of specific chemical constituents are needed to assess the significance of a water-quality issue. First-round sampling of ground water will continue at all scales of assessment. Wells completed in buried sand-and-gravel aquifers will be sampled to assess natural and human factors affecting the quality of that ground water. Communication of project plans and preliminary findings and information exchange will continue through the liaison-committee process, public meetings, and scientific conferences.

PUBLISHED REPORTS IN 1993:

Stoner, J.D., Lorenz, D.L., Wiche, G.J., and Goldstein, R.M., 1993, Red River of the North Basin, Minnesota, North Dakota, and South Dakota: American Water Resources Association Monograph Series no. 19, *and* Water Resources Bulletin, v. 29, no. 4, p. 575–615.

GROUND-WATER RESOURCES OF THE MILLE LACS INDIAN RESERVATION IN MINNESOTA

MN128

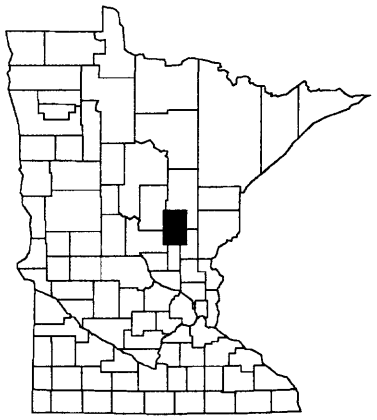
DATE PROJECT BEGAN: October 1990

PROJECT ENDS: September 1993

PROJECT CHIEF: Trotta, Lee C.

LOCATION: Central Minnesota

PRINCIPAL COOPERATING AGENCY: Mille Lacs Band of Chippewa Indians



PROBLEM: Information about the water resources of the 12 Indian reservations in Minnesota is limited, and a review of Indian water claims in Minnesota, as outlined by the Bureau of Indian Affairs, presently is not feasible. The Mille Lacs Tribal Council, in cooperation with the U.S. Geological Survey, is conducting a study to provide the data and analyses needed to define the presence, availability, and quality of ground-water resources on the Reservation. Water managers from the Mille Lacs Reservation are interested in the potential for development of ground-water supplies and the protection of ground water from human activities on the land. In addition, the levels of smaller lakes in the area are critical to the production of wild rice and favorable waterfowl habitat, both of which are important to the economy of the Reservation.

OBJECTIVES: Determined water availability from the uppermost confined-drift aquifers. Described the potential for contamination of the uppermost confined-drift aquifer caused by land-use activities. Described potential interaction between ground water and Lake Onamia.

APPROACH: A three-year study was conducted. About one-half the data collection necessary was completed during the first two years. Remaining data collection, data analysis, data interpretation, and report preparation were completed in the third year. Seismic surveys were conducted to identify the depth to sand-and-gravel layers and depth to bedrock. Maps and hydrogeologic sections showing the areal extent and thickness of the uppermost confined-drift aquifer were prepared from drill-log data and geophysical surveys. A test-drilling program was implemented to define aquifer boundaries in areas lacking sufficient data. The presence and movement of water in the glacial aquifers was defined by mapping the potentiometric surface from reported and measured water levels in wells. Temporal variations of the water surface were investigated by synoptic well water-level measurements and monthly and continuous water-level measurements in wells. Hydraulic properties of the aquifers were estimated from well-log descriptions and aquifer tests. Ground-water withdrawals were estimated by tabulating the principal ground-water uses in the area. Water quality of the glacial aquifers was determined by reviewing existing water-quality data and collecting new water from the aquifers for analysis. Areas of ground-water-pollution sus-

ceptibility were described in terms of confining-unit thickness. Water samples from the aquifer in high-susceptibility areas were collected and analyzed for priority pollutants indicative of local land-use activities. Water levels in wells around Lake Onamia were measured for one year. The potentiometric surface of shallow aquifers adjacent to the lake were compared to the lake level to determine potential ground-water interaction with Lake Onamia. A mid-winter mini-piezometer survey was conducted to improve the understanding of this interaction.

RESULTS LAST YEAR: Except for seismic data collection and preliminary well drilling/monitoring, all data collection, analysis and interpretation was completed last year. An interpretive report of the project was submitted for review in early September 1993.

PLANS NEXT YEAR: The final well remaining under U.S. Geological Survey ownership will be properly abandoned. The report will be published.

