WATER RESOURCES ACTIVITIES

IN MICHIGAN, 1985

Compiled by T. J. Spicer

U.S. GEOLOGICAL SURVEY

Open-File Report 85-566

Prepared in cooperation with

State and Federal agencies

Lansing, Michigan
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

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Foreword

1985 marks the eighty-fifth year the U.S. Geological Survey has collected data on the water resources of Michigan. During the winter of 1900-01, a Survey employee visited the State to measure the flow of streams, and to select sites for establishing 13 gaging stations. For the next quarter of a century the program remained small, and much of the effort was related to municipal needs and water-power requirements. State agency cooperation in the data-collection effort began in 1930, and with it, began the development of a close and unique Federal-State relationship. Although early efforts were largely related to the flow of streams, subsequent interest resulted in the inclusion of the collection of ground-water and water-quality information, as well as interpretive studies of water resources locally and statewide. Support for the program has fluctuated throughout its existence, largely in response to economic conditions. During the past few years, due to a number of factors, the program has decreased. Recent support for restoring and expanding the cooperative program from governmental units, universities, and industry in the State seems to have borne fruit. Prospects for the future look bright.

T. Ray Cummings
District Chief

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WATER RESOURCES ACTIVITIES

IN MICHIGAN

1985

Compiled by T. J. Spicer

INTRODUCTION

This report was compiled to provide information on the water resources activities of the U.S. Geological Survey in Michigan.

The U.S. Geological Survey

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

Since 1879, the research and fact-finding role of the USGS has grown and been modified to meet the changing needs of the Nation it serves. As part of that evolution, the USGS has become the Federal Government's largest earth-science research agency, the Nation's largest civilian mapmaking agency, the primary source of data on the Nation's surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs serve a diversity of needs and users.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the USGS remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation. One of the Nation's most important natural resources is water.

Water Resources Division's Mission and Program

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-resource appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water.

Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade.

Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.

Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters.

Providing scientific and technical assistance in hydrologic fields to other Federal, State and local agencies, to licensees of the Federal Power Commission, and to international agencies on behalf of the Department of State.

WATER-RESOURCES ACTIVITIES IN MICHIGAN

The water-resources program in Michigan is, for the most part, planned and funded with local and state agencies through cooperative programs. If a proposed project is mutually advantageous to the Geological Survey and an agency, the Geological Survey enters into formal cooperative agreement to provide needed information. In most cases, costs are shared equally between the Geological Survey and the cooperator. These cooperative programs are reviewed and renegotiated annually, and, thus, are responsive to the current needs in the state. In Michigan, the program is conducted in cooperation with the following agencies:

Michigan Department of Natural Resources (DNR)

Michigan Department of Transportation

Corps of Engineers, U.S. Army

U.S. Air Force

Local units of government

District Office Organization

The Michigan District office of the U.S. Geological Survey is located in Lansing, Michigan; field headquarters are located in Escanaba and Grayling (fig. 1).

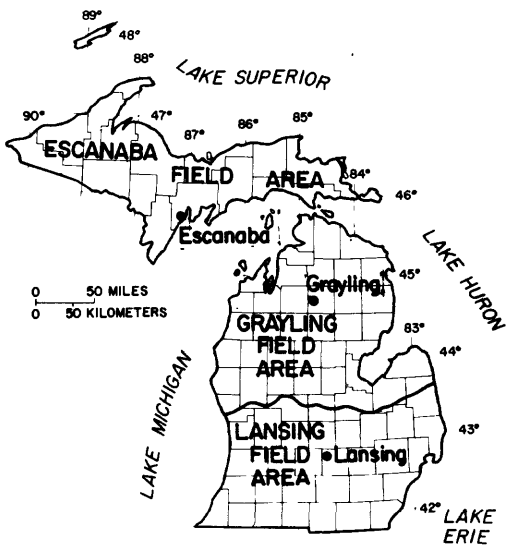
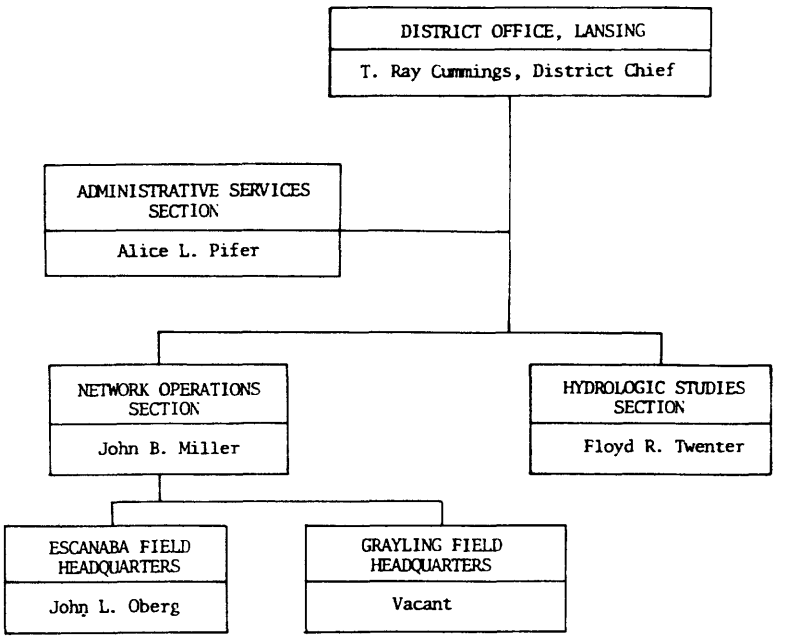


Figure 1.--U.S. Geological Survey Water Resources Division offices in Michigan.

The District has 31 employees. The employees consist of professional hydrologists that represent a variety of scientific backgrounds, including engineering, chemistry, geology, and mathematics. The hydrologists are supported by an experienced staff of engineering, hydrologic, and cartographic technicians.

District operations are grouped into three sections--administrative services, hydrologic studies, and network operations (fig. 2). The function and major purpose of each section are described in the following paragraphs.



Office	Phone	Address
Lansing	(517) 377-1608	6520 Mercantile Way, Suite 5 Lansing, Michigan 48910
Escanaba	(906) 786-0714	205 State Office Building Escanaba, Michigan 49829
Grayling	(517) 348-8291	P.O. Box 485 Grayling, Michigan 49738

Figure 2.--Michigan District organization chart and office addresses.

Administrative Services Section

This section provides administrative support to the Michigan District office and is responsible for:

- Budget formulation and execution;
- Preparation of financial summaries of cooperative programs;
- Assistance in personnel management of the District;
- Maintenance of all administrative files, vehicle control, and property records; and
- Insuring that staff members are familiar with regulations pertaining to administrative functions of the District.

Hydrologic Studies Section

This section analyzes and interprets hydrologic data as they relate to the problems of water-resources management and development. Present activities include studies of surface- and ground-water conditions in specified areas, investigations of the chemical, physical, and biological properties of water, studies related to ground-water contamination, land-use studies, and miscellaneous investigations to assist community and state planning agencies in management decisions. This section also conducts geohydrologic investigations to determine availability, quantity, quality, and use of water within the state; these investigations generally are of short duration, areal in nature, and require a thorough understanding of hydrology.

In addition to the above work, reports on the results of geohydrologic investigations are processed within this section prior to publication. Several different publication outlets are used to accommodate the diversity of subject matter. Most reports are published in a formal series of the U.S. Geological Survey or cooperating agency.

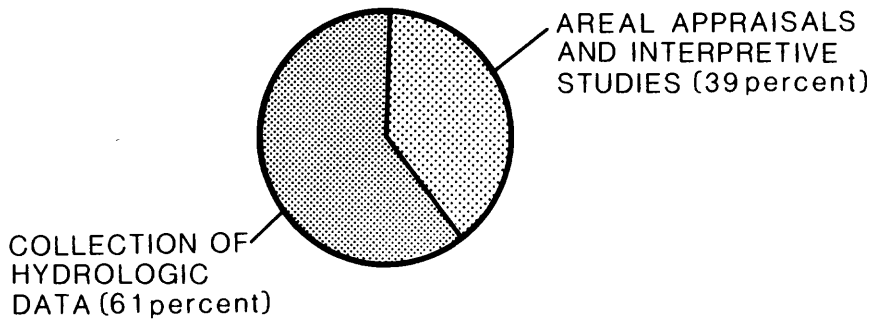
Network Operations Section

This section is responsible for the collection and publication of basic data including records of stream discharge, ground-water levels, and quality

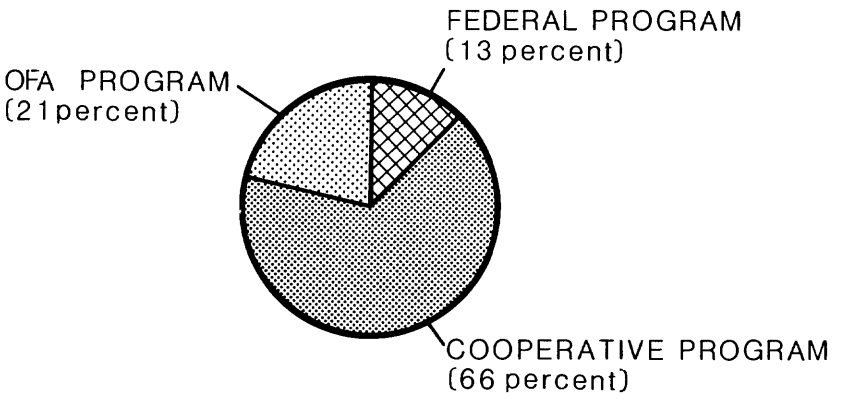
of water. Data are collected for the basic statewide network and for use in projects designed to appraise the water resources of the state. A backfile of basic water data is maintained. The data are published in annual and other reports and are used to respond to requests for information. Basic water data is also stored in the Survey's computer storage file called WATSTORE. Surface-water, ground-water, and quality of water data are available for tabular presentation, statistical manipulation, or graphical display. The thousands of records collected each year provide indispensable information on stream stage, discharge, sediment load and concentration, chemical quality of water, precipitation, ground-water levels, and many other factors.

Types of Funding

Funding for the water-resources programs falls into two broad categories. In the 1985 Fiscal year, almost two-thirds of the program is composed of hydrologic data collection--operation of surface-water gaging stations, measurement of ground-water levels, and collection of samples for chemical and physical analysis. These data are largely obtained on a routine basis at fixed sites. Periods of data collection vary from several months to many years. Areal appraisals and interpretive studies, which constitute slightly more than a third of the program, consist of a variety of investigations. Some may be statewide in character, others address very localized problems. Such studies may range from complex, highly technical mathematical models of surface-water or ground-water systems, to reconnaissance appraisals of water resources.



The water-resources program is supported by funds or services provided by State and local agencies and, as part of the Federal-State Cooperative program, are matched on a 50-50 basis by funds appropriated to the Geological Survey by Congress for that purpose. Other Federal agencies (OFA) also support data collection and studies; direct appropriations to the Geological Survey (Federal program) are also available. In Fiscal year 1985, the financial support for work in Michigan amounts to about $1,800,000. It is distributed as follows:



INFORMATION IN THIS REPORT

This report consists of four sections: (1) current projects, (2) hydrologic conditions, (3) hydrologic-data stations, and (4) sources of information. The current-projects section contains information concerning the status of all projects that are presently active. The section on hydrologic-data stations gives locations where surface-water and ground water-data are collected and the types of records available. The hydrologic-conditions section provides general statewide information on water resources. The sources-of-information section contains a listing of publications resulting from work done by the Geological Survey and cooperating organizations.

(PAGE 9 FOLLOWS)

CURRENT PROJECTS

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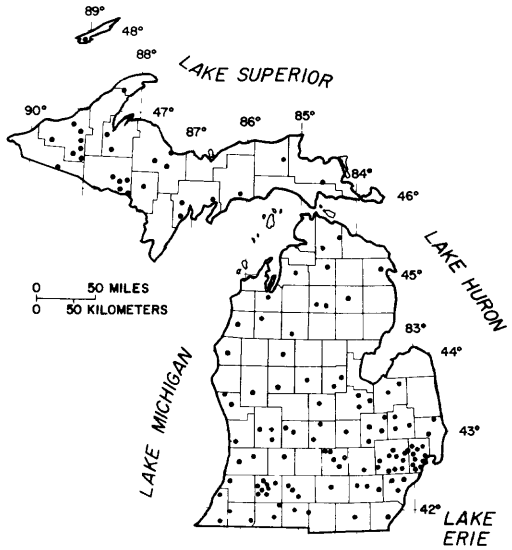
SURFACE-WATER STATIONS



PROJECT NO. - MI 001

PROBLEM: Surface-water information is needed for purposes of surveillance, planning, design, hazard warning, water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. To provide this information, an appropriate data base is necessary.

OBJECTIVE: (1) Collect surface-water data sufficient to satisfy needs for current-purpose uses, such as assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and pollution controls, discharge data to accompany water-quality measurements, compact and legal requirements, and research or special studies and (2) collect data necessary for analytical studies to define for any location the statistical properties of, and trends in, the occurrence of water in streams, lakes, bays, etc., for use in planning and design.

APPROACH: Standard methods of data collection will be used as described in the series, "Techniques of Water Resources Investigations of the United States Geological Survey." Partial-record gaging will be used instead of complete-record gaging where it serves the required purpose.

RESULTS LAST YEAR: Data were collected at, and published for, the number of stations given in the following table:

Station classification	Number of stations
Stream stations	221
Continuous record:	
Discharge and stage	128
Stage only	2
Partial record:	
Peak (maximum) flow only	55
Low (minimum) flow only	21
Peak and low flow	1
Lake and reservoir stations	31
Stage and contents	6
Stage only	25
Total	252

PLANS THIS YEAR: Gaging-station network will continue in operation. New stations will be constructed as projects develop and existing stations will be relocated, reequipped, and modernized to improve quality of record, or discontinued to meet changing needs of projects and cooperators and to fulfill network evaluation requirements.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

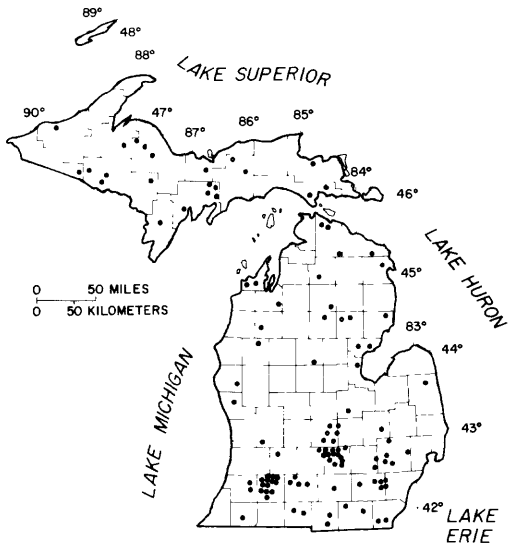
PROJECT CHIEF: John B. Miller

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES:
Michigan Department of Natural Resources
Michigan Department of Transportation
Local Units of Government
U.S. Army Corps of Engineers

REPORTS (COMPLETED): Data included in U.S. Geological Survey annual hydrologic-data report "Water Resources Data for Michigan."

GROUND-WATER STATIONS



PROJECT NO. - MI 002

PROBLEM: Long-term water-level records are needed to evaluate the effects of climatic variations on the recharge to and discharge from ground-water systems, to provide a data base from which to measure the effects of development, to assist in the prediction of future supplies, and to provide data for management of the resource.

OBJECTIVE: (1) Collect water-level data sufficient to provide a minimum long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known and potential problems can be defined early enough to allow proper planning and management and (2) provide a data base against which the short-term records acquired in areal studies can be analyzed. This analysis must provide an assessment of the ground-water resource, allow prediction of future conditions, detect and define pollution and supply problems, and provide the data base necessary for management of the resource.

APPROACH: Evaluation of regional geology allows broad, general definition of aquifer systems and their boundary conditions. Within this framework and with some knowledge of stress on the system in time and space and the hydrologic properties of the aquifers, a subjective decision can be made on the most advantageous locations for observation of long-term system behavior. This subjective network can be refined as records become available and detailed areal studies of the ground-water system more closely define the aquifers, their properties, and the stresses to which they are subjected.

