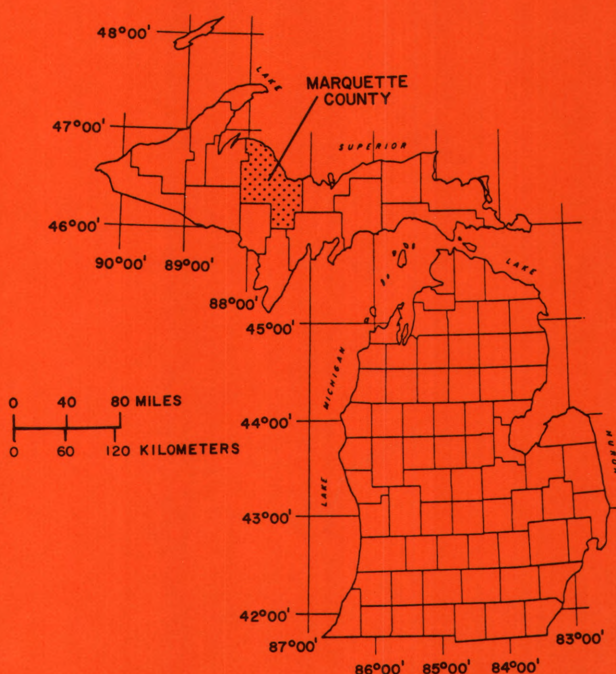
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY AND HYDROLOGY FOR ENVIRONMENTAL PLANNING IN MARQUETTE COUNTY, MICHIGAN

U.S. GEOLOGICAL SURVEY

Water Resources Investigations 80-90



Prepared in cooperation with the Michigan Department of Natural Resources

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.

4. Title and Subtitle
Geology and Hydrology for Environmental Planning in Marquette County, Michigan

5. Report Date
February 1981

6.

7. Author(s)
F. R. Twenter

8. Performing Organization Rept. No.
USGS/WRI 80-90

9. Performing Organization Name and Address
U.S. Geological Survey
Water Resources Division
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
U.S. Geological Survey
Water Resources Division
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes
Prepared in cooperation with the Michigan Department of Natural Resources

16. Abstract (Limit: 200 words)

Marquette County, in the glaciated area of the Upper Peninsula of Michigan, includes 1,878 square miles. Precipitation averages 32 inches per year.

Bedrock and glacial deposits contain materials that are good aquifers. Sedimentary bedrock units generally yield sufficient water for domestic supply and, in places, may yield more than 100 gallons per minute to large-diameter wells. In the glacial deposits, sand and gravel beds are the principal aquifers; yields to wells range from less than 10 to 200 gallons per minute. Igneous and metamorphic rocks yield little or no water to wells.

Suitable sewage and refuse disposal sites are not readily available because of the abundance of wetlands, streams, and lakes susceptible to infiltrating leachate.

17. Document Analysis a. Descriptors
Water resources*, Ground water, Surface water, Water quality, Waste disposal, Water supplies, Geology

b. Identifiers/Open-Ended Terms
Marquette County

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY AND HYDROLOGY FOR ENVIRONMENTAL PLANNING IN MARQUETTE COUNTY, MICHIGAN

By F. R. Twenter

U.S. GEOLOGICAL SURVEY

Water Resources Investigations 80-90

Prepared in cooperation with
the Michigan Department of
Natural Resources

Lansing, Michigan

1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

For additional information write to:

Office of the District Chief
Water Resources Division
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

CONTENTS

ILLUSTRATIONS

TABLES

DEFINITION OF TERMS

Altitude. The vertical distance of a point or line above or below the National Geodetic Vertical Datum of 1929. The National Geodetic Vertical Datum of 1929 (NGVD of 1929) is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." In this report, all altitudes are above NGVD of 1929.

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. Also called a ground-water reservoir.

Bedrock. Designates consolidated rocks.