HYDROGEOLOGY OF THE GRAND PORTAGE INDIAN RESERVATION, NORTHEASTERN MINNESOTA

MN129

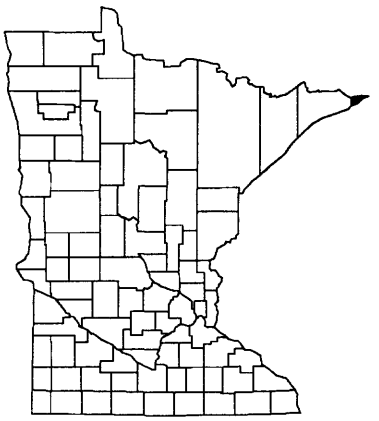
DATE PROJECT BEGAN: April 1991

DATE PROJECT ENDS: September 1993

PROJECT CHIEF: Ruhl, James F.

LOCATION: Northeastern Minnesota

PRINCIPAL COOPERATING AGENCY: Grand Portage Band of Chippewa Indians



PROBLEM: The Grand Portage Band of Chippewa Indians has identified two critical issues regarding the management, use, and protection of ground water on the Reservation. First, the efficient development of ground-water supplies for commercial and residential use. Second, the potential migration of contaminants from on-land waste-disposal sites to aquifers used as sources of drinking water. Information about the hydrogeology and water quality of the aquifers on the Reservation currently is limited to regional-scale descriptions determined from reconnaissance-level investigations. Reservation officials have expressed a need for more information about local ground-water conditions to better deal with these issues.

OBJECTIVES: Determined the general availability and quality of ground water. Evaluated the potential for aquifer contamination from on-land waste disposal sites.

APPROACH: Stream-discharge data were collected at gaging stations on the Reservation River and on Grand Portage Creek. Four monitoring wells were installed. Base-flow recession in the Reservation River was analyzed to estimate aquifer properties. Aquifer properties also were evaluated on the basis of geophysical logging and specific-capacity tests conducted on the monitoring wells, and on the basis of interpretation of well-log data that was done to estimate transmissivity.

RESULTS LAST YEAR: Two bedrock monitoring wells were hydrofractured and evaluated by low-capacity aquifer tests, vertical flow measurements, and conventional geophysical logging. A first draft was completed of the introduction of the interpretive report of the study.

PLANS NEXT YEAR: The final report will be written.

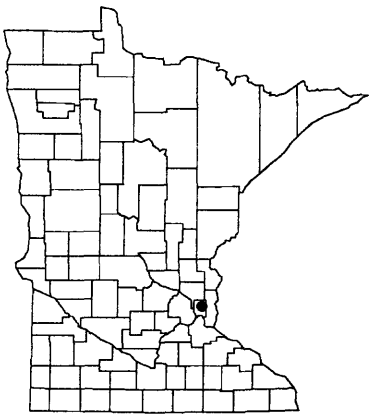
WATER QUALITY FROM ROADWAY RUNOFF
MN130

DATE PROJECT BEGAN: May 1992

DATE PROJECT ENDS: March 1996

PROJECT CHIEF: Mitton, Gregory B.

LOCATION: Northeastern quarter of Ramsey County



PRINCIPAL COOPERATING AGENCY: Local Road Research Board

PROBLEM: The Minnesota Department of Transportation is concerned about runoff from guttered-section(urban) and unguttered-section roadways(rural). Information is needed on the water quality of roadway runoff from streets and highways and the effects this runoff has on receiving waters.

OBJECTIVE: The objective of this study was to determine the loading of major ions, nutrients, selected minor elements, and selected man-made organic compounds from guttered-section and unguttered-section roadways.

APPROACH: Runoff will be collected from three roadway types over a three-year period (ten runoffs per year). Sites will be selected to minimize effects of adjacent land use. All sites will be equipped with stage recorders, Parshall flumes, and automatic samplers. Two sites will also have precipitation collectors. Runoff samples will analyzed for specific conductance, pH, nutrients, major ions, and selected metals. Grab samples will be taken as soon after the onset of the storms as possible and analyzed for bacteria, dissolved oxygen, and poly-nuclear aromatic hydrocarbons. Analysis of runoff will compare results from different roadway types, as well as from different seasons.