RESULTS LAST YEAR: Water levels were measured in, and published for, the number of wells given in the following table:

Station classification	Number of stations
Observation wells:	
Recording	60
Nonrecording	54
Total	114

PLANS THIS YEAR: Continue to operate network and evaluate station requirements for most effective network.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

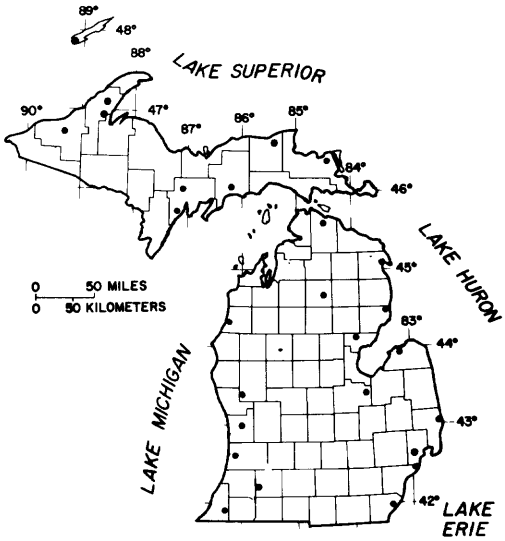
PROJECT CHIEF: Gary C. Huffman

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES:
Michigan Department of Natural Resources
Local Units of Government
Other Federal Agencies

REPORTS (COMPLETED): Data included in U.S. Geological Survey annual hydrologic-data reports "Water Resources Data for Michigan" and "Ground-Water Data for Michigan."

WATER-QUALITY STATIONS



PROJECT NO. - MI 003

PROBLEM: Water-resource planning and water-quality assessment require a nationwide base of information. To obtain this information, the chemical and physical quality of surface water and ground water must be defined and monitored. In addition, long-term sampling stations representing the numerous hydrological accounting units in Michigan must be operated to meet the objectives of the National Stream Quality Accounting Network (NASQAN).

OBJECTIVE: (1) Provide current and long-term data sufficient to describe water-quality conditions of surface and ground water in Michigan that are needed by planning and management agencies, (2) improve the water-quality data base in Michigan so that future assessments can be more effective, (3) participate in the operation of the National Stream Quality Accounting Network, and (4) collect samples from wells throughout the state to establish a base against which future water-quality data can be compared and against which the effect of new and additional stresses can be evaluated.

APPROACH: Operate a network of water-quality stations to meet the needs of the State of Michigan and the objectives of national programs. Standard methods of data collection will be used.

RESULTS LAST YEAR: Data were collected at, and published for, the number of data types given in the following table:

Surface water:

Data classification	Number of sites
Physical data (daily frequency):	
Water temperature	5
Specific conductance	2
Chemical data:	
Inorganic constituents	25
Organic constituents	3
Pesticides	3
Radiochemicial data	2
Biological data	25

Ground water:

Physical data:	
Water temperature	22
Specific conductance	16
pH	16
Chemical data:	
Inorganic constituents	16
Organic constituents	16
Radiochemical data	16

Several types of data were collected at some sites.

PLANS THIS YEAR: Continue network in operation. Number of collection sites, frequency of data collection, and parameters to be measured will be adjusted if and as necessary, in consultation with cooperating agencies, to keep network in line with current needs for water-quality data.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

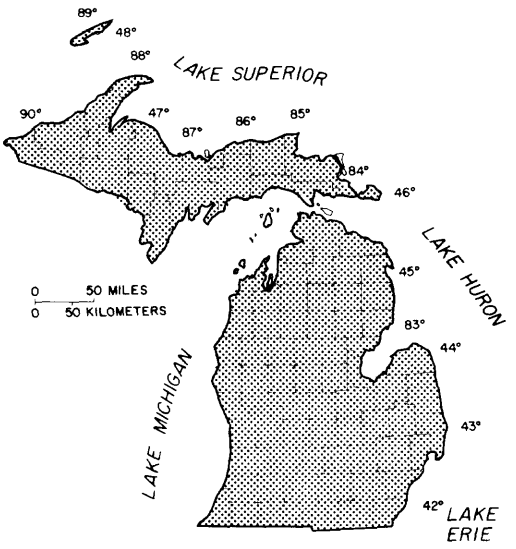
PROJECT CHIEF: John B. Miller

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS (COMPLETED): Data included in U.S. Geological Survey annual hydrologic-data report "Water Resources Data for Michigan."

SEDIMENT STATIONS



PROJECT NO. - MI 004

PROBLEM: Water-resources planning and water-quality assessment require a nationwide base level of relatively standardized information. Sediment concentrations and discharges in rivers and streams must be defined and monitored.

OBJECTIVE: (1) Establish and operate a network of daily and periodic fluvial sediment stations to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and particle size of sediment being transported by streams. Define yields and transport characteristics for the principal drainage basins in the state, (2) contribute to a national bank of sediment data for use in broad federal and state planning and action programs, and (3) provide data for federal management of interstate and international waters.

RESULTS LAST YEAR: Sediment data were collected, analyzed and prepared for publication for several NASQAN and miscellaneous stream measurement sites.

PLANS THIS YEAR: Sediment data will be collected at existing NASQAN stations and new stations will be established to meet the need of new projects.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

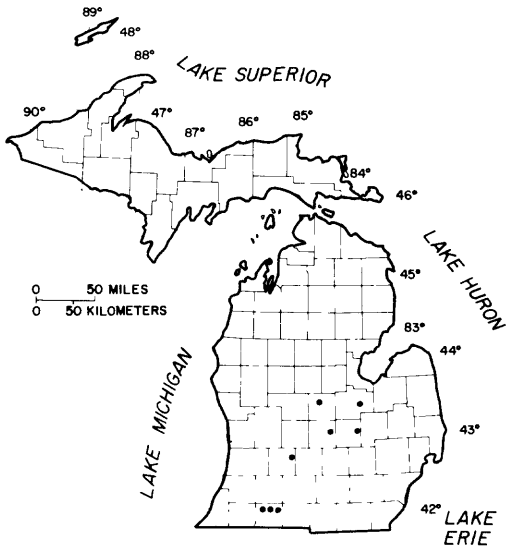
PROJECT CHIEF: John B. Miller

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS (COMPLETED): Data included in U.S. Geological Survey annual hydrologic-data report "Water Resources Data for Michigan."

FLOOD-INSURANCE STUDIES



PROJECT NO. - MI 006

PROBLEM: The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 provides for the operation of a flood insurance program. The Federal Emergency Management Agency (FEMA) needs flood studies in selected areas to determine applicable flood insurance premium rates.

OBJECTIVE: To conduct the necessary hydrologic and hydraulic evaluations and studies of areas assigned by FEMA and to present the results in an appropriate format.

APPROACH: To conduct the necessary evaluation or to conduct surveys by ground or photogrammetric methods. Determine flood-discharge frequency relationships using local historical information, gaging station records, step-backwater models or by other acceptable methods and furnish the results in reports prepared to FEMA specifications.

RESULTS LAST YEAR: Draft FIS report for one detailed study (Village of Colon) was 50 percent completed. Field work was done on less-detailed studies.

PLANS THIS YEAR: Field work, computations, and draft reports will be completed.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Lower Peninsula of Michigan

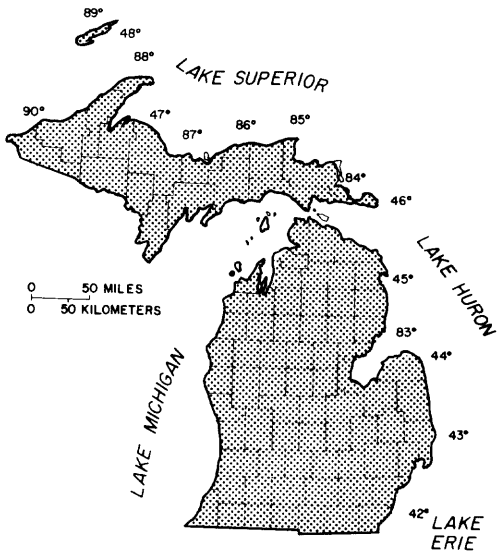
PROJECT CHIEF: Vincent D. Herreid

PERIOD OF PROJECT: June 1985 to September 1986

COOPERATING AGENCIES: Federal Emergency Management Agency

REPORTS IN PROGRESS:
Flood insurance study, Village of Colon, MI
Flood insurance study, Village of Vernon, MI
Flood insurance study, Village of Northport, MI
Flood insurance study, City of St. Louis, MI
Flood insurance study, Township of Castleton, MI
Flood insurance study, Township of Lockport, MI
Flood insurance study, Township of Nottawa, MI
Flood insurance study, Township of Taymouth, MI
Flood insurance study, Township of Victor, MI

WATER USE



PROJECT NO. - MI 007

PROBLEM: Michigan waters are under stress from increasing demands for domestic, industrial,, agricultural, and other uses, and from demands for greater protection of water quality. Competition for water dictates that available supplies are matched with uses most beneficial to the common good.

Water-use information for Michigan has been collected in the past for inclusion in the annual ground-water report and in miscellaneous reports of the Michigan Department of Natural Resources. There has been little standardization of data or of methods used in collecting the data. Standards of accuracy vary over a wide range. Because water-use data are being used increasingly for planning and making long-range forecasts, and in making estimates of water available from different sources, there is a need to coordinate efforts, systematize the approach to data collection, and develop standards of accuracy for the dissemination and use of these data.

OBJECTIVE: (1) Provide water-use information for the optimum utilization and management of the state's water resources for the overall benefit of the people of Michigan and the Nation. The system will be responsive to the data needs of local users, the Geological Survey, and other Federal agencies, (2) collect, store, and disseminate water-use data to complement data on availability and quality of the state's water resources, and (3) develop and operate a system to handle the data.

APPROACH: Responsibilities are divided between the State of Michigan and the U.S. Geological Survey to reflect the most efficient means of meeting the objectives of the program. Direction, management, and standards development to meet the National needs are the responsibility of the U.S. Geological Survey. Field activities for the acquisition and storage of the data are the primary responsibility of the State.

RESULTS LAST YEAR: Collection and analysis of information on water use for power generation was completed and report prepared. Power-generation water use and irrigation data were coded and entered into the National Water-Use System.

PLANS THIS YEAR: Publish report on water use for power generation; collect, assimilate, and evaluate industrial water-use information, prepare industrial water-use report. Develop a Federal-State work plan.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Floyd R. Twenter

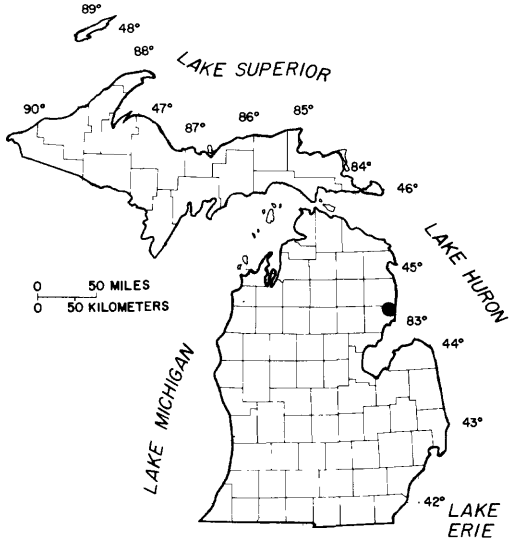
PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS IN PROGRESS: A 5-year report of water use in the United States will be published. State reports will be published periodically to update water-plan studies and as "situation reports" related to specific areas or problems.

REPORTS PUBLISHED: (1) D. J. Bedell and R. L. Van Til, 1979, Irrigation in Michigan, 1977: Michigan Department of Natural Resources, Water Management Division; (2) D. J. Bedell, 1982, Municipal water withdrawals in Michigan, Michigan Department of Natural Resources, Water Management Division.

GROUND-WATER STUDY OF
WURTSMITH AIR FORCE BASE, MICHIGAN



PROJECT NO. - MI 032

PROBLEM: Volatile hydrocarbons have been found at several places in the ground-water system at Wurtsmith Air Force Base. Continued study of newly detected problems is required to permit Air Force Base management to assess present remedial action and, if necessary, institute new action.

OBJECTIVE: (1) Determine the rate and direction of ground-water flow at Wurtsmith Air Force Base, (2) determine the extent and distribution of contaminants in the ground-water system, (3) investigate all suspected sources of ground-water contamination, including past and present landfill areas, (4) investigate sites for developing new Base water supplies, and (5) refine previously developed mathematical ground-water flow model.

RESULTS LAST YEAR: Study of newly detected contamination was continued, and plumes defined. Ground-water flow models modified to include an area south of the Base.

PLANS THIS YEAR: Continue investigations of contamination of water by fuel substances in central part of the Base. Report findings to Air Force. Prepare Water-Resources Investigations Report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Northeastern Lower Peninsula, Michigan

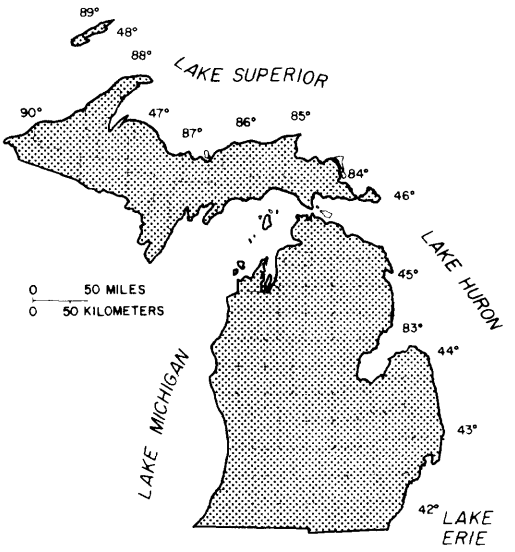
PROJECT CHIEF: T. Ray Cummings

PERIOD OF PROJECT: September 1983 to September 1985

COOPERATING AGENCY: U.S. Air Force

REPORTS: J. R. Stark, T. R. Cummings, and F. R. Twenter, 1983, Ground-water contamination at Wurtsmith Air Force Base, Michigan: U.S. Geological Survey Water-Resources Investigations Report 83-4002.

EVALUATION OF THE STREAMFLOW DATA NETWORK IN MICHIGAN



PROJECT NO. - MI 036

PROBLEM: Michigan's streamflow data network cannot be managed to optimize regional streamflow transfer capability with currently available information. As a result, inefficiencies in resource allocation, rather than real budgetary constraints, may limit data collection. Also available multiple-regression equations for estimating flow characteristics at ungaged sites have large standard errors of estimate. Thus, estimated flow characteristics frequently are less accurate than needed by many water-data users.

OBJECTIVE: (1) Document the purpose of operating each gaging station and crest-stage station, (2) develop regional regression equations to estimate natural low, mean, and high streamflow characteristics at ungaged sites using data available through 1982, and (3) evaluate the cost effectiveness of the present gaging-station network.

RESULTS LAST YEAR: Determined the cost effectiveness of the stream-gaging program in Michigan and prepared report.

PLANS THIS YEAR: Print report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: David J. Holtschlag

PERIOD OF PROJECT: November 1981 to September 1984

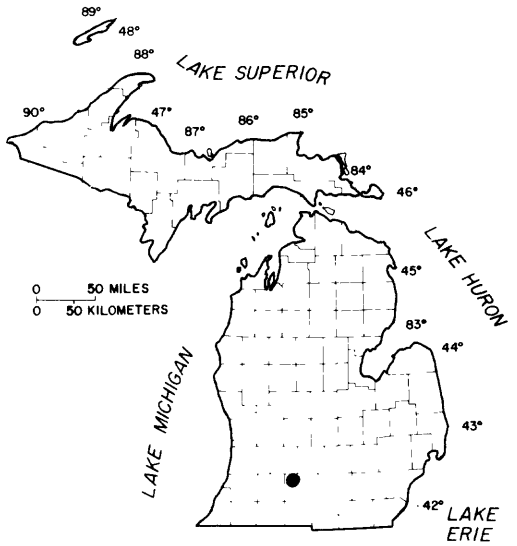
COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS: Croskey, H. M., and Holtschlag, D. J., 1983, Estimating generalized flood skew coefficients for Michigan: U.S. Geological Survey Water-Resources Investigations Report 83-4194.

Holtschlag, D. J., and Croskey, H. M., 1983, Statistical models for estimating flow characteristics of Michigan streams: U.S. Geological Survey Water-Resources Investigations Report 84-4207.

Holtschlag, D. J., 1985, Cost-effectiveness of stream-gaging program in Michigan: U.S. Geological Survey Water Resources Investigations Report, in preparation.

GROUND-WATER FLOW IN
MUNICIPAL WELL FIELD,
BATTLE CREEK, MICHIGAN



PROJECT NO. - MI 037

PROBLEM: Movement of ground water in the Battle Creek area is not understood in sufficient detail to permit accurate predictions of contaminant movement, nor to develop and evaluate remedial plans. It is impossible to determine which water-supply wells should be operated to prevent more extensive contamination of the Verona well field. The effects of previous industrial pumpage need to be assessed to understand the stresses affecting directions of ground-water movement in the area. Possible expansion of the well field should be examined.