Concentration. The weight of dissolved solids or sediment per unit volume of water; expressed in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Contour. An imaginary line connecting points of equal altitude, whether the points are on the land surface, on the clay surface, or on a potentiometric or water-table surface.

Ground water. Water in the ground that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Potentiometric surface. In aquifers, the levels to which water will rise in tightly cased wells. More than one potentiometric surface is required to describe the distribution of head. The water table is a particular potentiometric surface.

Recharge. The process by which water is infiltrated and is added to the zone of saturation. Also, the quantity of water added to the zone of saturation.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to which an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

Specific capacity. The rate of discharge of water from a well divided by the drawdown of water level within the well.

Specific conductance. A measure of the ability of water to conduct an electric current, expressed in micromhos (μmho) per centimeter at 25°C. Because the specific conductance is related to amount and type of dissolved material, it can be used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in milligrams per liter) to specific conductance (in micromhos) is in the range 0.5 to 0.8.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells.

CONVERSION FACTORS

The inch-pound units used in this report can be converted to the metric system of units as follows:

Multiply inch-pound unit	By	To obtain metric unit
inches	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
cubic feet per second per square mile ($ft^3/s/mi^2$)	0.0386	liters per second per square kilometer ($L/s/km^2$)
gallons per minute per foot (gpm/ft)	0.207	liters per second per meter (L/s/m)
degrees Fahrenheit (°F)	([1])	degrees Celsius (°C)

[1] Temperature °C = (temperature °F -32)/1.8.

GEOLOGY AND HYDROLOGY FOR ENVIRONMENTAL PLANNING IN MARQUETTE COUNTY, MICHIGAN

By

F. R. Twenter

ABSTRACT

Marquette County, in the glaciated area of the Upper Peninsula of Michigan, includes 1,878 square miles. Precipitation averages 32 inches per year.

Bedrock and glacial deposits contain materials that are good aquifers. Sedimentary bedrock units generally yield sufficient water for domestic supply and, in places, may yield more than 100 gallons per minute to large-diameter wells. In the glacial deposits, sand and gravel beds are the principal aquifers; yields to wells range from less than 10 to 200 gallons per minute. Igneous and metamorphic rocks yield little or no water to wells.

Suitable sewage and refuse disposal sites are not readily available because of the abundance of wetlands, streams, and lakes susceptible to infiltrating leachate.

INTRODUCTION

Purpose and Scope

The purpose of this report is to describe the geologic setting and hydrologic resources of Marquette County, Mich. Such information is essential to determine the most suitable use of the land and the probable long-term environmental effect of any proposed land use.

Published reports and driller's well records were the principal sources of data for the study; they were used to construct the maps and to prepare the text.

Location, General Features, and Economy

Marquette County is in the north-central part of Michigan's Northern Peninsula on the south shore of Lake Superior (fig. 1). It has a land area of 1,878 mi^2, making it the largest county in the State. In population, however, it ranks 21st. The occupation of many people is associated with mining. Recently, recreation has become important in the county's economy.

The chief industry is mining iron ore; 10 to 14 million tons is shipped annually from the Marquette Iron Range area (Peterson and Middlewood, 1978, and Michigan Geological Survey, oral comm.). Nearly 500 million tons of ore has been mined since iron was first discovered in 1844. In the past few years production has been from three mines--Empire, Republic, and Tilden (fig. 2)--the only active mines in the range. Because reserves are considerable, mining is expected to continue for many years.

Sand and gravel are abundant in the glacial deposits and, in places (fig. 2), are being mined for road and building construction. Crushed construction aggregate is mined at a site just southwest of the city of Marquette.