RESULTS LAST YEAR: Sampling sites were instrumented and activated. Data-logger programs were developed to collect flow data and flow-weighted runoff samples. Three snowmelt-runoffs and seven rainfall runoffs were sampled. Results of water-quality analyses show elevated concentrations of sodium as high as 2,100 milligrams per liter (mg/L) and chloride as high as 2,800 mg/L from snowmelt runoff which probably reflects application of road de-icing salts. Rainfall-runoff samples had lower concentrations of these ions, but showed higher levels of biochemical-oxygen demand, which may be associated with elevated numbers of fecal *Streptococcus* and fecal coliform bacteria. Comparisons of water quality between unguttered- and guttered-roadway sections will be difficult to make until additional samples are collected over the follow-

ing two years of the study.

PLANS NEXT YEAR: Prepare equipment for the 1994 sampling season. Continue sampling snowmelt runoffs and rainfall runoffs. Begin work on a data report.

HYDROLOGY AND GEOCHEMISTRY OF CALCAREOUS FENS IN SOUTH-CENTRAL MINNESOTA

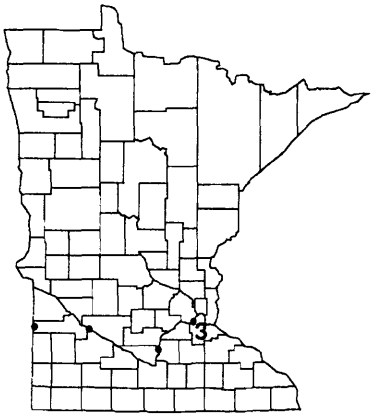
MN131

DATE PROJECT BEGAN: October 1991

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Almendinger, James E.

LOCATION: Minnesota River Basin, southern Minnesota



PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources

PROBLEM: Calcareous fens are rare plant communities that develop on saturated peat substrates where calcium magnesium bicarbonate ground water discharges. Preservation of calcareous fens requires knowledge of the range of water compositions and climatic conditions tolerated by the rare vegetation. Effective management of calcareous fens also requires information about hydraulic connections between shallow water in the fens and ground water in underlying aquifers. Furthermore, the viability of calcareous-fen plant communities depends directly on the chemistry of peat soils and water in the rooting zone. Information about geochemical and hydrologic processes in the peat will provide insight into the conditions required to maintain stable calcareous fens.

OBJECTIVE: The project is divided into reconnaissance and detailed components. The reconnaissance component will investigate six calcareous fens in the Minnesota River Basin. The objectives of the reconnaissance component are to measure selected physical factors for the six fens, and to measure hydraulic gradients between shallow water in the fens and deeper ground water in aquifers beneath the fens. The detailed investigation will concentrate on the Savage Fen located in the lower Minnesota River Valley. The objectives for the Savage Fen are to determine the chemistry of pore water and ground water in Savage Fen, and the chemistry and mineralogy of peat and other sediments in the fen; determine the magnitudes and directions of fluxes of dissolved constituents in pore water in the peat; document the microbially mediated processes that occur in the peat and the depth intervals over which they operate; characterize chemical exchange between solid materials and pore water in the peat; to assess evidence for chemical contamination of the fen by runoff from urbanized areas, fallout from airborne pollutants, or influx of polluted ground water.

APPROACH: For the reconnaissance component, a representative patch of calcareous fen vegetation was selected at each site. Within each patch two shallow piezometer nests were installed along a ground-water flow line. Each nest will consist of a water-table well and a well com-

pleted in the inorganic substrate beneath the peat. Physical factors to be measured at each site include substrate factors (peat thickness, composition, fiber content, and permeability) and hydrologic factors (hydraulic head gradients and water chemistry). At two of the sites, deeper nests of piezometers were installed to determine the vertical head gradients in the unconsolidated material between the peat and the underlying bedrock. Water from each piezometer was sampled twice for chemical analyses. For the detailed component, five shallow piezometer nests were installed along a ground-water flow line in Savage Fen. Water levels in each piezometer were measured monthly to document hydraulic head gradients in the fen. Water samples for chemical and isotopic analyses were collected in May, July, and September of the first year of the project. In July two 1-meter cores of peat were collected from the fen. Each core was divided into 20 subsamples, which were analyzed for a complete suite of major and trace constituents. Stable-isotope compositions of pore water and sediments also were measured.