OBJECTIVE: (1) Determine the effect that current water-supply pumping has on the direction and rate of natural ground-water flow, and how changes in the quantity and location of pumping affect flow, (2) determine the most appropriate pumping pattern to assure minimum impact of existing contamination in the well field, (3) evaluate hydrologically suitable locations for installing purge wells if needed, (4) evaluate the effects of industrial pumping on the well field, and (5) determine the feasibility of extending the well field northward.

RESULTS LAST YEAR: Report prepared for publication.

PLANS THIS YEAR: Print report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Southwestern Lower Peninsula, Michigan

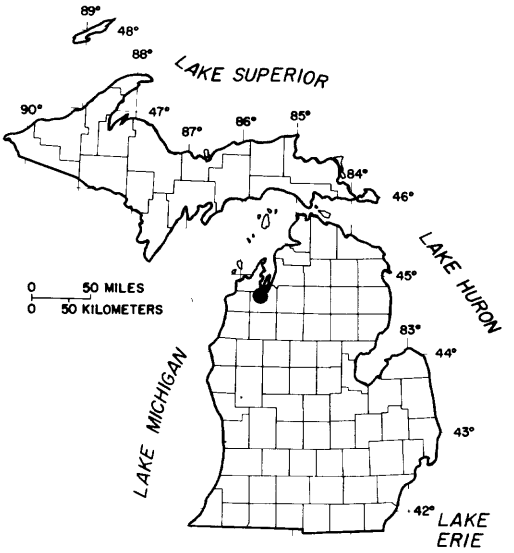
PROJECT CHIEF: Norman G. Grannemann

PERIOD OF PROJECT: Project completed.

COOPERATING AGENCIES: City of Battle Creek, Michigan

REPORTS: N. G. Grannemann and F. R. Twenter, 1985, Geohydrology and groundwater flow at Verona well field, Battle Creek, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4056.

GROUND-WATER CONTAMINATION AT THE COAST GUARD AIR STATION, TRAVERSE CITY, MICHIGAN



PROJECT NO. - MI 038

PROBLEM: Domestic ground-water supplies and the ground-water system in the vicinity of the United States Coast Guard Air Station, Traverse City, Michigan have been contaminated with organic chemicals. The principal contaminants are chlorinated hydrocarbons, benzene, toulene, and xylene. Additional study is needed to permit the Coast Guard to assess present remedial action and, if necessary, institute new action.

OBJECTIVE: (1) Determine rate and direction of ground-water flow at or near the Coast Guard Air Station, (2) assist in locating new sources of ground-water contaminants, (3) determine the extent and distribution of contaminants, and (4) evaluate hydrologically suitable locations for installing purge wells.

APPROACH: (1) Drill additional wells in the general area of the Air Station, (2) measure water levels periodically in wells, (3) make pumping tests to determine specific capacity, hydraulic conductivity, and transmissivity, and (4) redefine a flow model of the ground-water system.

RESULTS LAST YEAR: Installed wells to locate ground-water divide and assisted in locating and installing interdiction wells. Published report.

PLANS THIS YEAR: Use model to simulate ground-water flow under varying conditions.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Northwestern Lower Peninsula, Michigan.

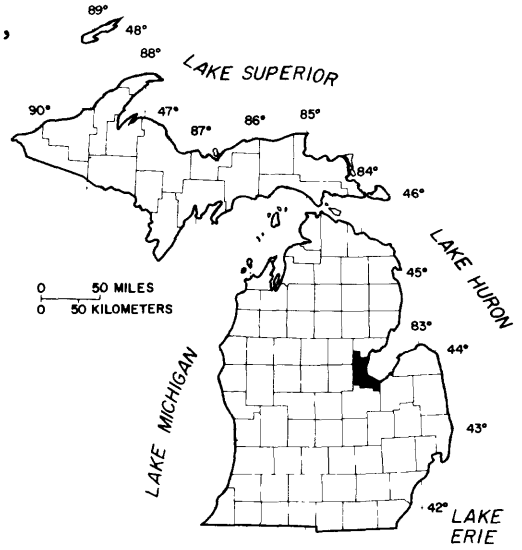
PROJECT CHIEF: Floyd R. Twenter

PERIOD OF PROJECT: July 1982 to September 1985

COOPERATING AGENCIES: U.S. Coast Guard

REPORTS: F. R. Twenter, T. R. Cummings, and N. G. Grannemann, 1985, Ground-water contamination in East Bay Township, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4064.

RELATION OF WATER QUALITY OF DOMESTIC WATER SUPPLIES TO ABANDONED COAL MINES, BAY COUNTY, MICHIGAN



PROJECT NO. - MI 039

PROBLEM: Domestic ground-water supplies in some areas of Bay County have been judged unsuitable for use by Health officials during the past few years. Scant data suggests that abandoned coal mines may have caused the problem. Suitable supplies can be developed only by understanding the movement, quantity, and quality characteristics of ground water in both the mined and unmined areas.

OBJECTIVE: (1) Determine chemical and physical characteristics of water from wells drilled to coal deposits, abandoned mines, and aquifers of the Saginaw Formation in Monitor and Williams Townships, Bay County, and (2) evaluate the effect of abandoned coal mines on natural ground-water quality, with particular reference to domestic water supplies and assess the extent of any effect.

RESULTS LAST YEAR: Well installation was completed, water samples were collected, data were evaluated, and report was prepared.

PLANS THIS YEAR: Print report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: East Central Lower Peninsula, Michigan

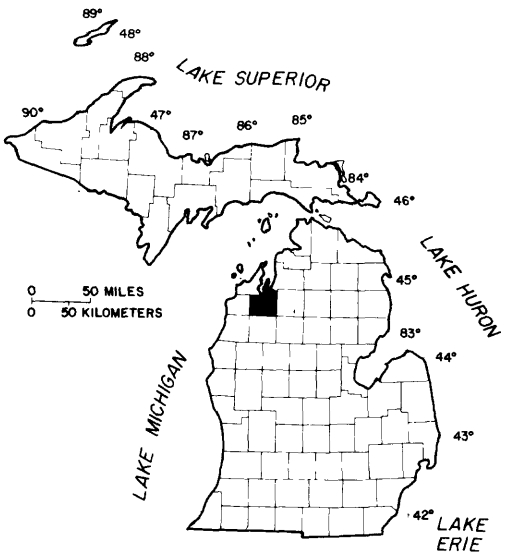
PROJECT CHIEF: Floyd R. Twenter

PERIOD OF PROJECT: January 1983 to April 1985

COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS: F. R. Twenter, and T. R. Cummings, 1985, Quality of ground water in Monitor and Williams Townships, Bay County, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4110.

WATER RESOURCES OF GRAND TRAVERSE COUNTY, MICHIGAN



PROJECT NO. - MI 040

PROBLEM: An increased demand for water by irrigators, municipalities, and industries is affecting economic development in parts of Grand Traverse County, the world's largest producer of cherries. Irrigation alone has increased by more than 300 percent since 1970. The effect of this expansion is unknown, and available information is inadequate to provide a basis for solving problems when they occur. Deteriorating ground-water quality at some places is likely related to use of fertilizer. Studies have shown that nitrate levels in heavily irrigated areas have made water unsuitable for domestic use.

OBJECTIVE: (1) Determine the quantity and quality of ground water and surface water, with particular attention to the use of water for irrigation, and the causes of contamination, (2) evaluate the chemical characteristics of precipitation and integrate this information into hydrologic assessments, (3) relate quality of ground water to land use, with emphasis on agricultural use, (4) relate, if possible, the transport of dissolved and sorbed substances and suspended sediment by streams to agricultural practices and land use, and (5) use mathematical models, where appropriate, to better understand the ground-water system.

APPROACH: (1) Evaluate available data contained in State, County, and Geological Survey files, (2) make routine discharge measurements at 15 stream sites 10 to 12 times per year, at 10 miscellaneous sites three times per year, and at several sites as needed during high flow, (3) measure ground-water levels at about 50 sites and install twenty 4-inch, twenty-five 2-inch, and two 6-inch wells, (4) install recording rain gages at two sites, (5) collect water-quality data from about 250 wells, 15 lakes, and 25 streams, (6) measure quality of precipitation, (7) develop mathematical models for assessing local ground-water conditions, and (8) analyze and evaluate data; write report.

RESULTS LAST YEAR: Reviewed existing geologic and hydrologic data. Established streamflow and water-quality monitoring network. Located sites for monitoring wells and prepared drilling contract.

PLANS THIS YEAR: Install ground-water monitoring wells. Measure ground-water levels and collect water-quality samples from wells. Run levels to determine well elevations and conduct pumping test. Continue to operate streamflow and water-quality monitoring network.

HEADQUARTERS OFFICE: Lansing, Michigan

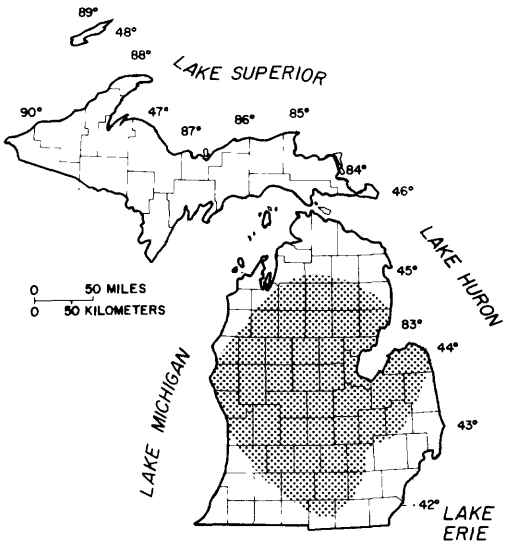
FIELD LOCATION: Northwest Lower Peninsula, Michigan

PROJECT CHIEF: Floyd R. Twenter

PERIOD OF PROJECT: May 1984 to April 1987

COOPERATING AGENCIES:
Michigan Department of Natural Resources
Grand Traverse County

MICHIGAN BASIN REGIONAL
AQUIFER SYSTEM ANALYSIS



PROJECT NO. - MI 041

PROBLEM: About half of Michigan's population depends on ground water as the source of domestic and public supply. The potential for development of supplies in large areas of glacial deposits and bedrock aquifers in the Lower Peninsula, however, is not well defined. The Marshall and Saginaw Formations of the Michigan Basin are extensively used, and in one area water levels are as much as 160 feet below prepumping levels. Migration of saline water resulting from excessive pumping has also caused abandonment of well fields. A better understanding of the hydrogeology and the occurrence of fresh and saline water is necessary if the effects of future development are to be determined.

OBJECTIVE: (1) Describe the geologic, hydrologic, and chemical quality characteristics of water-bearing rocks in the central part of the Michigan Basin, (2) delineate the vertical and areal extent of saline water and identify areas subject to saline-water contamination, (3) using computer models, simulate the effects of additional stress on aquifer systems, (4) develop a computerized data-base management system for the aquifer; (5) using simulation techniques, evaluate alternative management schemes for the aquifer system, and (6) evaluate hydrologic data to develop a network for monitoring water use, water levels, and water quality.

APPROACH: (1) Develop a detailed work plan and review existing literature, (2) compile pertinent data from all sources, (3) using file data, define geologic framework, (4) conduct surface and borehole geophysical surveys to delineate saline-water bodies, (5) develop a density-dependent solute transport model to simulate the saline-fresh water interface, and (6) collect geologic, hydrologic, and water-quality data to define areal and aquifer variability by installing test wells.

RESULTS LAST YEAR: Began review of existing literature and compilation of data.

PLANS THIS YEAR: Develop detailed work plan. Continue review of existing literature and compilation of data from file sources and from reports.

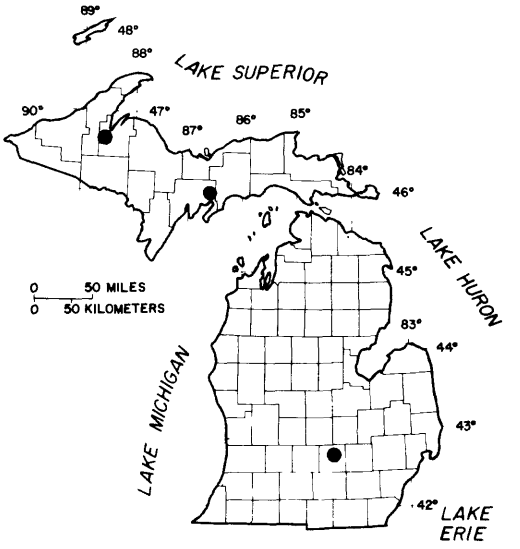
HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Lower Peninsula, Michigan

PROJECT CHIEF: Richard J. Mandle

PERIOD OF PROJECT: July 1984 to September 1988.

MATHEMATICAL MODELS OF
STREAMFLOW UNDER ICE, MICHIGAN



PROJECT NO. - MI 042

PROBLEM: Ice cover on an open channel often alters the flow characteristics of streams. Current methods of computing discharge in an ice covered channel are primarily empirical and often rely upon the experience of a hydrologist. A new theoretical model uses indicated stage, float depth of the ice, and the open-water stage-discharge relationship, to compute ice-affected river flows at times of solid ice cover. Although the model seems to offer advantages over current techniques, it has not been evaluated by a rigorous field investigation.

OBJECTIVE: To investigate the accuracy of simulations of streamflow under ice made by a theoretical model developed by Santeford and Alger (1984), and to extend, if possible, simulations to periods of stream freeze-up and ice break-up.

APPROACH: (1) Install and equip two gaging stations on the Sturgeon River upstream from the index gaging station near Sidnaw, (2) obtain detailed river cross sections at all three gages and establish benchmarks along the river between the gages, (3) make discharge measurements at Sturgeon River at Nahma Junction and Red Cedar River near Williamston to verify model during times of complete ice cover, (4) develop open-water ratings for the two new gages near Sidnaw, and (5) modify existing computer program to calculate discharge for comparison to field measurement of discharge at Sturgeon River and Red Cedar River gaging stations.

RESULTS LAST YEAR: Installed and equipped two gaging stations on Sturgeon River. Made detailed cross sections and flow measurements on Sturgeon and Red Cedar Rivers.

PLANS THIS YEAR: Evaluate the accuracy of the theoretical model with discharge measurements and hydrologic data collected at three sites during the winter of 1984-85. Collect supplemental hydrologic data as needed. Publish report.

HEADQUARTERS OFFICE: Lansing, Michigan

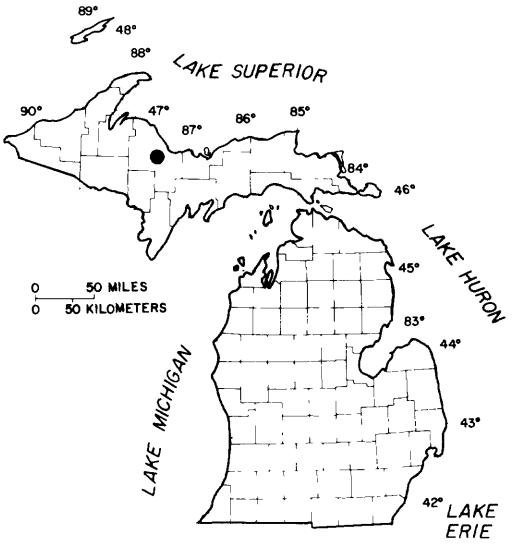
FIELD LOCATION: Western Upper Peninsula and Central Lower Peninsula, Michigan

PROJECT CHIEF: John B. Miller

PERIOD OF PROJECT: May 1984 to September 1985.

COOPERATING AGENCY: Michigan Technological University

GROUND-WATER STUDY OF
K.I. SAWYER AIR FORCE BASE,
MICHIGAN



PROJECT NO. - MI 043

PROBLEM: Information on the hydrogeology at K.I. Sawyer Air Force Base is inadequate for description and evaluation of potential problems, for management and protection of Base water resources, and for development of needed Base water-supply capacity. Trichloroethylene has been found in ground water at one location on the Base, and in Silver Lead Creek. Without information on the hydraulics of the ground-water system, movement and dispersion of contaminants cannot be predicted, nor can contaminants be traced to their origin.

OBJECTIVE: (1) Determine geologic conditions at and near K. I. Sawyer Air Force Base, (2) determine rate and direction of ground-water flow, (3) determine chemical characteristics of ground water, including both organic and inorganic substances, (4) locate source or sources of contaminants, (5) determine extent and distribution of contaminants, (6) determine if there is a relation between trichloroethylene detected in ground water and trichloroethylene detected in Silver Lead Creek, and (7) identify hydrologically suitable locations at which new water-supply wells may be installed.