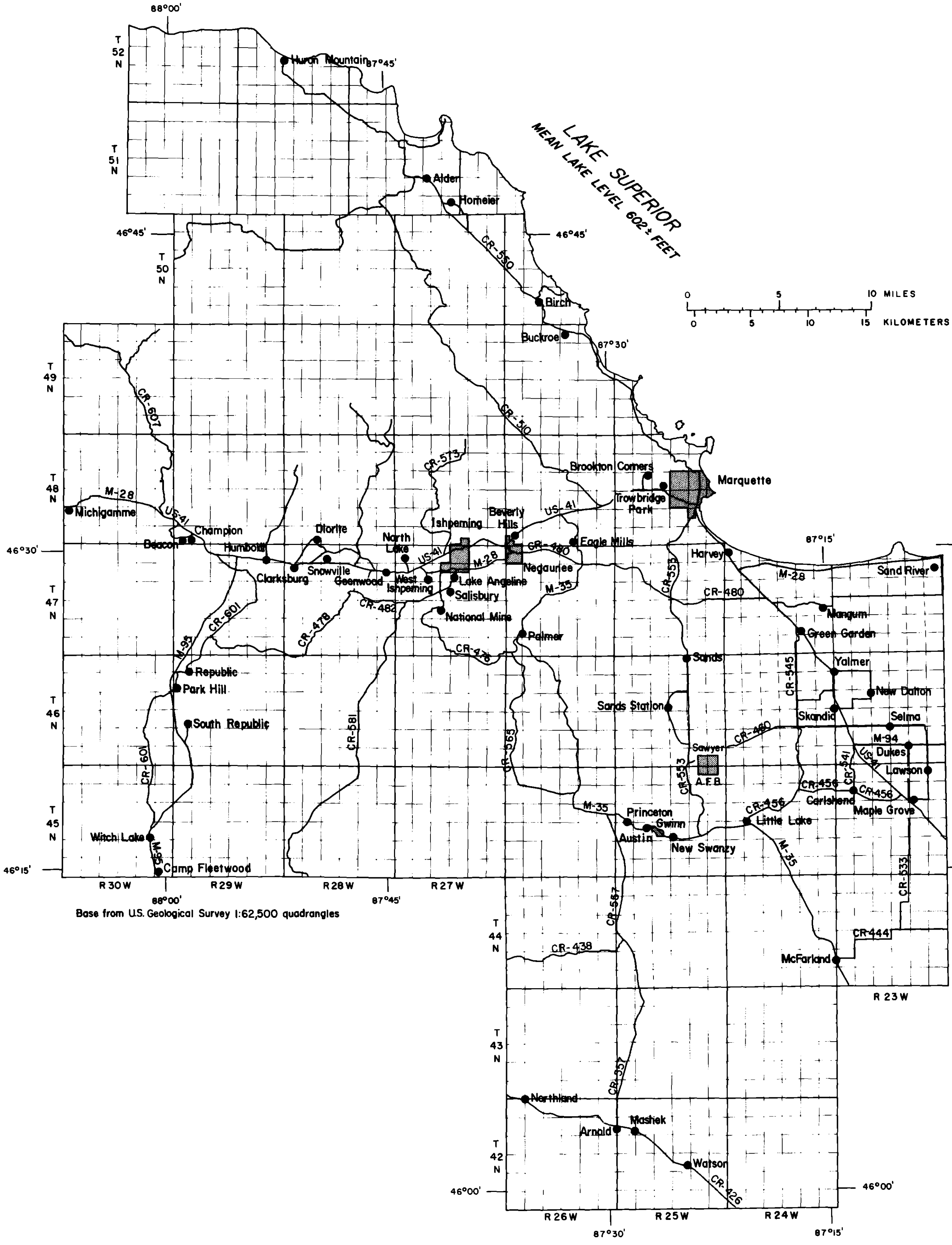


Figure 1.--Marquette County, Michigan.