RESULTS LAST YEAR: For the reconnaissance component, peat cores from Fort Snelling Fen and Sioux Nation Fen were analyzed for fiber content in the District laboratory. Subsamples of the cores were submitted to the University of Minnesota for determination of organic, carbonate, and non-carbonate inorganic content. Subsamples from a core from Fort Snelling Fen were also submitted to U.S. Geological Survey laboratories for stable isotope analyses of carbon and oxygen in carbonates and of carbon in organic matter. These analyses may provide information about the botanical and possibly climatic history of the fen. Data from 134 slug tests are being analyzed. Methods of slug-test analysis have been documented and sent to the Regional Ground-Water Specialist for review and approval. Files containing water-level and water-quality data were modified and updated. A paper titled, "Geochemistry, stable-isotope geochemistry, and hydrology of Savage Fen, a calcareous fen in the Minnesota River Valley (USA)" has been written by S.C. Komor and submitted to the journal Geochimica et Cosmochimica Acta.

PLANS NEXT YEAR: For the reconnaissance component, the project will shift in emphasis from geochemistry to peatland hydraulics and to a compilation of data from all the fens in the study. The geochemical processes identified by S.C. Komor will be a valuable tool in these efforts. Slug-test data will be analyzed and summarized. The resulting estimates of hydraulic conductivity will be related to the fiber contents of the peat, and to other variables, if appropriate. A draft of a journal article describing these findings will be written.

GLACIAL-DRIFT AQUIFERS AND SOURCES OF GROUND WATER IN THE SOUTHERN RED RIVER VALLEY, NORTHWESTERN MINNESOTA

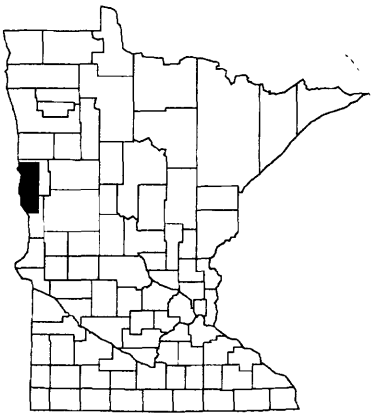
MN132

DATE PROJECT BEGAN: March 1992

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Schoenberg, Michael E.

LOCATION: Western Clay County and northwestern Wilkin County



PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources

PROBLEM: Water levels in the Wahpeton aquifer have declined as much as 50 feet since the development of well fields in 1978 near Breckenridge, Minnesota, and Wahpeton, North Dakota. Water levels in the Buffalo aquifer near Moorhead, Minnesota, also have declined as much as 30 feet since the first well field was developed in 1947 in this aquifer.These declines have caused concern about the future availability and quality of ground water in the Breckenridge and Moorhead, Minnesota area. Information is needed to determine the extent and thickness of aquifers in this area to manage and estimate the ground-water resources.

OBJECTIVE: Delineate the extent of glacial-drift aquifers in the Breckenridge, Minnesota area. Estimate recharge and discharge between the Buffalo aquifer and adjacent confining units, and the Buffalo aquifer and the Buffalo River and its tributaries in the Moorhead, Minnesota area.

APPROACH: Maps and geologic sections prepared by the Minnesota Geological Survey will be used to help identify hydrogeologic units. Water-level measurements and other hydraulic-head data from wells will be used to help identify connections between and the extent of hydrogeologic units. Recharge to and discharge from the Buffalo aquifer in the Moorhead, Minnesota area, will be estimated from data from observation-well construction, water-level measurements, and streamflow measurements. Water-level piezometers will be installed to the east, west, and over the center of the Buffalo aquifer. An estimate of the flow between the Buffalo River and its tributaries and the Buffalo aquifer will be determined by low-flow measurements along the Buffalo River and its tributaries, in conjunction with measured water levels in wells and measured river stage.

RESULTS LAST YEAR: The Wahpeton aquifer in Wilkin County near Breckenridge, Minnesota, contains layers of silty clayey sand grading to gravely coarse sand. Hydraulic head response to pumping indicates connected water-bearing horizons within the Wahpeton Buried

Valley Aquifer and surrounding deposits. The Buffalo aquifer in Clay and Wilkin Counties near Moorhead, Minnesota, contains silty sand to cobbly gravel layers that are confinfed in many areas. During August 1993 an aquifer test was run in the Buffalo aquifer. The test consisted of 10 days of continuous pumping from a well open to a gravel and cobble layer in the bottom 80 feet of the Buffalo aquifer. The pumping rate was about 1,000 gallons per minute. Drawdown in the pumped well was 6.5 feet. Head changes in the second well in this layer started simultaneously with head changes in the pumped well and were about 3.6 feet. In a well 100 feet north of the pumping well, open to a gravelly sand layer in the Buffalo aquifer immediately above the lowermost gravelly and cobbly layer, drawdown was about 4.1 feet. In these wells, the initial response to either the starting of pumping or the stopping of pumping began five to ten seconds after the pump was started or stopped. Drawdown ranged from 2.6 to 3.1 feet in three water-table wells that were between 50 and 275 feet northwest of the pumping well. The drawdown in two wells, one mile south and five miles south of the pumped well, respectively, ranged from zero to less than one foot. Heads in water table wells in adjacent confining units did not respond to the pumping. Hydraulic heads in adjacent confining units are higher than hydraulic heads in the aquifer. During the aquifer tests, hydraulic heads in the lower most part of the adjacent confining units responded to pumpage within the aquifer.