APPROACH: (1) Evaluate available geologic and hydrologic data, (2) using geophysical techniques, determine altitude of bedrock surface and lithologic characteristics of glacial deposits, (3) install wells on Base and in surrounding area, (4) make routine water-level measurements, either weekly, monthly, or with recording equipment, (5) conduct pumping tests on selected wells to determine hydraulic properties of the aquifer, (6) collect water samples from wells for analysis of volatile hydrocarbon and common dissolved substances (make field measurements of specific conductance and temperature), (7) make periodic measurements of discharge of Silver Lead Creek, and (8) develop a finite-difference model of the ground-water system.

RESULTS LAST YEAR: Reviewed literature and compiled available data. Evaluated data. Drilled 35 observation wells. Ran geophysical logs on wells and performed a resistivity survey. Made ground-water level and stream-discharge measurements. Collected water samples from wells for quality analysis.

PLANS THIS YEAR: Continue to evaluate data, conduct pumping test, and prepare report.

HEADQUARTERS OFFICE: Lansing, Michigan

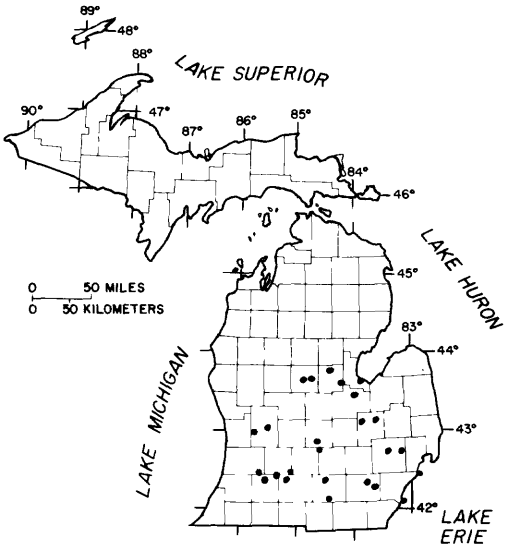
FIELD LOCATION: Central Upper Peninsula, Michigan

PROJECT CHIEF: Norman G. Grannemann

PERIOD OF PROJECT: April 1985 to May 1986

COOPERATIVE AGENCIES: U.S. Air Force

WATER QUALITY TRENDS OF MICHIGAN STREAMS



PROJECT NO. - MI 044

PROBLEM: A major effort has been made by the State of Michigan in the past 10 years to control the discharge of pollutants to streams in urban areas. Costly treatment facilities have been installed and regulations developed to protect water quality. The effectiveness of pollution control efforts, however, has not been assessed by rigorous analysis of data obtained at monitoring stations. Thus, decisions affecting the management of stream-water quality must be made without the guidance and benefit such study would provide. A trend analysis of major water-quality characteristics is needed.

OBJECTIVES: (1) Determine trends in concentration and transport for 9 selected water-quality characteristics at 23 stream sites in 11 urban areas by determining the average concentration and whether monotonic or step trends occur in flow-adjusted water-quality characteristics at the sites and within urban areas, (2) compare trends to known changes in basin characteristics, and (3) outline possible strategies for improving the water-quality monitoring network.

APPROACH: (1) Retrieve water-quality data from USEPA's STORET file, (2) develop fortran program code to manipulate and transform water-quality data for processing, (3) compute univariate statistics and develop box plots for each constituent, (4) flow adjust concentration data for all monitoring sites, (5) use raw and/or flow-adjusted concentration and transport data to conduct non-parametric tests for time-series trends, (6) analyze changes in concentration and transport within urban areas based on differences between upstream and downstream sites, (7) relate observed trends to changes in pollution-abatement facilities, regulations, or other variables, and (8) identify strategies to improve the data-collection network.

PLANS THIS YEAR: Conduct the project and prepare a report documenting the analysis.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

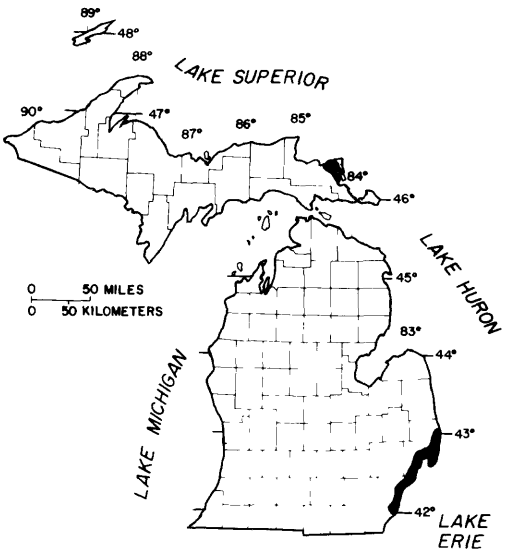
PROJECT CHIEF: David. J. Holtschlag

PERIOD OF PROJECT: March 1985 to September 1985.

COOPERATING AGENCIES: Michigan Department of Natural Resources

REPORTS IN PROGRESS: A water-resources investigations report describing trends in surface-water quality of Michigan streams.

GROUND-WATER MOVEMENT NEAR UPPER GREAT LAKES CONNECTING CHANNELS



PROJECT NO. - MI 045

PROBLEM: Information on the movement of ground water to Great Lakes connecting channels in Michigan is inadequate for an evaluation of its impact on the water quality of the channels. Contaminants from landfills, waste-disposal sites, and areas of known ground-water contamination could be a significant factor in determining water quality of the Great Lakes. In areas adjacent to the St. Marys River, Lake St. Clair, the St. Clair River, and the Detroit River, more than 100 hazardous-waste sites lie within 10 miles of the channels. Five of these sites are on the National Priority List. Upward movement of chemical substances from deep geologic strata, either from natural sources or from areas where deep injection of wastes has occurred, is also a possibility.

OBJECTIVE: (1) Determine the geologic conditions near connecting channels, (2) determine configuration of the water table and direction of ground-water flow, (3) determine the chemical and physical characteristics of ground water, with particular attention to the characteristics near known hazardous-waste sites, (4) assess the movement of dissolved substances from deep geologic strata to the connecting channels, and (5) assess the ground-water contribution of contaminants and natural occurring substances in the connecting channels.

APPROACH: Data collection and analyses activities will be conducted in three phases to meet the requirements of the United States-Canadian agreements developed by the project Management and Activities Intergration Committees. Phase I will be concerned with assembling data and identifying sites where ground-water contamination is suspected or known; phase II will consist of a preliminary designation of potentially hazardous sites; and phase III will consist of site specific investigation for prioritizing waste sites and calculating loading.

PLANS THIS YEAR: Compile and evaluate available data for hydrology, geology, land use, and ground-water conditions. Field locate sites with potential or known contaminant contribution. Locate wells usable for collecting water-level and water-quality information. Measure water levels and collect water samples.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Eastern Upper Peninsula and southeastern Lower Peninsula

PROJECT CHIEF: Floyd R. Twenter

PERIOD OF PROJECT: July 1985 to February 1987

COOPERATING AGENCIES: U.S. Environmental Protection Agency

HYDROLOGIC CONDITIONS

Most of Michigan has water resources sufficient to meet present needs. Much of the State is bounded by water and annual precipitation ranges from 28 to 36 inches (fig. 3). Eight to 16 inches of precipitation becomes surface runoff (fig. 4) and 9 to 15 inches recharges the ground-water reservoir; the remainder is returned to the atmosphere by evapotranspiration. The discharge of streams is shown in figures 5 and 6; the availability of ground water is shown in figures 7 and 8. Fresh water withdrawals from both surface- and ground-water sources average about 15 billion gallons per day. Nearly 97 percent is from surface-water sources; particularly from the Great Lakes and connecting waters. Largest municipal withdrawals are in the heavily populated counties in the southern part of the State (fig. 9). Glacial deposits are the source of municipal ground-water supplies in most of the State (fig. 10). In some parts of the State, the base of fresh ground water is less than 200 feet deep (fig. 11), and some wells produce salty water.

Michigan has identified more than 1,000 sites where ground water has been contaminated to some degree and an even greater number of sites where pollution is suspected (Michigan Department of Natural Resources, 1985). A wide range of contaminants is involved. At many sites, chlorinated hydrocarbons and hydrocarbons that are contained in fuel substances are the contaminants. Nitrates from surface sources have contaminated domestic ground-water supplies in concentrations of as much as 30 mg/L at some locations in the Lower Peninsula (Cummings and others, 1984).

The current program of the Michigan District of the U.S. Geological Survey is effectively addressing many water-resource issues and is providing the hydrologic information needed for the best utilization and long-term management of the Nation's water resources. Hydrologic-data stations, at which data are collected for surface water, ground water, and water quality, are located throughout the State.

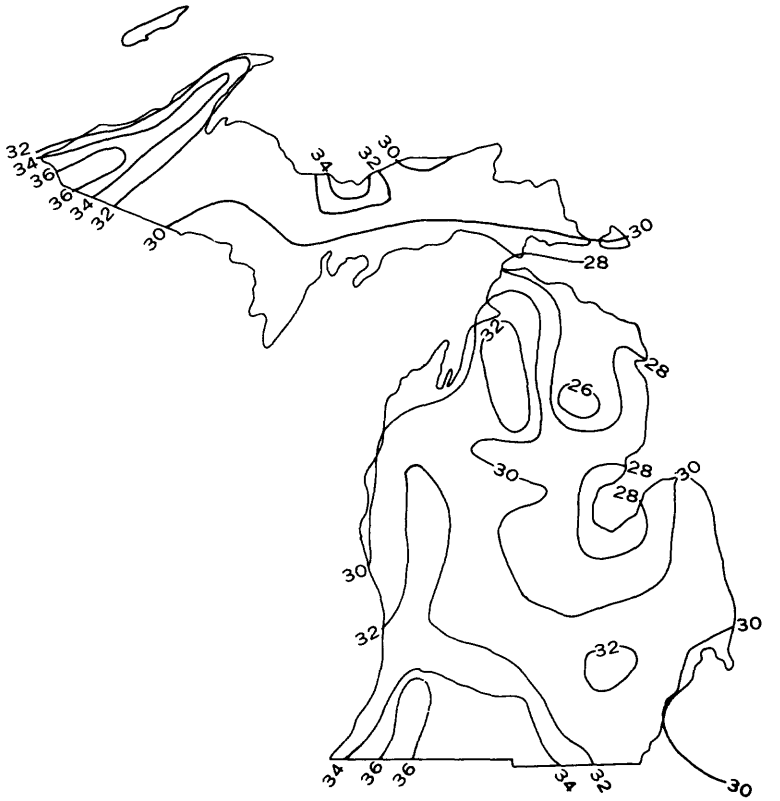


Figure 3.--Average annual precipitation (in inches) (Data from National Weather Service--NOAA).

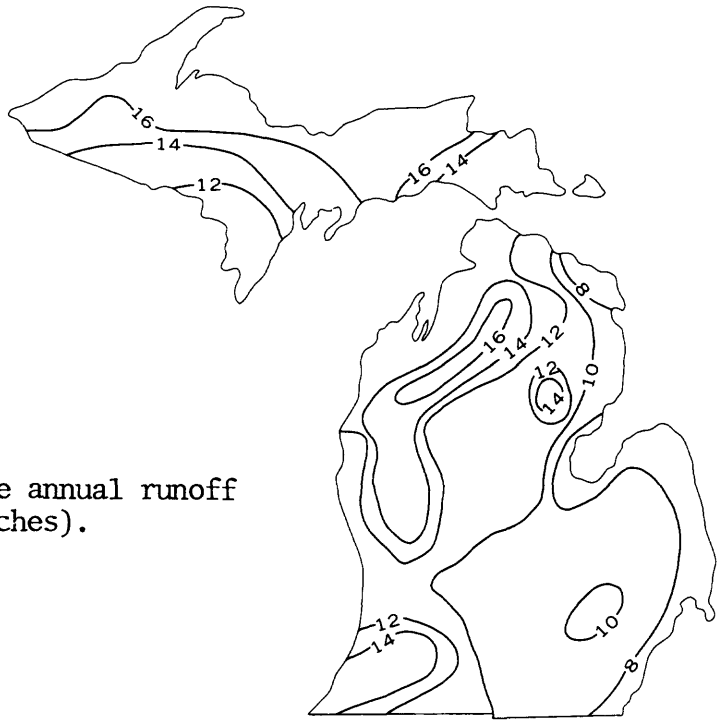


Figure 4.--Average annual runoff (in inches).

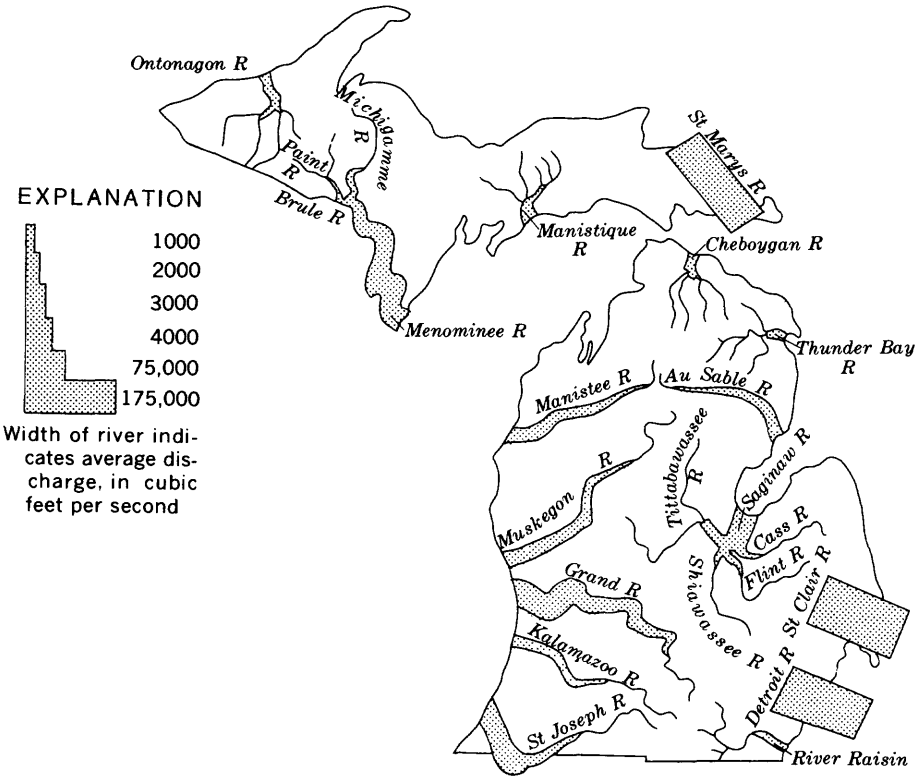


Figure 5.--Average discharge of streams (For streams draining an area of 1000 square miles or more at mouth).

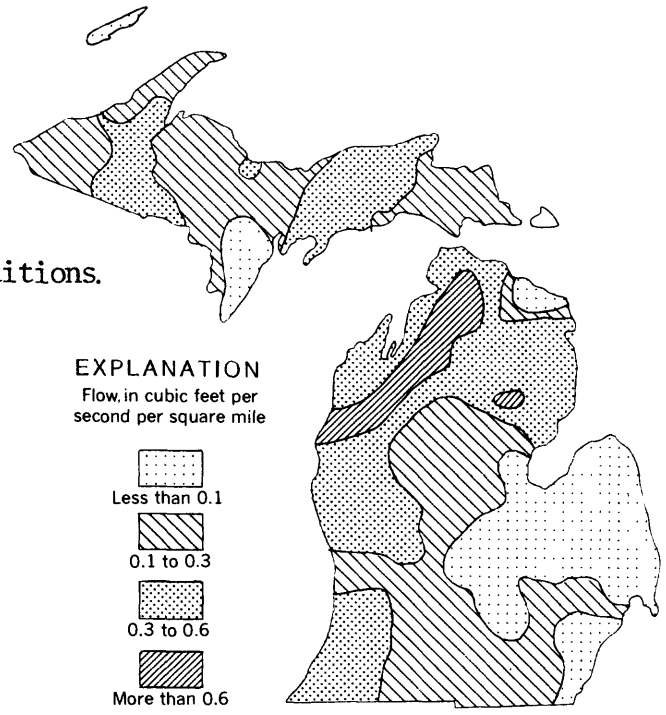


Figure 6.--Low-flow conditions.