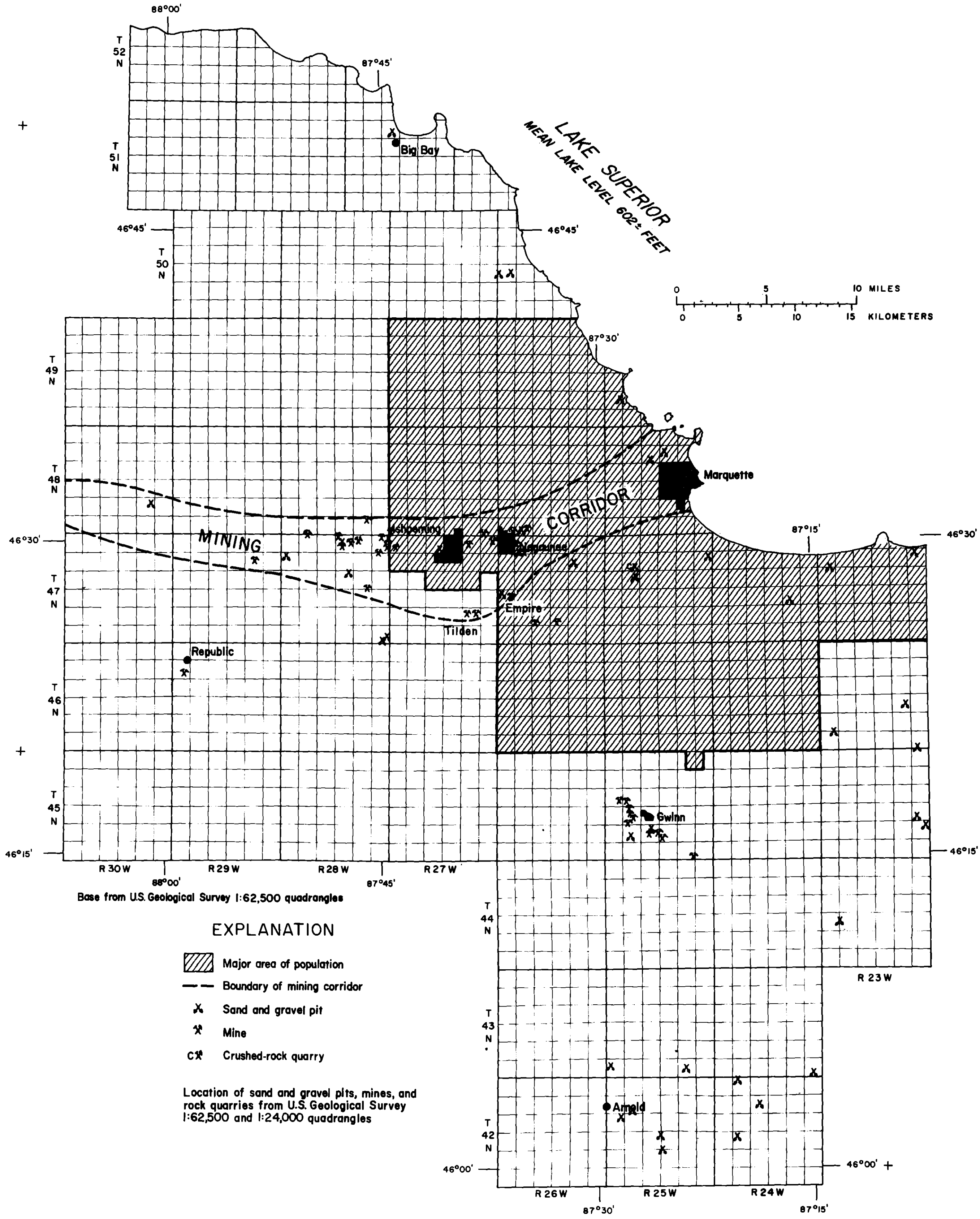


Figure 2.--Location of mines, pits, and quarries and population distribution.

Population

The population of Marquette County was 64,686 in 1970. Of this total, 54,967, or 85 percent, lived in a 430 square-mile area in and around Marquette (fig. 2). The other 15 percent lived in the remaining 1,448 square-mile, mostly rural, area.