PLANS FOR NEXT YEAR: Field work will be completed and the final report will be written.

RELATION OF LAND USE TO THE PRESENCE OF NITRATE AND PESTICIDES IN GROUND WATER IN THE UNCONFINED-SURFICIAL-OUTWASH AQUIFER IN THE STRAIGHT RIVER BASIN, NORTH–CENTRAL MINNESOTA

MN135

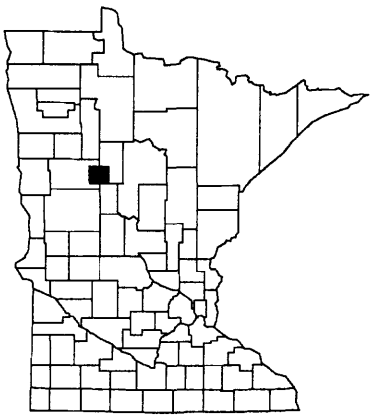
DATE PROJECT BEGAN: May 1992

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Ruhl, James F.

LOCATION: North-central Minnesota

COOPERATORS: Becker and Hubbard County Soil and Water Conservation Districts.



PROBLEM: The widespread use of the Straight River Basin for irrigated farming may have affected the quality of shallow ground water in the basin. Information is needed to gain an understanding of the sources, distribution, and fate of nitrates and pesticides in the unconfined aquifer of the Straight River Basin.

OBJECTIVE: Describe the general quality of the ground water in the unconfined-surficial-outwash aquifer, and identify changes. Investigate the sources, pathways, and fates of nitrates in the unconfined aquifer. Determine the relation of land-uses, such as agricultural practices, treatment of municipal waste water, and residential development, on the nitrate concentration on both a small- and large-scale basis. Determine the presence of pesticides in the unconfined-surficial-outwash aquifer.

APPROACH: Approximately 20 wells were installed in nested sets of 2 at 10 sites. The screened intervals of these wells were either at the water table or at or near the bottom of the unconfined-surficial-outwash aquifer. These wells were located at sites upgradient and downgradient from land-use areas that are potential sources of nitrates and pesticides in the unconfined-surficial-outwash aquifer. Ground-water-quality data of water samples from these wells were studied to determine the effects of land use on ground-water quality. Additionally, ground-water samples were analyzed for isotopic nitrogen to determine the source of the nitrates. Ground-water samples were analyzed at the U.S. Geological Survey Water-Quality Laboratory in Denver, Colorado, for pesticides. During the third year of the study an interpretive report on the results of the study will be prepared and presented to the cooperator.

RESULTS LAST YEAR: Ground-water samples were collected in September 1992 from 11 pre-existing monitoring wells and 19 recently installed nested wells located upgradient and downgradient from five land-use areas. These samples were analyzed for nitrate, nitrite, ammonia, and organic nitrogen. Collection of water samples for hydrogen and oxygen isotope analysis began in March 1993 when two water samples each were collected from snow and shallow water table wells. Two new wells were installed in June 1993. One of these wells was installed in the northwestern part of the study area near a residential well known to have high nitrate lev-