EXPLANATION

Throughout most of these areas wells in bedrock will yield less than 10 gallons per minute. Locally, wells 6 inches or more in diameter may yield several tens of gallons per minute

Throughout most of these areas wells 6 inches or more in diameter in bedrock will yield from 10 to 100 gallons per minute. Locally, wells may yield less than 10 gallons per minute or more than 100 gallons per minute

Throughout most of these areas wells 8 inches or more in diameter in bedrock will yield from 100 to 500 gallons per minute. Locally, wells will yield less than 100 or more than 500 gallons per minute

Throughout most of these areas wells 10 inches or more in diameter in bedrock will yield more than 500 gallons per minute

Throughout most of these areas wells in bedrock will yield water that is too highly mineralized for domestic or public supplies-dissolved solids content of more than 1,000 milligrams per liter. Locally, the water may be of relatively good chemical quality. In general, the water becomes more mineralized with an increase in depth

As in the glacial drift the water in the bedrock is usually hard and may contain iron locally. With increasing depth water tends to become more mineralized

Figure 7.--Availability and quality of ground water in bedrock.

EXPLANATION

Throughout most of these areas wells in glacial deposits will yield less than 10 gallons per minute. Locally, wells 6 inches or more in diameter may yield several tens of gallons per minute and in places, especially where sand and gravel deposits occur along streams, will yield more than 100 gallons per minute

Throughout most of these areas wells 6 inches or more in diameter in glacial deposits will yield from 10 to 100 gallons per minute. Locally wells may yield less than 10 gallons per minute, and in places, especially where sand and gravel deposits occur along streams, will yield several hundred gallons per minute

Throughout most of these areas wells 8 inches or more in diameter in glacial deposits will yield from 100 to 500 gallons per minute. Locally, wells will yield less than 100 gallons per minute, and in places, especially where sand and gravel deposits occur along streams, will yield more than 500 gallons per minute

Throughout most of these areas wells 10 inches or more in diameter in glacial deposits will yield more than 500 gallons per minute

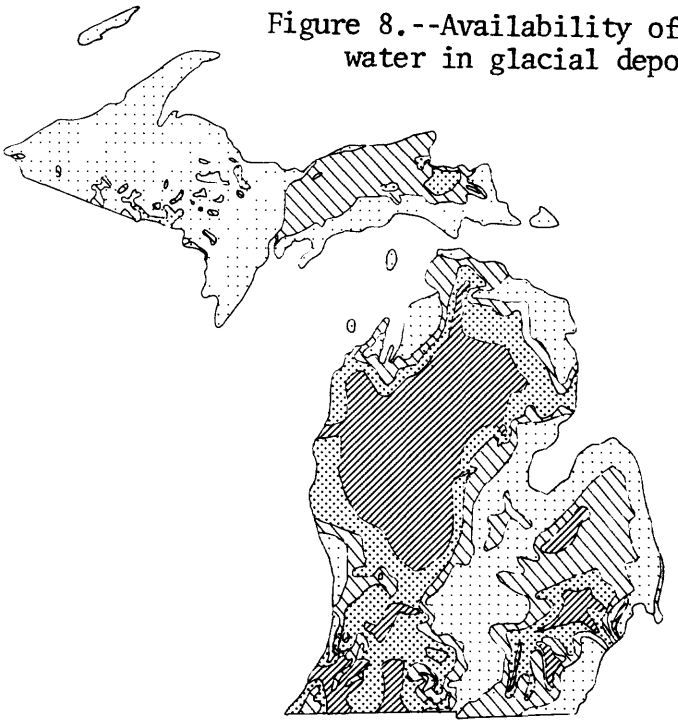


Figure 8.--Availability of ground water in glacial deposits.

Water in the glacial deposits is of generally good quality although hard and may contain iron locally

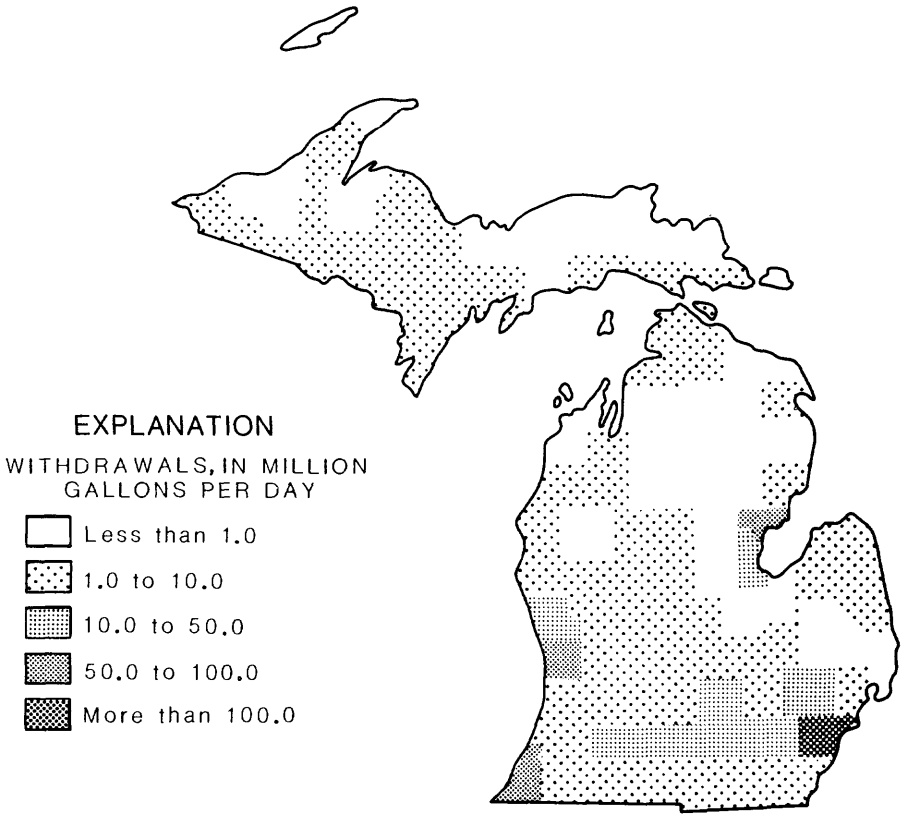


Figure 9.--Municipal water withdrawals, 1978.

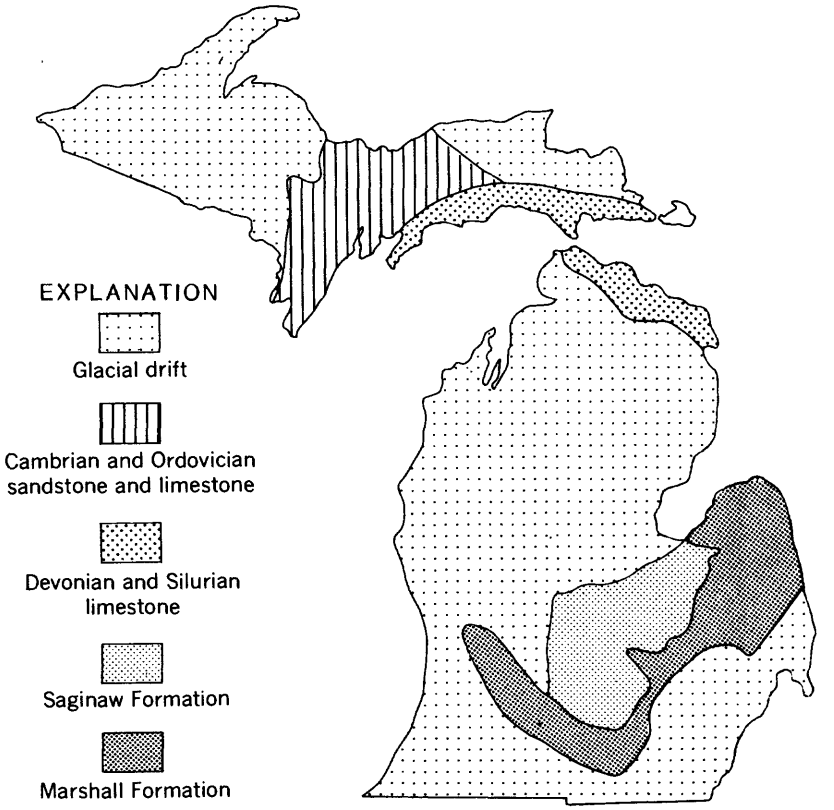
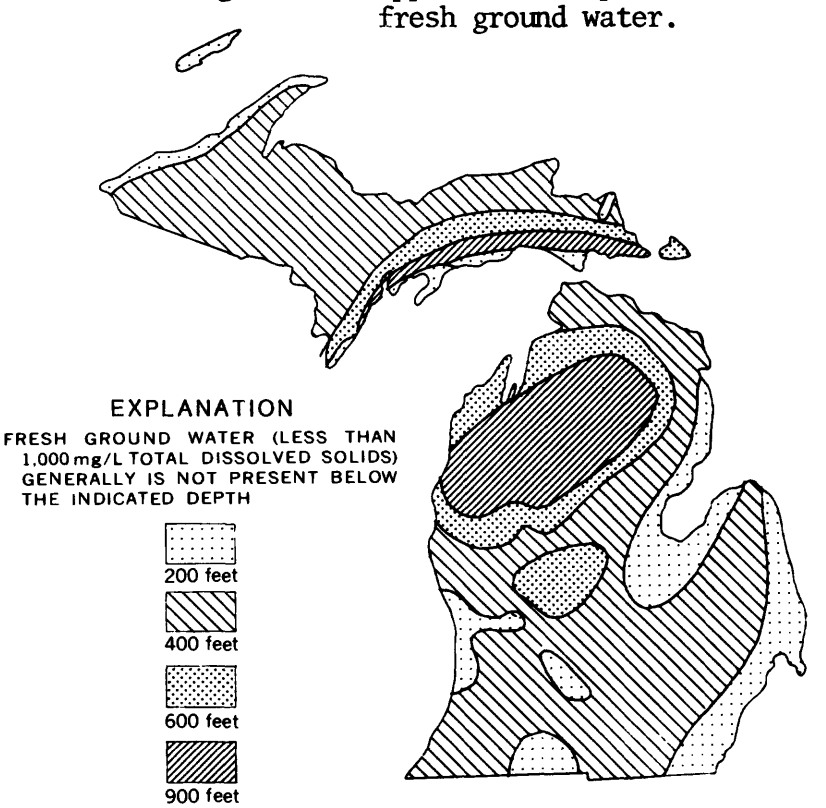


Figure 10.--Principal sources of public ground-water supplies.

Figure 11.--Approximate depth to base of fresh ground water.



HYDROLOGIC-DATA STATIONS

Hydrologic-data stations are maintained by the Geological Survey at selected key locations throughout Michigan to constitute a basic-data network for obtaining records on stream discharge or stage, reservoir and lake storage, ground-water levels, and the quality of surface and ground water. Every year stations are added and others are terminated; thus, the Geological Survey has both a current and historical file of hydrologic data. Much of the information collected is stored in the Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and are available to water planners and other involved in making decisions affecting the State's water resources.

Surface-Water Stations

In table 1, the station number is a permanent numerical designation for surface-water stations that has been adopted on a nationwide basis by the Geological Survey. Stations are numbered and listed in a downstream direction along the main stem. All stations on the tributary entering above a main-stem station are listed before that station. A tributary entering between two main-stem stations is listed between them.

Table 1.--Surface-water hydrologic data stations

Station Number	Station Name	Type of Data[1]
04001000	Washington Creek at Windigo, MI	Q1CPTR
04033000	Middle Branch Ontonagon River near Paulding, MI	Q1
04033500	Bond Falls Canal near Paulding, MI	Q1
04034000	Bond Falls Reservoir near Paulding, MI	14
04034500	Middle Branch Ontonagon River near Trout Creek, MI	Q1
04035500	Middle Branch Ontonagon River near Rockland, MI	Q1
04036000	West Branch Ontonagon River near Bergland, MI	Q1
04037500	Cisco Branch Ontonagon River at Cisco Lake Outlet, MI	Q1
04040000	Ontonagon River near Rockland, MI	Q1CS
04040500	Sturgeon River near Sidnaw, MI	Q1
04041000	Perch River near Sidnaw, MI	2
04041500	Sturgeon River near Alston, MI	Q1
04043004	Sturgeon River near Chassell, MI	MCS
04043050	Trap Rock River near Lake Linden, MI	Q1T
04044200	Carp Creek at Ishpeming, MI	2
04044400	Carp Creek near Negaunee, MI	Q1
04044609	Sand River Wildlife Flooding at Sand River, MI	1
04044813	Two Hearted River near Paradise, MI	2
04045500	Tahquamenon River near Tahquamenon Paradise, MI	Q1CS
04045538	West Branch Waiska River near Brimley, MI	2
04045559	East Branch Waiska River near Brimley, MI	2
04045580	St. Marys River above Sault Ste. Marie, MI	MCSR
04046000	Black River near Gernet, MI	2
04056500	Manistique River near Manistique, MI	Q1
04057004	Manistique River above Manistique, MI	MCS
04057510	Sturgeon River near Nahma Junction, MI	Q1
04057580	Whitefish River near Rapid River, MI	3
04057800	Middle Branch Escanaba River at Humbolt, MI	Q1
04057811	Greenwood Reservoir near Greenwood, MI	14
04057812	Greenwood Afterbay near Greenwood, MI	T
04057813	Greenwood Diversion near Greenwood, MI	Q1
04057814	Greenwood Release near Greenwood, MI	Q1
04057900	Black River near Republic, MI	2
04058120	Green Creek near Palmer, MI	3
04058190	Schweitzer Reservoir near Palmer, MI	14
04058200	Schweitzer Creek near Palmer, MI	Q1
04058400	Goose Lake Outlet near Sands Station, MI	2
04059000	Escanaba River at Cornell, MI	Q1CS
04059034	Escanaba River near Wells, MI	3
04059400	Tenmile Creek at Perronville, MI	2
04059500	Ford River near Hyde, MI	Q1CS
04061000	Brule River near Florence, MI	Q1
04061500	Paint River at Cyrstal Falls, MI	Q1
04062000	Paint River near Alpha, MI	Q1
04062300	Michigamme River at Republic, MI	2
04062500	Michigamme River near Crystal Falls, MI	Q1
04063000	Menominee River near Florence, WI	Q1

Table 1.--Surface-water hydrologic data stations--Continued

Station Number	Station Name	Type of Data[1]
04065393	East Branch Sturgeon River below Skunk Creek near Felch, MI	Q1
04096272	Beebe Creek near Hillsdale, MI	2
04096340	St. Joseph River at Clarendon, MI	2
04096400	St. Joseph River near Burlington, MI	Q1
04096515	Hog Creek near Allen, MI	Q1
04096517	Hog Creek tributary near Allen, MI	3
04096600	Coldwater River near Hodunk, MI	Q1
04096900	Nottawa Creek near Athens, MI	Q1
04097170	Portage River near Vicksburg, MI	2
04097195	Gourdneck Canal near Schoolcraft, MI	Q1
04097540	Prairie River near Nottawa, MI	Q1
04099000	St. Josepb River at Mottville, MI	Q1
04101500	St. Joseph River at Niles, MI	Q1CST
04101800	Dowagiac River at Sumnerille, MI	Q1
04102500	Paw Paw River at Riverside, MI	Q1
04102700	South Branch Black River near Bangor, MI	Q1
04105000	Battle Creek at Battle Creek, MI	Q1
04105500	Kalamazoo River near Battle Creek, MI	Q1
04105700	Augusta Creek near Augusta, MI	Q1
04106180	Portage Creek at Portage, MI	Q1
04106300	Portage Creek near Kalamazoo, MI	Q1
04106320	West Fork Portage Creek near Oshtemo, MI	Q1
04106400	West Fork Portage Creek at Kalamazoo, MI	Q1
04106500	Portage Creek at Kalamazoo, MI	Q1T
04108500	Kalamazoo River near Fennville, MI	Q1
04108600	Rabbit River near Hopkins, MI	Q1
04108645	Rabbit River at Hamilton, MI	2
04108690	Kalamazoo River at Saugatuck, MI	MCS
04108800	Macatawa River near Zeeland, MI	Q1
04109000	Grand River at Jackson, MI	Q1
04111379	Red Cedar River near Williamston, MI	Q1
04111500	Deer Creek near Dansville, MI	Q1
04112000	Sloan Creek near Williamston, MI	Q1
04112500	Red Cedar River at East Lansing, MI	Q1
04112700	Sycamore Creek near Mason, MI	2
04113000	Grand River at Lansing, MI	Q1
04113090	Carrier Creek near Grand Ledge, MI	2
04114500	Looking Glass River near Eagle, MI	Q1
04114594	Maple River near St. Johns, MI	3
04115000	Maple River at Maple Rapids, MI	Q1
04116000	Grand River at Ionia, MI	Q1
04116500	Flat River at Smyrna, MI	Q1
04117000	Quaker Brook near Nashville, MI	2
04117500	Thornapple River at Hastings, MI	Q1
04118000	Thornapple River near Caledonia, MI	Q1
04119000	Grand River at Grand Rapids, MI	Q1
04119055	Plaster Creek at Grand Rapids, MI	2
04119160	Buck Creek at Grandville, MI	2
04119300	Grand River near Eastmanville, MI	MCST
04120295	Black Creek near Muskegon, MI	23
04121300	Clam River at Vogel Center, MI	Q1