The greatest concentration of people is at Sawyer Air Force Base and in the mining area, especially in the mining corridor, which lies in an east-west direction across the center of the county (fig. 2). About 22,000 people live in Marquette (table 1). The number of people living on farms is small--probably less than 600.

The estimated 1990 population of Marquette County is 90,000 (State of Michigan, Planning and Policy Analysis Division, 1974). Most growth will be in the mining corridor, especially in the vicinity of Marquette and in the area around Gwinn.

Table 1.--Population (for communities for which population is known or can be estimated)

Community	Population (1970)
Beacon	U[1/];270
Big Bay	U;185
Champion	U;500
Diorite	U;190
Greenwood	U;355
Gwinn	1,054
Ishpeming	8,245
Little Lake	U;135
Marquette	21,967
Michigamme	U;180
National Mine	U;370
Negaunee	5,248
Palmer	U;765
Park Hill	U;270
Republic	U;510
Sawyer AFB	6,679
Trowbridge Park	U;1,100
West Ishpeming	U;1,700

1/ U = Unincorporated, approximate population given.

Physical Setting

The general physiographic features of Marquette County formed during the retreat of continental glaciers. Many lakes, including Lake Superior, are a result of glacial scour. The location of streams and the direction of their flow was also determined by glaciation.

Topography is related both to scouring and depositional action of glaciation. In much of the northern part of the county, the glaciers carved rocks of Precambrian age into mountainous and rugged terrain having relief that, in places, is as much as 400 ft (fig. 3). To the south, however, scouring is not evident because the land is composed of unconsolidated materials deposited by glaciers. Relief in most places in the southern part of the county is less than 100 ft.

Altitudes range from about 600 ft along Lake Superior to 1,900 ft in sec. 31, T. 50 N., R. 29 W., in the northwestern part of the county.