els. The other well was installed in an irrigated potato field. Two other wells, that were out of service because of clogged or deteriorated screens, were repaired. Ground-water samples were collected from 35 monitoring wells in June 1993 and analyzed for dissolved-nitrogen nutrients. Analyses for isotopic nitrogen in dissolved nitrate also were made in water collected from 10 of the recently installed monitoring wells. The new well in the potato field was sampled four times during the summer for dissolved nitrate nitrogen, and hydrogen and oxygen isotopes. Precipitation was collected and analyzed for hydrogen and oxygen isotopes. Soil scientists from the University of Minnesota installed a network of suction lysimeters in the spring to collect soil-moisture samples from the potato field where the new well was installed. Soil moisture from these lysimeters was analyzed for hydrogen and oxygen isotopes, and dissolved nitrate nitrogen. Soil moisture data also were collected from gravity-fed lysimeters following three storms and analyzed for dissolved nitrate nitrogen, and hydrogen and oxygen isotopes. Water samples were collected during late August from the 35 monitoring wells and analyzed for dissolved nitrogen nutrients. Water collected from eight of these wells was analyzed for selected pesticides. Water from 10 monitoring wells was again collected and analyzed for isotopic nitrogen. Water from the monitoring well in the potato field and precipitation was again collected and analyzed for stable isotopes of hydrogen and oxygen. Water from three monitoring wells was collected and analyzed for the unstable isotope tritium. Soil moisture collected from the suction lysimeters was analyzed again for dissolved-nitrogen nutrients, and hydrogen and oxygen isotopes. Following collection of all samples the potato-field monitoring well was removed.

PLANS FOR NEXT YEAR: An interpretive report of the study will be prepared.

RESIDENCE TIME OF WATER AND FLUX OF AGRICULTURAL CHEMICALS THROUGH THE UNSATURATED ZONE AT THE PRINCETON, MINNESOTA, MANAGEMENT SYSTEMS EVALUATION AREA

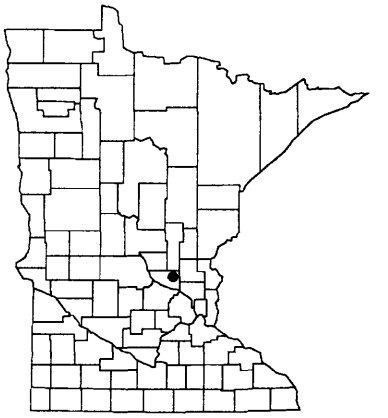
MN136

DATE PROJECT BEGAN: April 1993

DATE PROJECT ENDS: December 1994

PROJECT CHIEF: Landon, Matthew K.

LOCATION: Management Systems Evaluation Area, Princeton, Minnesota



PRINCIPAL COOPERATING AGENCY: Minnesota Pollution Control Agency

PROBLEM: The residence time of water in the unsaturated zone is a critical factor influencing the transport of agricultural chemicals into ground water. Simply tracking water movement through the unsaturated zone does not reveal the residence time of water entering the unsaturated zone as recharge because the recharge water can be composed of: water previously stored in the unsaturated zone that is displaced by new precipitation infiltrating into the soil (piston flow); water from intergranular flow of new precipitation; or water from preferential flow of new precipitation with a very short residence time in the unsaturated zone. Analyses of stable isotopes (oxygen (δO^{18}) and hydrogen (δD)) allow differentiation of water from precipitation falling at different times of the year, and water modified by evapotranspiration in the soil. By monitoring soil-moisture movement and stable isotopic compositions, water associated with these events or processes can be tracked through the unsaturated zone to the water table and the residence time of water in the unsaturated zone can be determined. Concurrent monitoring of agricultural-chemical concentrations would allow determination of the effects of residence time of water in the unsaturated zone on the flux of agricultural chemicals to the water table. Because results of stable-isotope analyses can yield information on the seasonal variation in recharge rates to ground water and on the residence time of recharge water in the unsaturated zone, measurements of the stable isotopic composition of precipitation and ground water also could provide information on regional recharge processes and timing regionally.

OBJECTIVE: Determine the residence time of recharge water in the unsaturated zone in different land-use and topographic settings at the Princeton, Minnesota, Management Systems Evaluation Area (MSEA). Determine the relation of concentrations of agricultural chemicals in ground water and soil moisture to the residence time of recharge water in the unsaturated zone. Evaluate the use of stable isotopes as a tool in determining recharge processes and timing.

APPROACH: Precipitation samples from the Princeton MSEA were collected monthly and following major rainfalls and analyzed for stable isotope compositions. Samples of irrigation water

also were collected during selected applications of irrigation water. Hourly to daily monitoring of soil-moisture contents and water levels at topographic upland and lowland sites within a field planted in corn was conducted to track water movement through the unsaturated zone to the water table and identify opportune times for sample collection.