Table 1.--Surface-water hydrologic data stations--Continued

Station Number	Station Name	Type of Data[1]
04121500	Muskegon River at Evart, MI	Q1T
04121900	Little Muskegon River near Morley, MI	Q1T
04122000	Muskegon River at Newaygo, MI	Q1
04122030	Muskegon River near Bridgeton, MI	MCS
04122100	Bear Creek near Muskegon, MI	Q1
04122200	White River near Whitehall, MI	Q1
04122230	North Branch Pentwater River near Pentwater, MI	2
04122500	Pere Marquette River at Scottville, MI	Q1T
04124000	Manistee River near Sherman, MI	Q1
04124500	East Branch Pine River near Tustin, MI	2
04126000	Mannistee River near Manistee, MI	Q1
04126520	Manistee River at Manistee, MI	MCS
04126600	Betsie River near Benzonia, MI	2
04127000	Boardman River near Mayfield, MI	Q1
04127800	Jordan River near East Jordan, MI	Q1T
04127850	Boyne River near Boyne City, MI	2
04127918	Pine River near Rudyard, MI	Q1
04128000	Sturgeon River near Wolverine, MI	Q1T
04129000	Pigeon River near Vanderbilt, MI	Q1
04130500	Black River near Tower, MI	Q1
04132052	Cheboygan River at Cheboygan, MI	MCS
04135000	Thunder Bay River near Alpena, MI	Q1CST
04135500	Au Sable River at Grayling, MI	Q1
04135600	East Branch Au Sable River at Grayling, MI	Q1
04135700	South Branch Au Sable River near Luzerne, MI	Q1T
04136500	Au Sable River at Mio, MI	Q1
04137500	Au Sable River near Au Sable, MI	MCS
04139000	Houghton Creek near Lupton, MI	2
04140200	Klacking Creek near Selkirk, MI	2
04140500	Rifle River at Selkirk, MI	2
04141000	South Branch Shepards Creek near Selkirk, MI	2
04142000	Rifle River near Sterling, MI	Q1CS
04143900	Shiawassee River at Linden, MI	Q1
04144500	Shiawassee River at Owosso, MI	Q1
04146000	Farmers Creek near Lapeer, MI	Q1
04146020	South Branch Flint River near Millville, MI	2
04146063	South Branch Flint River near Columbiaville, MI	Q1
04146450	North Branch Flint River near Columbiaville, MI	3
04147000	Holloway Reservoir near Otisville, MI	14
04147500	Flint River near Otisville, MI	Q1
04148140	Kearsley Creek near Davison, MI	Q1
04148500	Flint River near Flint, MI	Q1
04148610	Cole Creek near Flushing, MI	2
04148640	Armstrong Creek near Montrose, MI	2
04150500	Cass River at Cass City, MI	Q1
04150800	Cass River at Wahjamega, MI	Q1
04151500	Cass River at Frankenmuth, MI	Q1
04154000	Chippewa River near Mount Pleasant, MI	Q1
04155000	Pine River at Alma, MI	Q1

Table 1.--Surface-water hydrologic data stations--Continued

Station Number	Station Name	Type of Data[1]
04155500	Pine River near Midland, MI	Q1
04156000	Tittabawassee River at Midland, MI	Q1
04157000	Saginaw River at Saginaw, MI	Q1CS
04159010	Pigeon River near Caseville, MI	MCS
04159130	St. Clair River at Port Huron, MI	MCS
04159500	Black River near Fargo, MI	Q1
04160350	Pine River near Rattle Run, MI	2
04160570	North Branch Belle River at Imlay City, MI	Q1
04160600	Belle River at Memphis, MI	Q1
04160800	Sashabaw Creek near Drayton Plains, MI	Q1
04160900	Clinton River near Drayton Plains, MI	Q1
04161000	Clinton River at Auburn Heights, MI	2
04161100	Galloway Creek near Auburn Heights, MI	Q1
04161500	Paint Creek near Lake Orion, MI	2
04161540	Paint Creek at Rochester, MI	Q1
04160580	Stony Creek near Romeo, MI	Q1
04161760	West Branch Stony Creek near Washington, MI	2
04161790	Stony Lake near Washington, MI	14
04161800	Stony Creek near Washington, MI	Q1
04162010	Red Run near Warren, MI	Q1
04162900	Big Beaver Creek near Warren, MI	Q1
04163400	Plum Brook at Utica, MI	Q1
04164000	Clinton River near Fraser, MI	Q1
04164010	North Branch Clinton River at Almont, MI	2
04164050	North Branch Clinton River near Romeo, MI	2
04164100	East Pond Creek at Romeo, MI	Q1
04164150	North Branch Clinton River near Meade, MI	2
04164200	Coon Creek near Armada, MI	2
04164300	East Branch Coon Creek at Armada, MI	Q1
04164350	Highbank Creek near Armada, MI	2
04164360	East Branch Coon Creek near New Haven, MI	2
04164400	Deer Creek at Meade, MI	2
04164450	McBride Drain near Macomb, MI	2
04164500	North Branch Clinton River near Mount Clemens, MI	Q1
04164600	Middle Branch Clinton River near Macomb, MI	2
04164800	Middle Branch Clinton River at Macomb, MI	2
04165200	Gloede Ditch near Waldenburg, MI	2
04165500	Clinton River at Mount Clemens, MI	Q1CS
04165700	Detroit River at Detroit, MI	MCS
04166000	River Rouge at Birmingham, MI	Q1
04166100	River Rouge at Southfield, MI	Q1
04166200	Evans Ditch at Southfield, MI	Q1
04166300	Upper River Rouge at Farmington, MI	Q1
04166500	River Rouge at Detroit, MI	Q1
04167000	Middle River Rouge near Garden City, MI	Q1
04168000	Lower River Rouge at Inkster, MI	Q1
04168660	Frank and Poet Drain at Trenton, MI	2
04168800	Huron River near Andersonville, MI	2
04170000	Huron River at Milford, MI	Q1CSP
04170500	Huron River near New Hudson, MI	Q1CSP
04172000	Huron River near Hamburg, MI	Q1

Table 1.--Surface-water hydrologic data stations--Continued

Station Number	Station Name	Type of Data
04173250	Mill Creek near Lima Center, Mi	2
04174050	Huron River at Delhi Mills, MI	P
04174500	Huron River at Ann Arbor, MI	Q1
04175960	South Branch River Raisin near Adrian, MI	2
04176000	River Raisin near Adrian, MI	Q1
04176400	Saline River near Saline, MI	2
04176500	River Raisin near Monroe, MI	Q1CS

1/ TYPE OF DATA:

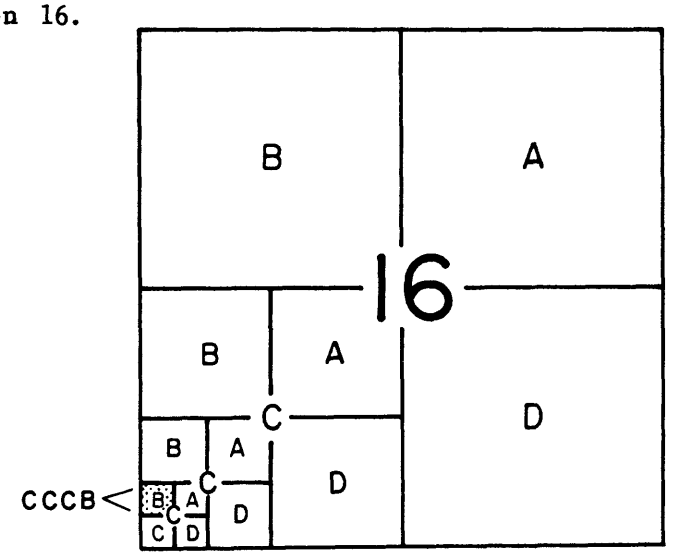
Surface-water data:
- Q - Daily discharge.
- 1 - Stage
- 2 - Peak stage and discharge.
- 3 - Low flow.
- 4 - Reservoir contents.
- M - Miscellaneous.

Quality analyses:
- C - General chemical, organic, and biological analyses.
- S - Sediment analyses.
- P - Pesticide.
- T - Temperature.
- R - Radiochemical
- D - Partial chemical analysis.

Ground-Water Stations

Table 2 lists the ground water stations established as part of the State-wide observation network. In addition to ground-water information collected at sites listed in table 2, chemical analyses of ground water have been collected at other locations in the State. Further information is available upon request.

The well-numbering system for Michigan indicates the location of wells within the rectangular subdivision of the land with reference to the Michigan meridian and base line. The first two segments of the well number designate township and range, the third segment of the number designates the section, and the letters A through D designate successively smaller subdivisions of the section as shown below. Thus, a well designated as 32N 6 E 16CCCB would be located to the nearest 2.5 acres (1 hectare) and would be within the shaded area in section 16.



For many wells in this report, locations are only given to the nearest 40-acre (16 hectares) tract, for example, 16CC. In the event that two or more wells are located in the same tract, a sequential number designation is added--for example, 16CC1, 16CC2, 16CC3, etc.

Table 2.--Ground-water hydrologic data stations

County	Well Number[1]	Name of Well	Depth (ft)	Aquifer[2]	Type of Data[3]
ALGER	45N 19W 25BDCD1	CCC	66	GLCL	Q,QC
ALPENA	32N 06E 23DDDA1	Alpena State Forest	88	GLCL	R,QC
ARENAC	19E 05E 07DABA1	Omer, D	185	SGNW	M,QC
	07DABA2	Omer, S	21	GLCL	M,QC
BARAGA	48N 32W 12DD	WMP 14	10	GLCL	M
BARRY	04N 09W 05DA	Solomon Road	131	GLCL	Q
BAY	17N 04E 22DCAA1	Pinconning Twp.	110	SGNW	M,QC
BRANCH	06S 06W 18CCCD1	Coldwater Twp.	56	GLCL	M,QC
	22CA	Coldwater Test 4	113	GLCL	R
CALHOUN	01S 07W 10BB	Sabin	12	GLCL	W
	32BDCC1	Penfield Twp.	95	MRSL	R,QC
	32DA	Battle Creek	127	MRSL	D
	02S 06W 25AA	Marshall	59	MRSL	M
CASS	08S 14W 17BA	Little	55	GLCL	M
CHEBOYGAN	33N 01W 26DABB1	Pigeon River CCC	164	GLCL	R,QC
	39N 03W 29CBCB1	Mackinaw, D	125	DUND	M,QC
	39N 03W 29CBCB2	Mackinaw, S	55	GLCL	M,QC
CHIPPEWA	46N 04W 24DADA1	Raco	54	GLCL	R
CLARE	17N 04W 34DCAD	Clare	91	GLCL	R
CLINTON	05N 02W 31CBBA1	Capital City Airport	195	SGNW	R,QC
	32DC	Quarantine Farm	135	SGNW	M
	06N 01W 3BB2	Sleepy Hollow 5	62	GLCL	I
	06N 02W 16DDAD1	MSHD, U.S. 27	23	GLCL	M
	07N 01W 34CC	Sleepy Hollow 7	32	GLCL	I
CRAWFORD	25N 01W 15DDCD1	Eldorado	56	GLCL	R,QC
DELTA	39N 23W 28AC	Schemmel	530	MNSG	R
	41N 18W 31CD	Isabella	250	LMSN	M
	42N 18W 17ABBD	Cooks CCC	60	GLCL	Q
	42N 19W 20AA	Pollack CCC	134	GLCL	Q
	43N 19W 24BB	Clarage	405	TBRV	Q
DICKINSON	43N 28W 32ADAB1	Felch	31	GLCL	M,QC
EATON	03N 03W 02BA	Lansing, Stiefel	66	GLCL	R
	04N 03W 12CD	Robins Road	381	SGNW	R
GENESSEE	06N 07E 09DCCC1	Fisher Body No.2	385	SGNW	R,QC
GRAND TRAVERSE	26N 09W 14ABAA1	Fife Lake State Forest	80	GLCL	R,QC
HILLSDALE	07S 02W 10BDDD1	Pittsford Game Area	20	GLCL	M,QC
	07S 02W 15BCBA1	Osseo	150	OTSH	M,QC
INGHAM	02N 01E 34DB	Dansville Game Area	87	GLCL	Q
	02N 01W 05BCAB1	Mason	210	SGNW	R,QC
	03N 01E 07DDCA1	Lotte	184	SGNW	M
	02W 23BCBD	Holt	188	SGNW	R
	04N 01W 16DADD	Meridian Twp.	398	SGNW	M
	28BCAD1	Okemos	125	SGNW	R
	04N 02W 16DA	Lansing, Cedar	417	SGNW	R
	17AB	Lansing, Logan	424	SGNW	R
	21BA2	Lansing, Scott Park	400	SGNW	R
	22BC	Lansing, P-5	338	SGNW	M
	24CA	Spartan Village	453	SGNW	R

Table 2.--Ground-water hydrologic data stations --Continued

County	Well Number[1]	Name of Well	Depth (ft)	Aquifer[2]	Type of Data[3]
INGHAM (cont.)	04N 02W 27BB	Fenner Arboretum	215	SGNW	R
	02W 31CC	Maybel Street	204	SGNW	M
IOSCO	24N 07E 13ADAD1	Oscoda	69	GLCL	M,QC
IRON	43N 35W 11AD	WMP 23	47	GLCL	M
	20DC	WMP 25	48	GLCL	M
	44N 37W 14BB	CCC	102	GLCL	Q
JACKSON	03S 01W 11AA1	Jackson - 4a, Belden	360	SGNW MRSL	D
KALAMAZOO	02S 10W 04D	Kalamazoo, Campbell	13	GLCL	R
	09B	Kalamazoo, Schoonover	21	GLCL	R
	02S 11W 20BB2	Kalamazoo, Kendall	106	GLCL	R
	22CD	Kalamazoo, Stockbridge	137	GLCL	R
	28AA	Kalamazoo, Maple	245	GLCL	R
	31CD	Kalamazoo, Colony	226	GLCL	R
	36CB	Kalamazoo, Emerald	226	GLCL	R
	03S 11W 04AD1	Kalamazoo, A-D	135	GLCL	R
	04AD2	Kalamazoo, A-S	40	GLCL	R
	14AA	Upjohn 28	233	GLCL	R
	22BBCD	Portage	102	GLCL	R
	12W 11BD	Kalamazoo, Atwater	248	GLCL	R
	11AD1	Kalamazoo,Sabo,D	300	GLCL	R
	11AD2	Kalamazoo,Sabo,S	38	GLCL	R
KALAMAZOO (cont.)	04S 11W 03CDDA1	Prairie View Park	190	GLCL	R,QC
KENT	05N 12W 04DCCD1	Wyoming, Wobma	86	GLCL	R,QC
	10N 12W 13DD	Rouge River Game Area	30	GLCL	Q
LAKE	20N 13W 13ACAC1	Irons	58	GLCL	M,QC
LEELANAU	28N 14W 08DDCA1	Sleeping Bear,D	138	GLCL	M,QC
	18BABB1	Sleeping Bear,S	60	GLCL	M,QC
LENAWEE	05S 01E 12DDBD1	Onstead Game Area	39	GLCL	M
	06S 04E 08DDBA1	Fisher Body	81	GLCL	R,QC
LIVINGSTON	01N 06E 13DBAD1	American Aggregate	29	GLCL	R,QC
	02N 06E 31BA2	Brighton	83	GLCL	R
MACKINAC	41N 05W 23BC	Round Lake CCC	47	SLINT	Q
	42N 02W 07AABB1	Pontchartrain CCC	102	MNSQ	R,QC
MARQUETTE	47N 28W 03CCDC1	Ely Township	75	GLCL	R,QC
	49N 30W 22AC	WMP 13	17	GLCL	M
MENOMINEE	37N 26W 19DADA1	Carney	17	GLCL	Q,QC
MONROE	07S 06E 15ACAA1	Petersburg, rock	73	DRRV	M,QC
	15ADBB1	Petersburg Game Area	17	GLCL	M
MUSKEGON	11N 15W 34ADDD1	Muskegon Game Area	31	GLCL	Q,QC
OAKLAND	02N 07E 05BA	Honeywell Lake	44	GLCL	R
	08E 18DBAD1	Proud Lake Park	45	GLCL	R,QC
	03N 07E 05DA	Fish Lake Road	49	GLCL	R
	10E 13AC	Oakland Univ.	183	GLCL	R
	05N 08E 08ACAC1	Holly Recreation Area	42	GLCL	M