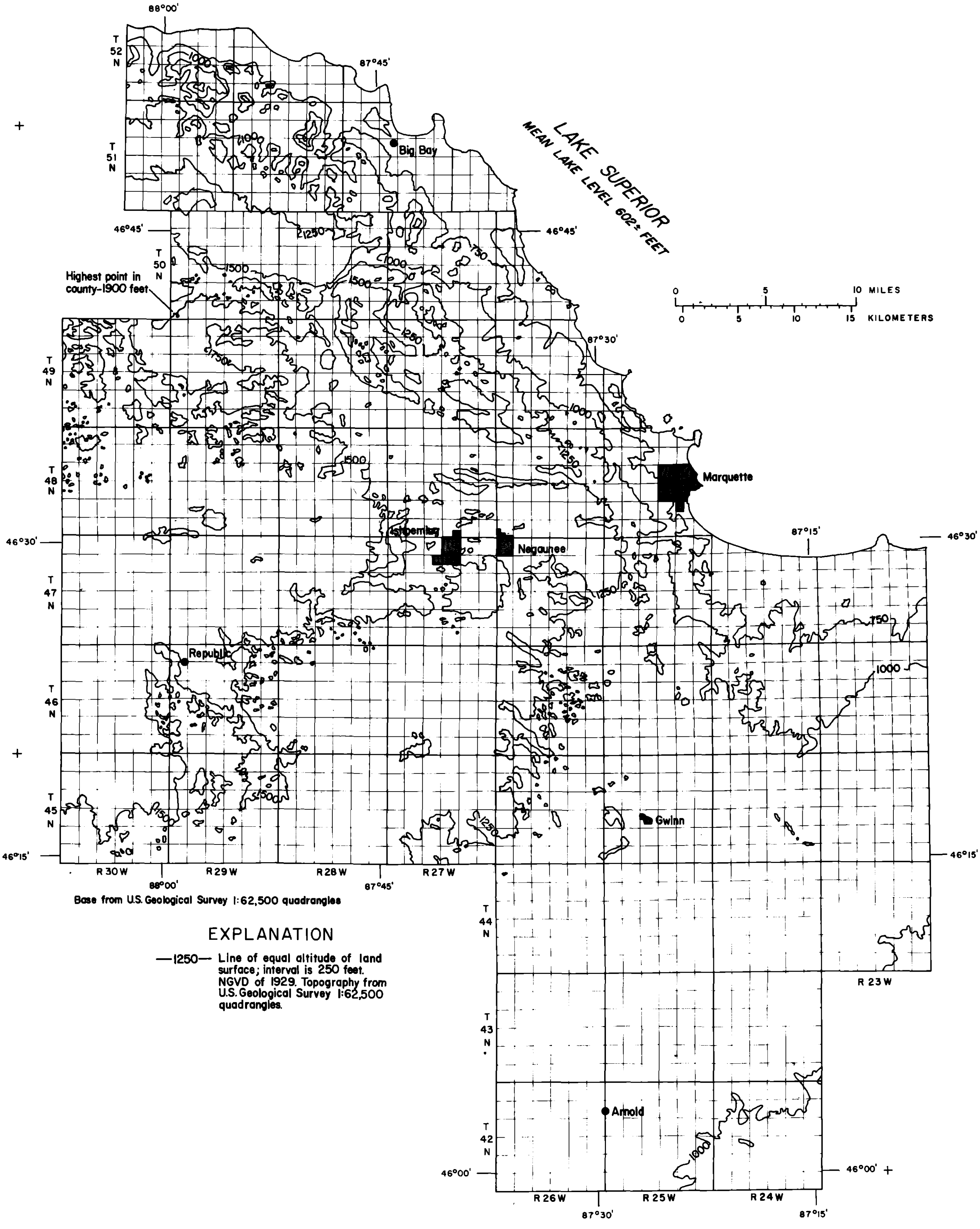


Figure 3.--Configuration of the land surface.

Climate

Variations in climate are monitored by National Weather Service stations at Champion and Marquette (U.S. Department of Commerce, 1971). The Champion station, operated since 1952, is in the west-central part of the county; whereas, the Marquette station, operated since 1880, is near Lake Superior. A general description of climatic conditions follows.

At Champion, day-to-day weather is influenced by large atmospheric pressure systems. Monthly average temperatures range between 10° and 65°F (fig. 4). The record high temperature, in June 1963, is 97°F; the record low, in February 1967, is -40°F. The average dates of first and last frost are August 31 and June 14, respectively. Normal precipitation is 33 inches annually and 1.5 to 4 inches monthly (fig. 4). Average annual snowfall is 139 inches. Estimated yearly evaporation in the Champion area is 25 inches. Evaporation during the summer exceeds precipitation by about 17 percent.