Water samples were collected from the water table at five different sites at the MSEA both monthly and during selected short-duration recharge events to identify temporal changes in the concentrations of selected major anions, herbicides and metabolites, and stable-isotope compositions. Samples from the water table were collected from the upland and lowland sites, in an adjacent woodland, in an adjacent grassland, and in a field farmed using the Best Management Practices. Water samples were collected from the unsaturated zone at the upland and lowland sites at the same time as samples were collected from the water table. The stable-isotopic compositions of precipitation, ground water, and soil moisture were compared to identify the season (or precipitation event) during which the recharge occurred. Concentrations of agricultural chemicals and stabl- isotopic compositions of ground water in the different settings were compared to evaluate differences in the recharge dynamics and in the flux of agricultural chemicals at the different sites. Results of data collected will be used to refine an understanding of the variables which control stable-isotopic compositions in the unsaturated zone and at the water table.

RESULTS LAST YEAR: A total of 22 precipitation, 3 irrigation, 44 ground-water (water table), and 66 soil-moisture samples were collected at the Princeton MSEA for stable isotopic analyses. Snow samples were significantly lighter isotopically than rain samples. Precipitation became isotopically heavier from spring into summer. All of the ground-water samples collected plotted on the meteoric water line. However, there were significant areal differences in the isotopic composition of water-table samples. These spatial variations in isotopic composition appear to be linked to the timing and quantity of recharge occurring at the different sites. Ground water at all of the sites became lighter between March 1 and July 14, most likely as a result of recharge of isotopically light water from snowmelt or early spring (April) rainfall. Greater shifts toward lighter isotopic composition at the lowland site and the woodland site may indicate that greater amounts of recharge of isotopically light snowmelt and early spring rainfall occurred at these sites especially compared to the grassland site. Differences in the timing of a shift to lighter isotopic compositions for ground water at the different sites indicate that the residence time, or travel time, of spring recharge water through the unsaturated zone varied from less than 1 week to as much as 3 months. It was hypothesized that these differences in travel time are most strongly related to topography and were secondarily related to land use and vegetation cover.

All soil-moisture samples collected from the unsaturated zone at the upland and lowland sites plotted on the meteoric water line. Therefore, water collected from these samplers was unaffected by evaporation. There was greater variability in the isotopic composition of soil-moisture samples than for ground-water samples.

The fact that many soil moisture samples collected in June and July continued to have lighter isotopic compositions consistent with snowmelt or April precipitation indicated that some of the water which infiltrated into the soil in the early spring had a residence time in the unsaturated zone of at least two months at the upland and lowland site. There were not significant differences in the isotopic composition of soil moisture between the upland and lowland sites.

PLANS NEXT YEAR: The number of samples collected at each site during 1994 will be reduced by 20 to 30 percent. Collections of water-table samples will be discontinued at the crop

rotation site because of the similarity of this site to the upland site. Based on the results from 1993, major trends in isotopic compositions over the course of 1994 should still be identifiable even with the reduced sampling frequency.

Precipitation samples for stable-isotopic analyses from the Princeton MSEA will continue to be collected approximately monthly. Snow samples will be collected from the suction lysimeters and wick samplers. Pore-water extracted from the cores will be analyzed to obtain detailed vertical profiles of stable isotopic compositions through the unsaturated zone. Analyses of pore water from a core collected in the spring will be used to evaluate the effects of evaporation over the summer. The stabl- isotopic compositions of unsaturated zone water samplers will be compared to evaluate the different methods of soil moisture sample collection.

A journal article reporting the results of the first year of the study will be written.

Plans for reporting the results of 1994 data collection will be developed later in 1994. Data will continue to be interpreted as soon as possible after it is received so that adjustments can be made to the sampling plan, if necessary.

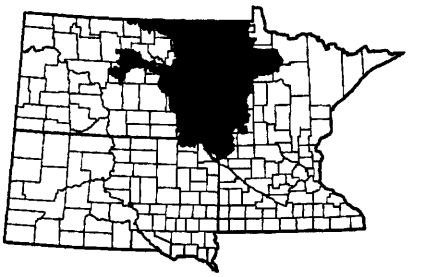
FUNCTION OF PRAIRIE-POTHOLE WETLANDS ON WATER QUALITY OF THE RED RIVER OF THE NORTH BASIN

MN137

DATE PROJECT BEGAN: January 1993

DATE PROJECT ENDS: September 1995

PROJECT CHIEF: Brigham, Mark E.