Table 2.--Ground-water hydrologic data stations --Continued

County	Well Number[1]	Name of Well	Depth (ft)	Aquifer[2]	Type of Data[3]
OCEANA	13N 15W 18AAAA1	Hesperia	79	OTSH	R,QC
OGEMAW	23N 01E 02BAAA1	Rose City Road,D	105	GLCL	Q
	02BAAA2	Rose City Road,S	20	GLCL	Q,QC
ONTONAGON	51N 41W 08BDBC1	Silver City	100	FRED	Q,QC
OTSEGO	30N 03W 19ABBB1	Gaylord	90	OTSH	M,QC
PRESQUE ISLE	33N 06E 8BBBB1	Styma	61	TRVR	Q,QC
ROSCOMMON	24N 02W 20BABA1	Exp. Station	14	GLCL	R,QC
SAGINAW	10N 01E 22DADA1	Marion Springs,D	210	SGNW	R,QC
SANILAC	13N 13E 12ADAA1	Minden Game Area	130	MRSL	R,QC
SCHOOLCRAFT	45N 13W 16CCCB1	Seney	154	LMSN	R,QC
	47N 16W 30BBBB1	Cusino CCC	57	PRDC	R,QC
VAN BUREN	02S 13W 02BBCD1	Almena, D	108	GLCL	M
	02BBCD2	Almena, S	44	GLCL	M
WASHTENAW	02S 03E 09DAAB2	Waterloo Park	48	GLCL	R,QC
	03S 06E 16BCCD1	Ann Arbor	55	GLCL	R,QC
	07E 05BB	Ypsilanti, Superior	69	GLCL	R
	03S 07E 09AD	Ypsilanti,Gilbert	94	GLCL	R
	24CA1	Ypsilanti Township 104	87	GLCL	R
	24CD	Ypsilanti Township 117	75	GLCL	R
WEXFORD	22N 12W 13BA	Harrietta Fish Hatchery	141	GLCL	R

1/ LOCAL WELL NUMBER: For explanation of well numbers see introduction to table.

2/ AQUIFER:

- GLCL - Glacial deposits; Pleistocene
- OTSH - Outwash; Pleistocene
- SGNW - Saginaw Formation; Middle Pennsylvanian
- MRSL - Marshall Formation; Lower Mississippian
- TRVR - Traverse Group; Middle and Upper Devonian
- DUND - Dundee Formation; Middle Devonian
- DRRV - Detroit River Group; Lower Devonian
- SLINT - Saline Formation; Middle and Upper Silurian
- MNSQ - Manistique Group Middle Silurian
- LMSN - Upper Ordovician limestones
- TBRV - Black River and Tenton Groups; Middle Ordovician
- PRDC - Prairie du Chien Group; Lower Ordovician
- MNSG - Munising Sandstone; Upper Cambrian
- FRED - Freda Sandstone; Precambrian

3/ TYPE OF DATA:

Ground-water levels:
- R - Continuous record
- D - Daily measurement
- W - Weekly measurement
- M - Monthly measurement
- Q - Quarterly measurement
- A - Annual measurement
- I - Intermittently

Quality analyses:
- QC - General chemical, organic, and pesticide analyses

SOURCES OF INFORMATION

The U.S. Geological Survey publishes an annual series of reports, "Water Resources Data for Michigan," in which hydrologic data collected for each water year (October 1 to September 30) are included. The Survey publishes another annual series of reports "Ground-Water Data for Michigan", in which ground-water data collected for each calender year are included. These reports are available upon request to the District Chief. Topographic maps showing areas inundated by 100-year floods are available from the District Office. Additional information on surface- and ground-water conditions in Michigan is given in reports shown in the following published reports listing (table 3). Inquiries concerning the availability of these reports should be addressed to:

District Chief
Water Resources Division
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910
Telephone: (517) 377-1608
(FTS) 374-1608

or

Director
Michigan Department of Natural Resources
Stevens T. Mason Bldg.
Box 30028
Lansing, Michigan 48909
Telephone: (517) 373-2329

or

Chief Hydrologist
U.S. Geological Survey
420 National Center
Reston, Virginia 22092

Table 3.--Published reports

Allen, W. B., 1977, Flowing wells in Michigan, 1974: Michigan Geological Survey Information Series Report 2, 27 p., 5 figs, 2 pls., 16 refs.

Allen, W. B., Miller, J. B., and Wood, W. W., 1972, Availability of water in Kalamazoo County, Michigan: U.S. Geological Survey Water-Supply Paper 1973, 129 p., 36 figs., 9 pls., 34 refs.

Ash, A. D., and others, 1958, Sloan-Deer Creek Basins--Report 1, Hydrologic studies of small watersheds in agricultural areas of southern Michigan: Michigan Water Resources Commission, 77 p., 17 maps, 13 figs., 9 tables.

Bedell, D. J., and Van Til, R. L., 1979, Irrigation in Michigan, 1977: Michigan Department of Natural Resources, Water Management Division, 44 p., 10 figs., 5 tables, 13 refs.

Bedell, D. J., 1982, Municipal water withdrawals in Michigan: Michigan Department of Natural Resources, Water Management Division, 43 p., 14 figs., 2 tables, no refs.

Bent, P. C., 1970, A proposed streamflow data program for Michigan: U.S. Geological Survey Open-File Report, unnumbered, 44 p., 5 figs., 8 tables, 1 pl.

Bent, P. C., 1971, Influence of surface glacial deposits on streamflow characteristics: U.S. Geological Survey Open-File Report, unnumbered, 37 p., 5 tables, 11 refs.

Brown, E. A., and Stuart, W. T., 1951, Ground-water resources of the glacial deposits in the Bessemer Area, Michigan, 1950: Michigan Geological Survey Progress Report 14, 68 p., 8 figs., 8 tables, 8 refs.

Croskey, H. M., and Holtschlag, D. J., 1983, Estimating generalized flood skew coefficients for Michigan: U.S. Geological Survey Water-Resources Investigation Report 83-4194, 27 p., 4 figs., 4 tables, 6 refs.

Cummings, T. R., 1973, Relation of channel slope to reaeration of Michigan Streams: U.S. Geological Survey Open-File Report, unnumbered, 19 p., 5 figs., 1 table, 4 refs.

Cummings, T. R., 1978, Agricultural land use and water quality in the upper St. Joseph River Basin, Michigan: U.S. Geological Survey Open-File Report 78-950. 106 p., 25 figs., 4 plates, 24 tables, 41 refs.

Cummings, T. R., 1980, Chemical and physical characteristics of natural ground waters in Michigan: A Preliminary report: U.S. Geological Survey Open-File Report 80-953, 34 p., 12 figs., 5 tables, 13 refs.

Cummings, T. R., and Miller, J. B., 1982, Time of travel of the Flint River, Utah Dam to Highway M-13, Michigan: U.S. Geological Survey Open-File Report 82-853, 21 p., 1 pl., 11 figs., 4 tables.

Cummings, T. R., 1984, Estimates of dissolved and suspended substance yield of stream basins in Michigan: U.S. Geological Survey Water-Resources Investigations Report 83-4288, 57 p., 4 figs., 14 tables, 2 refs.

Cummings, T. R., Twenter, F. R., and Holtschlag, D. J., 1984, Hydrology and land use in Van Buren County, Michigan: U.S. Geological Survey Water Resources Investigations Report 84-4112, 124 p., 31 figs., 2 pls., 4 tables, 25 refs.

Deutsch, Morris, 1956, Effects of dissemination of radioactive materials on water resources conservation--with special references to Michigan: Michigan State University Agricultural Experiment Station Water Bulletin 2, 62 refs.

Deutsch, Morris, 1961a, Hydrogeologic aspects of ground-water pollution: Water Well Journal, V. 15, No. 9.

Deutsch, Morris, 1961b, Incidents of chromium contamination of ground water in Michigan in ground water contsminstion: U.S. Public Health Service Technical Report W61-5, p. 98-104, 5 figs., 7 refs.

Deutsch, Morris, 1962a, Controlled induced-recharge tests at Kalamazoo, Michigan: Journal of American Water Works Association, v.54, no. 2, p. 181-196, 3 refs.

Deutsch, Morris, 1962b, Phenol contamination of an artesian aquifer at Alma, Michigan: Proceedings of the Society for Water Treatment and Examination, v. 11, p. 94-100, 2 figs., 5 refs.

Deutsch, Morris, 1963, Ground-water contamination and legal controls in Michigan: U.S. Geological Survey Water-Supply Paper 1691, 79 p., 23 figs., 68 refs.

Deutsch, Morris, 1967, Artifical recharge by induced inter-aquifer leakage: I.A.S.H., Symposium of Haifa, p. 159-172, 11 figs., 2 tables, 5 refs.

Deutsch, Morris, Burt, E. M., and VanLier, K. E., 1958, Summary of ground-water investigations in the Holland area, Michigan: Michigan Geological Survey Progress Report 20, 87 p., 16 figs., 17 refs.

Deutsch, Morris, VanLier, K. E., and Giroux, P. R., 1960, Ground-water hydrology and glacial geology of the Kalamazoo area, Michigan: Michigan Geological Survey Progress Report 23, 122 p., 21 figs., 25 refs.

Deutsch, Morris, and VanLier, K. E., 1961, Ground water for Michigan's future: U.S. Geological Survey Open-File Report, unnumbered, 42 p., 10 figs., 30 refs.

Doonan, C. J., and Hendrickson, G. E., 1967, Ground water in Iron County, Michigan: Michigan Geological Survey Water Investigation 7, 61 p., 3 figs., 2 pls., 7 refs.

Doonan, C. J., and Hendrickson, G. E., 1968, Ground water in Gogebic County, Michigan: Michigan Geological Survey Water Investigation 8, 22 p., 5 figs., 2 pls., 5 refs.

Doonan, C. J., and Hendrickson, G. E., 1969, Ground water in Ontonagon County, Michigan: Michigan Geological Survey Water Investigation 9, 29 p., 5 figs., 1 pl., 4 refs.

Table 3.--Published reports--Continued

Doonan, C. J., Hendrickson, G. E., and Byerlay, J. R., 1970, Ground water and geology of Keweenaw Peninsula, Michigan: Michigan Geological Survey Water Investigation 10, 41 p., 1 fig., 2 pls., 10 refs.

Doonan, C. J., and VanAlstine, J. L., 1982, Ground water and geology of Marquette County, Michigan: U.S. Geological Survey Open-File Report 82-501, 46 p., 1 pl., 6 figs., 7 tables, 20 refs.

Doonan, C. J., and Byerlay, J. R., 1973, Ground water and geology of Baraga County, Michigan: Michigan Geological Survey Water Investigation 11, 26 p., 2 figs., 2 pls., 12 refs.

Ferris, J. G., 1948, Ground-water hydraulics as a geophysical aid: Michigan Geological Survey Technical Report 1, 12 p., 11 figs., 7 refs.

Ferris, J. G., and others, 1954, Ground-water resources of southeastern Oakland County, Michigan: Michigan Geological Survey Progress Report 16, 158 p., 44 figs., 6 pls., 9 tables, 57 refs.

Fleck, W. B., 1980, Geology and hydrology for environmental planning in Washtenaw County, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 23 p., 21 figs., 1 table, 14 refs.

Fleck, W. B., and McDonald, M. G., 1978, Three-dimensional finite-difference model of ground-water system underlying the Muskegon County wastewater disposal system, Michigan: U.S. Geological Survey Journal of Research, V. 6, No. 3, p. 307-318, 16 figs., 14 refs.

Giroux, P. R., Hendrickson, G. E., Stoimenoff, L. E., and Whetstone, G. W., 1964, Water resources of Van Buren County, Michigan: Michigan Geological Survey Water Investigation 3, 144 p., 45 figs., 13 refs.

Giroux, P. R., and Huffman, G. C., 1967-69, Summary of ground-water conditions in Michigan: U.S. Geological Survey Open-File Report (one volume for each year)

Giroux, P. R., Stoimenoff, L. E., Nowlin, J. O., and Skinner, E. L., 1966, Water Resources of Branch County, Michigan: Michigan Geological Survey Water Investigation 6, 158 p., 34 figs., 2 pls., 8 refs.

Grannemann, N. G., 1978, Water supply potential of the Lake Sally System, Marquette County, Michigan: U.S. Geological Survey Open-File Report 78-1046, 14 p., 6 figs., 1 table, 12 refs.

Grannemann, N. G., 1979, Water resources of the Marquette Iron Range area, Marquette County, Michigan: U.S. Geological Survey Open-File Report 79-1339, 77 p., 34 figs., 20 tables, 23 refs.

Grannemann, N. G., and Twenter, F. R., 1982, Ground water for public supply at Windigo, Isle Royle National Park, Michigan: U.S. Geological Survey Open-File Report 82-567, 16 p., 4 figs., 3 tables, 5 refs.

Grannemann, N. G., and Twenter, F. R., 1985, Geohydrology and ground-water flow at Verona Well Field, Battle Creek, Michigan: U.S. Geological Survey Water Resources Investigations Reort 85-4056, 54 p., 31 figs., 7 tables.

Handy, A. H., 1982, Water quality of coal deposits and abandoned mines, Saginaw County, Michigan: U.S. Geological Survey Open-File Report 82-511, 35 p., 7 figs., 5 tables, 13 refs.

Handy, A. H., and Stark, J. R., 1984, Water resources of Sleeping Bear Dunes National Lakeshore, Michigan: U.S. Geological Survey Water Resources Investigations Report 83-4253, 38 p., 16 figs., 7 tables, 13 refs.

Handy, A. H., and Twenter, F. R., Water Resources of Pictured Rocks National Lakeshore, Michigan, 1985, U.S. Geological Survey Water Resources Investigations Report 85-4103 (in press).

Hendrickson, G. E., 1966, Michigan's Au Sable River--Today and tomorrow: Michigan Geological Survey Bulletin 3, 80 p., 29 figs., 11 photos, 27 refs.

Hendrickson, G. E., and Doonan, C. J., 1966, Ground-water resources of Dickinson County, Michigan: Michigan Geological Survey Water Investigation 5, 49 p., 5 figs., 3 pls., 5 refs.

Hendrickson, G. E., and Doonan, C. J., 1970, Reconnaissance of the Pigeon River, A cold-water river in the north-central part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 333, 2 sheets.

Hendrickson, G. E., and Doonan, C. J., 1971, Reconnaissance of the Sturgeon River, a cold-water river in the north-central part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 353, 2 sheets.

Hendrickson, G. E., and Doonan, C. J., 1971, Reconnaissance of the Black River of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 354, 2 sheets.

Hendrickson, G. E., and Doonan, C. J., 1971, Reconnaissance of the Pere Marquette River, a cold-water river in the central part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 384, 2 sheets.

Hendrickson, G. E., and Doonan, C. J., 1971, Reconnaissance of the Rifle River, a cold-water river in the northeastern part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 426.

Hendrickson, G. E., and Doonan, C. J., 1972, Hydrology and recreation on the cold-water rivers of Michigan's southern peninsula: U.S. Geological Survey Water Information Series Report 3, 83 p., 76 figs., 5 tables, 62 refs.

Hendrickson, G. E., and Doonan, C. J., 1972, Reconnaissance of the Manistee River, a cold-water river in the northwestern part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Investigations Atlas 436, 2 sheets.

Table 3.--Published reports--Continued

Hendrickson, G. E., and Doonan, C. J., 1974, Reconnaissance of the Upper Au Sable River, A cold-water river in the north-central part of Michigan's southern peninsula: U.S. Geological Survey Hydrologic Inveatigations Atlas 527, 1 sheet.

Hendrickson, G. E., Knutilla, R. L., and Doonan, C. J., 1973, Hydrology and recreation of selected cold-water rivers of the St. Lawrence River Basin in Michigan, New York, and Wisconsin: U.S. Geological Survey Water-Resources Investigations 8-73, 73 p., 12 figs., 13 tables, 36 refs.