LOCATION: Northwestern Minnesota and eastern North Dakota

PRINCIPAL COOPERATING AGENCY: U.S. Environmental Protection Agency

PROBLEM: Prairie-pothole and riparian wetlands are an important feature that affects water quality in the Red River of the North drainage basin. Wetlands play an important role in cycling of chemicals from anthropogenic sources, especially pesticides and nutrients from land applications. A better understanding of the concentrations and cycling of these chemicals (especially pesticides) in wetlands and streams that drain areas where wetlands exist is necessary to assess potential risks to wetland ecosystems and to assess stream water-quality benefits that wetlands offer.

OBJECTIVES: Assess the water quality of streams, including biological integrity, in watersheds containing prairie-pothole and riparian wetlands in each of four major ecoregions in the Red River of the North Basin. Assess the quality of water and bottom sediments in natural wetlands within agricultural areas of the four major ecoregions. Examine nutrients and pesticides in prairie-pothole and riparian wetlands at areas of surface- and ground-water interactions.

APPROACH: Available data on wetlands chemistry and landscape characterization within the Red River of the North Basin will be reviewed. Ancillary data will be compiled and processed using an Arc-Info Geographical Information System (GIS). These data include spatial data such as land cover and soils associations STATSGO (State Soil Geographic Data Base) at the 1:250,000 scale. In addition, data for land use (including cropping patterns), surficial geology, and land slope may be processed as GIS coverages.

Sampling of the Sheyenne River near Warwick, North Dakota (6–12 samples, flow-weighted primarily after agricultural chemical applications) will be conducted for analysis of nutrients, sediment, and selected pesticides. This will allow comparison to other stream-monitoring sites throughout the Red River of the North Basin that receive runoff from agricultural lands having a smaller density of natural wetlands. This sampling would begin in the summer of 1993 after spring application of nutrients and pesticides.

Water and bottom sediments in wetlands will be sampled for major ions, nutrients, and pesti-

cides. Where possible, sites will be chosen in coordination with other studies in the region.

Sampling sites will be selected in surficial aquifers and wetlands in areas of ground-water recharge from prairie-pothole wetlands or in riparian wetlands that lie between surficial aquifers and receiving streams. Potholes above the Warwick aquifer near the Sheyenne River are among known wetland sites for this effort. A riparian wetland site will be colocated with each of the NAWQA ground-water flowpath studies planned in the Red River Valley and the North Central Hardwood Forests ecoregions. These stream-aquifer sites include the Sheyenne Delta-Sheyenne River and Otter Tail outwash-Otter Tail River areas. Surface- and ground- water samples will be analyzed for pesticides, nitrogen species, phosphorus, and major ions.

RESULTS LAST YEAR: Work plans for the 1993 field season were developed, and revised largely because of concerns by the cooperator that spatial coverage of sampling and sampling objectives were not adequate. The principal goal of this year's work is to gather data on pesticide presence in wetlands. This effort may highlight important analytes for further study as the project continues.

Efforts were made to sample some wetlands that had been sampled for pesticides within the last two years, or that were part of ongoing pesticide studies. Personnel from U.S. Fish and Wildlife Service (USFWS), Jamestown, North Dakota, were consulted regarding sampling of wetlands that are part of the Environmental Monitoring and Assessment Program (EMAP). Four EMAP sites in the Red River Valley ecoregion were selected for sampling for this study. Personnel from the USFWS in the Twin Cities Field Office (Bloomington, Minn.) were consulted regarding their pesticide sampling program for wetlands (primarily Waterfowl Production Areas (WPA's)) in the North Central Hardwood Forests ecoregion of Minnesota. Three WPA's that had crops planted along one side of the wetland were chosen for sampling for this study. Natural Resources Department personnel from the Red Lake Band of Chippewa Indians had no ongoing or recent pesticide studies, but are actively involved in wetlands issues and assisted the project chief with site selection and sampling of three wetland sites and two streams that drain extensive wetland areas (Black Duck River and Battle River) near agricultural land. The stream sites were downstream from cultivated wild rice paddies, where pesticides are used. Sampling of bottom sediments from five wetlands or lakes in the prairie pothole region near Warwick, North Dakota was coordinated with water-column pesticide work that is being done by U.S. Geological Survey personnel from the North Dakota District. That group is gathering pesticide data as part of a study for the Fort Totten Indian Reservation of wetlands and ground water in the Warwick aquifer region.

Water samples were collected for pesticide analysis from 17 wetlands (one site was sampled twice) and 3 streams; bottom-sediment samples were collected from 5 wetlands or lakes.

PLANS NEXT YEAR: A data compilation will be completed under the Red River of the North NAWQA study to complete the project.

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