Hendrickson, G. F., Knutilla, R. L., and Doonan, C. J., 1973, Hydrology and recreation of the cold-water rivers of Michigan's upper peninsula: Michigan Department of Natural Resources Water Information Series Report 4.

Hendrickson, G. E., and Knutilla, R. L., 1974, Hydrology and trout populations of cold-water rivers of Michigan and Wisconsin: Wisconsin Academy of Sciences, Arts, and Letters, v. LXII, p. 181-193.

Holtschlag, D. J., 1981, Flow model of Saginaw River near Saginaw, Michigan: U.S. Geological Survey Open-File Report 81-1061, 20 p., 14 figs., 3 refs.

Holtschlag, D. J., and Croskey, Hope M., 1984, Statistical models for estimating streamflow characteristics of Michigan streams, U.S. Geological Survey, Water-Resources Inveatigations Report 84-4207, 80 p., 8 figs., 15 tables, 15 refs.

Holtschlag, D. J., and Eagle, D. V., 1985, Streamflow in Michigan--miscellaneous measurements, U.S. Geological Survey, Open-File Report (in press).

Huffman, G. C., 1982, Ground-water Data for Michigan, 1982, U.S. Geological Survey Open-File Report 83-753 54 p., 5 figs., 3 tables, 98 refs., similar reports for years 1972-81.

Hulbert, G. C., 1972, A study of the Flint River, Michigan, as it relates to low-flow augmentation: U.S. Geological Survey Open-File Report, unnumbered.

Kelly, R. W., and Farrand, W. R., 1967, The glacial lake around Michigan: Michigan Geological Survey Bull. 4, 23 p., 17 figs., 10 refs.

Knutilla, R. L., 1966, Surface-water characteristics of the North Branch Clinton River Sasin, Michigan: U.S. Geological Survey Open-File Report, unnumbered.

Knutilla, R. L., 1967, Flow characteristics of Michigan streams: U.S. Geological Survey Open-File Report, unnumbered.

Knutilla, R. L., 1968, Regional draft storage relationships for the Grand River Basin, Michigan: U.S. Geological Survey Open-File Report, unnumbered.

Knutilla, R. L., 1969, Water resources of the Belle River Basin, Southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-317, 1 map.

Knutilla, R. L., 1969, Water resources of the Pine River Basin, Southeastern Michigan: U.S. Geological Survey Hydrologic Inveatigations Atlas HA-327, 1 map.

Knutilla, R. L., 1969, Gazetteer of hydrologic data for the Belle River Basin, Southeastern Michigan water resources study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 2, 24 p., 2 figs., 5 tables.

Knutilla, R. L., 1969, Gazetteer of hydrologic data for the Black River Basin, southeastern Michigan water resources study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 3, 54 p., 2 figs., 7 tables.

Knutilla, R. L., 1969, Gazetteer of hydrologic data for the Pine River Basin, southeastern Michigan water resources study: U.S. Army Corps of Engineers, Detroit Distict, Technical Paper 4, 20 p., 2 figs., 3 tables.

Knutilla, R. L., 1970, Statistical summaries of Michigan streamflow data: U.S. Geological Survey Open-File Report, unnumbered, 283 p., 5 figs.

Knutilla, R. L., 1970, Water resources of the Black River Basin, southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-338, 3 maps and booklet.

Knutilla, R. L., 1971, Water resources of the River Rouge Basin, southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-356, 2 maps and booklet.

Knutilla, R. L., 1971, Gazetteer of Hydrologic Data for the River Raisin Basin, southeastern Michigan Water Resources Study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 6, 100 p., 4 figs., 7 tables.

Knutilla, R. L., 1972, Gazetter of Hydrologic Data for the Huron River Basin, southeastern Michigan Water Resources Study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 7, 115 p., 6 figs., 15 tables.

Knutilla, R. L., 1974, Compilation of miscellaneous streamflow measurements in Michigan through September 1970: U.S. Geological Survey Water Information Series Report 5, 185 p.

Knutilla, R. L., and Allen, W. B., 1975, Water resources of the River Raisin Basin, southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-520, 2 maps and booklet.

Knutilla, R. L., and Swallow, L. A., 1975, Flood of April 1975 at Williamston, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 1 sheet.

Knutilla, R. L., and Swallow, L. A., 1975, Flood of April 1975 at East Lansing, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 1 sheet.

Knutilla, R. L., and Swallow, L. A., 1975, Flood of April 1975 at Meridian Township, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 2 sheets.

Table 3.--Published reports--Continued

Knutilla, R. L., Twenter, F. R., and Larson, R. W., 1971, Upper Rifle River Basin, Northeastern lower peninsula--an evaluation of its water resources and hydrologic environment: Michigan Geological Survey Water Information Series Report 1, 66 p., 64 figs., 20 refs.

Knutilla, R. L., and Twenter, F. R., 1973, Gazetteer of hydrologic data for incidental streams draining into St. Clair River, Lake St. Clair, Detroit River, and Lake Erie, southeastern Michigan water resources study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 8, 75 p., 6 figs., 7 tables.

Larson, R. W., Allen, W. B., and Hanson, S. D., 1975, Water resources of the Huron River Basin, southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-514, 2 maps and booklets.

McDonald, M. G., and Fleck, W. B., 1978, Model analysis of the impact on groundwater conditions of the Muskegon County wastewater disposal system, Michigan: U.S. Geological Survey Open-File Report 78-99, 63 p., 17 figs., 14 refs.

McDonald, M. G., 1981, Hydraulic characteristics of an under-drained irrigation circle, Muskegon County wastewater disposal system, Michigan: U.S. Geological Survey Water Supply Paper 2081, 14 p., 9 figs., 9 refs.

McGuinness, C. L., Poindexter, O. F., and Otton, E. G., 1949, Ground-water supplies of the Ypsilanti Area, Michigan: U.S. Geological Survey Water-Supply Paper 1078, 105 p., 7 figs., 5 pls., 14 refs.

Miller, J. B., and Thompson, T., 1970, Compilation of data for Michigan Lakes: U.S. Geological Survey Open-File Report, unnumbered, 368 p., 1 fig.

Miller, J. B., and Swallow, L. A., 1975, Flood of April 1975 at Lansing, Michigan: U. S. Geological Survey Open-File Report, 2 sheets.

Miller, J. B., Oberg, J. L., and Sieger, T. Jr., 1983, Water Resources Data - Michigan, Water Year 1983: U.S. Geological Survey Water-Data Report MI-83-1, 289 p., 9 figs., tables.

Noecker, M., and Wittala, S. W., 1948, Revised by Knutilla, R. L., 1969, Flood of August 1942 in the Ontonagon River Basin, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 29 p., 8 figs., 9 photos, 3 tables, no refs.

Nowlin, J. O., 1971, Gazetteer of hydrologic data for the Clinton River Basin, southeastern Michigan Water Resources Study: U.S. Army Corps of Engineers, Detroit District, Technical Paper No. 5, 157 p., 2 figs., 36 tables.

Nowlin, J. O., 1973, Water Resources of the Clinton River Basin, southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas HA-469, 2 maps and booklet.

Pettijohn, F. J., 1952, Geology of the northern Crystal Falls Area, Iron County, Michigan: U.S. Geological Survey Circular 153, 17 p., 8 plates, 1 fig., 3 tables, 14 refs.

Reed, J. E., Deutsch, Morris, and Wiitala, S. W., 1966, Induced recharge of an artesian glacial-drift aquifer at Kalamazoo, Michigan: U.S. Geological Survey Water-Supply Paper 1594-D, 62 p., 36 figs., 2 pls., 12 refs.

Sinclair, W. C., 1959, Reconnaissance of the ground-water resources of Schoolcraft County, Michigan: Michigan Geological Survey Progress Report 22, 84 p., 14 figs., 14 refs.

Sinclair, W. C., 1960, Reconnaissance of the ground-water resources of Delta County, Michigan: Michigan Geological Survey Progress Report 24, 93 p., 13 figs., 22 refs.

Stark, J. R., and McDonald, M. G., 1980, Ground water of coal deposits, Bay County, Michigan: U.S. Geological Survey Open-File Report 80-591, 36 p., 22 figs., 1 table, 13 refs.

Stark, J. R., Cummings, T. R., and Twenter, F. R., 1983, Ground-water contamination at Wurtsmith Air Force Base, Michigan: U.S. Geological Survey Water Resources Investigations Report 83-4002, 93 p., 1 pl., 43 figs., 4 tables, 22 refs.

Stoimenoff, L. E., 1960, Floods of May 1959 in the Au Gres and Rifle River Basins, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 14 p.

Stoimenoff, L. E., 1963, Floods in southeastern Michigan, magnitude and frequency: U.S. Geological Survey Open-File Report, unnumbered, 9 p.

Stoimenoff, L. E., 1972, Regional draft-storage relationships for central and western upper peninsula of Michigan, U.S. Geological Survey Open-File Report, unnumbered, 13 p.

Stoimenoff, L. E., 1975, Flood plains of the South Branch Shiawassee River, Livingston County, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 7 p., 6 pls.

Stoimenoff, L. E., 1975, Flood plains of the Portage River, Livingston County, Michigan: U.S. Geological Survey Open-File Report, 9 p., unnumbered, 8 pls.

Stramel, G. J., Wisler, C. O., and Laird, L. B., 1954, Water resources of the Grand Rapids area, Michigan: U.S. Geological Survey Circular 323, 40 p., 29 figs., 3 pls., 21 refs.

Stromman, N. D., Knutilla, R. L., Mueller, C., and Kidder, E. H., 1968, Sloan-Deer Creek Basin, streamflow characteristics 1954-67, streamflow data 1954-67, and precipitation data 1956-67--Report 3, Hydrologic studies of small watersheds in agricultural areas of southern Michigan: Michigan Water Resources Commission, 191 p., 15 figs., 16 tables.

Stuart, W. T., 1945, Ground-water resources of the Lansing area, Michigan: Michigan Geological Survey Progress Report 13, 35 p., 11 figs., 8 refs.

Stuart, W. T., Brown, E. A., and Rhodehamel, E. C., 1954, Ground-water investigations of the Marquette iron-mining district, Michigan: Michigan Geological Survey Technical Report 3, 92 p., 8 figs., 20 tables, 19 refs.

Table 3.--Published reports--Continued

Stuart, W. T., and Stallman, R. W., 1945, Ground-water resources of the Benton Harbor area, Michigan: Michigan Geological Survey Progress Report 12, 15 p., 4 figs., no refs.

Stuart, W. T., Theis, C. V., and Stanley, G. M., 1948, Ground-water problems in the Iron River district, Michigan: Michigan Geological Survey Technical Report 2, 59 p., 16 figs., 16 refs.

Swanson, D. E., 1970, Ground water in Ionia County, Michigan: Michigan State University Master of Science Thesis, 75 p., 19 figs., 5 tables, 23 refs.

Twenter, F. R., 1966a, General availability and quality of ground water in the bedrock deposits in Michigan: State Resources Planning Division, Michigan Department of Commerce and Michigan Water Resources Commission, map (color).

Twenter, F. R., 1966b, General availability of ground water in the glacial deposits in Michigan: State Resources Planning Division, Michigan Department of Commerce and Michigan Water Resources Commission, map (color).

Twenter, F. R., 1975, Ground water and geology--southeastern Michigan: U.S. Army Corps of Engineers, Detroit, Michigan, 143 p., 31 figs., 36 tables, 46 refs.

Twenter, F. R., 1981, Geology and hydrology for environmental planning in Marquette County, Michigan: U.S. Geological Survey Water Resources Investigations 80-90, 44 p., 16 figs., 21 refs.

Twenter, F. R., and Knutilla, R. L., 1972, Water for a rapidly growing urban community--Oakland County, Michigan: U.S. Geological Survey Water-Supply Paper 2000, 150 p., 90 figs., 68 refs.

Twenter, F. R., Knutilla, R. L., and Cummings, T. R., 1975, Water resources of basins for minor streams draining into St. Clair River, Lake St. Clair, Detroit River, and Lake Erie, Southeastern Michigan: U.S. Geological Survey Hydrologic Investigations Atlas 546, 3 maps and booklet.

Twenter, F. R., Knutilla, R. L., and Nowlin, J. O., 1976, Water resources of Washtenaw County, Michigan: Washtenaw County Planning Commission, 143 p., 43 figs., 18 tables, 25 refs.

Twenter, F. R., Cummings, T. R., and Grannemann, N. G., 1983, Ground-water contamination in East Bay Township, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4064, 63 p., 25 figs., 5 pls., 20 refs.,

Twenter, F. R., and Cummings, T. R., 1985, Quality of ground water in Monitor and Williams Townships, Bay County, Michigan, U.S. Geological Survey Water Resources Investigations Report 85-4110, 39 p., 16 figs.

VanLier, K. E., 1959, Reconnaissance of the ground-water resources of Luce County, Michigan: Michigan Geological Survey progress Report 21, 76 p., 11 figs., 3 pls., 20 refs.

VanLier, K. E., 1962, Summary of ground-water investigations in the Elsie Area, Michigan: Michigan Geological Survey Progress Report 25, 35 p., 7 figs., 4 refs.

VanLier, K. E., 1963a, Reconnaissance of the ground-water resources in Alger County, Michigan: Michigan Geological Survey Water Investigation 1, 55 p., 13 figs., 14 refs.

VanLier, K. E., 1963b, Ground-water in Menominee County, Michigan: Michigan Geological Survey Water Investigation 2, 42 p., 11 figs., 4 refs.

VanLier, K. E., 1963c, Ground-water resources of the Alma area, Michigan: U.S. Geological Survey Water-Supply Paper 1619-E, 66 p., 20 figs., 2 pls., 14 refs.

VanLier, K. E., 1966, Ground-water resources of the Battle Creek area, Michigan: Michigan Geological Survey Water Investigation 4, 52 p., 19 figs., 2 refs.

VanLier, K. E., 1968, Comprehensive planning study of the Grand River Basin, Michigan, Appendix E, Ground-water resources and geology of the Grand River Basin, Michigan: U.S. Army Engineers District, Detroit, Michigan, 82 p., 6 tables, 22 figs., 37 refs.

VanLier, K. E., and Deutsch, Morris, 1958a, Reconnaissance of the ground-water resources of Chippews County, Michigan: Michigan Geological Survey Progress Report 17, 56 p., 7 figs., 7 pls., 7 tables, 49 refs.

VanLier, K. E., and Deutsch, Morris, 1958b, Reconnaissance of the ground-water resources of Mackinac County, Michigan: Michigan Geological Survey Progress Report 19, 82 p., 8 figs., 8 pls., 7 tables, 46 refs.

VanLier, K. E., and Wheeler, M. L., 1968, Analog simulation of ground-water development of the Saginaw Formation, Lansing Metropolitan area, Michigan (also called "Lansing ground water"): Tri-County Planning Commission, Lansing Ground-Water Report, 40 p., 23 figs., 3 tables, 3 refs.

VanLier, K. E., and Wheeler, M. L., 1968, Ground-water potential of the Saginaw Formation in the Lansing Metropolitan Area, Michigan: U.S. Geological Survey Open-File Report, unnumbered, 40 p., 23 figs., 3 tables, 3 refs.

VanLier, K. E., Wood, W. W., and Brunett, J. O., 1973, Water-Supply development and management alternatives for Clinton, Eaton, and Ingham Counties, Michigan: U.S. Geological Survey Water-Supply Paper 1969, 111 p., 3 plates, 35 figs., 6 tables, 34 refs.

Wiitala, S. W., 1961, Some aspects of effect of urban and suburban development upon runoff: U.S. Geological Survey Open-File Report, unnumbered, 28 p., 9 figs., 2 tables.

Wiitala, S. W., 1962, Floods in Mount Clemens, Michigan: U.S. Geological Survey Hydrologic Investigations Atlas 59.

Wiitala, S. W., Newport, T. G., and Skinner, E. L., 1967, Water resources of the Marquette iron range area, Michigan: Water-Supply Paper 1842, 142 p., 40 figs., 4 pls., 24 tables, 27 refs.

Table 3.--Published reports--Continued

Wiitala, S. W., VanLier, K. E., and Krieger, R. A., 1963, Water Resources of the Flint area, Michigan: U.S. Geological Survey Water-Supply Paper 1499-E, 86 p., 32 figs., 6 pls., 25 refs.

Wisler, C. O., Stramel, G. J., and Laird, L. B., 1952, Water Resources of the Detroit Area, Michigan: U.S. Geological Survey Circular 183, 36 p., 30 figs., 4 pls., 25 refs.

Wood, W. W., 1970, Chemical quality of Michigan streams: U.S. Geological Survey Circular 634, 21 p., 12 figs., 1 table, 20 refs.