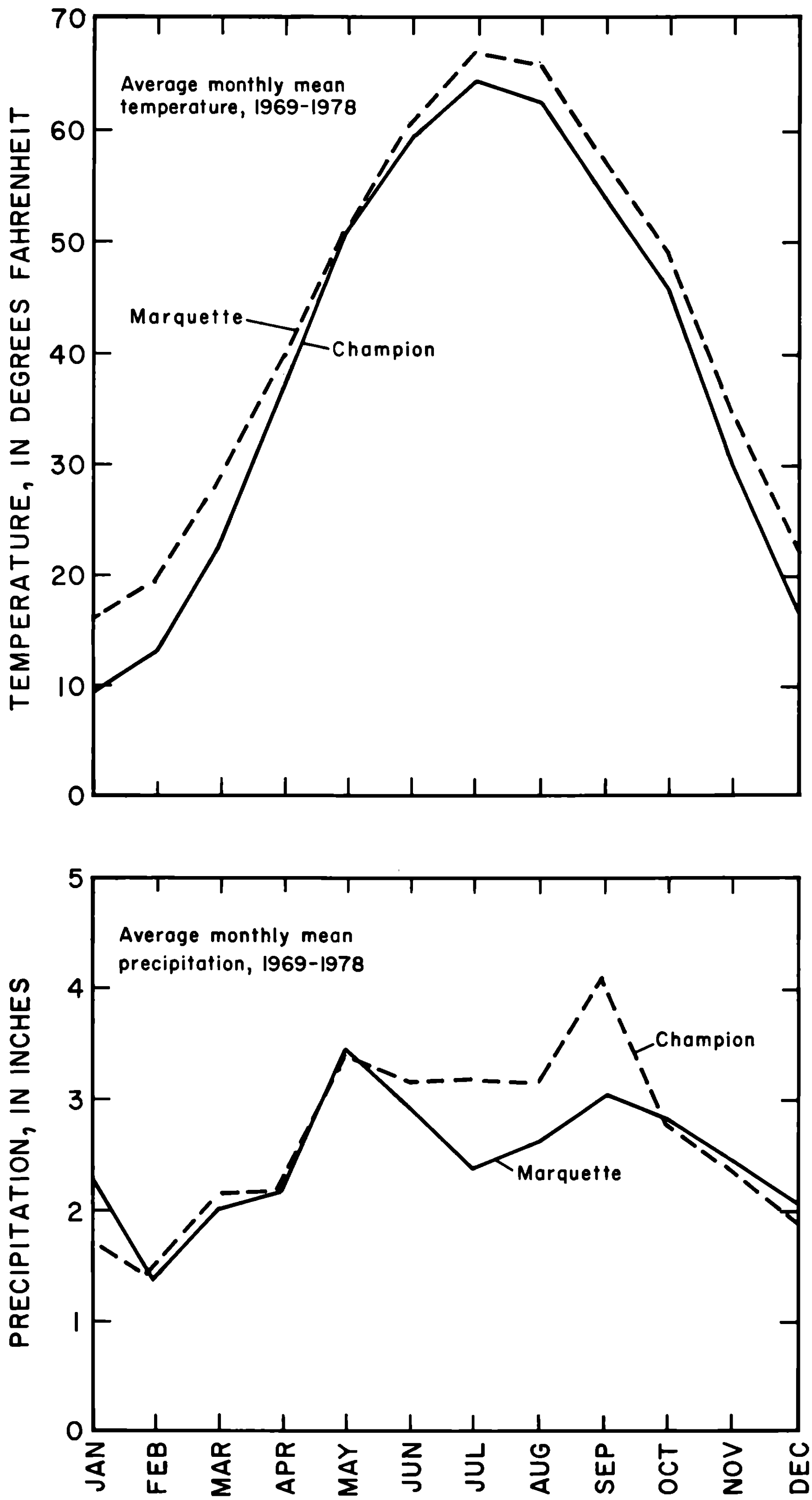


Figure 4.--Monthly temperature and precipitation at Marquette and Champion.

At Marquette, climate is influenced by the proximity of Lake Superior. Monthly average temperatures range between 15° and 70°F (fig. 4). The record high temperature, in August 1947, is 102°F; the record low, in January 1963, is -21°F. The average date for freezing temperatures is May 14 for the last and October 20 for the first. Normal precipitation is 32 inches annually and 1.3 to 3.4 inches monthly (fig. 4). Precipitation during the driest year on record, 1925, was 19.68 inches; that during the wettest year, 1881, was 42.70 inches. Snowfall is heavy, exceeding 100 inches in 7 out of every 10 years. The greatest snowfalls were 189.1 inches in 1890-91 and 188.1 in 1959-60.

Water from precipitation is more than adequate for most needs. However, much water is lost by evaporation, transpiration, and surface runoff and is not available for man's use. Evaporation and transpiration returns 45 to 60 percent (14 to 19 inches) of the yearly average precipitation to the atmosphere (fig. 5). The remaining 40 to 55 percent (13 to 18 inches) goes to runoff. About 7 inches of precipitation percolates to ground-water reservoirs annually.

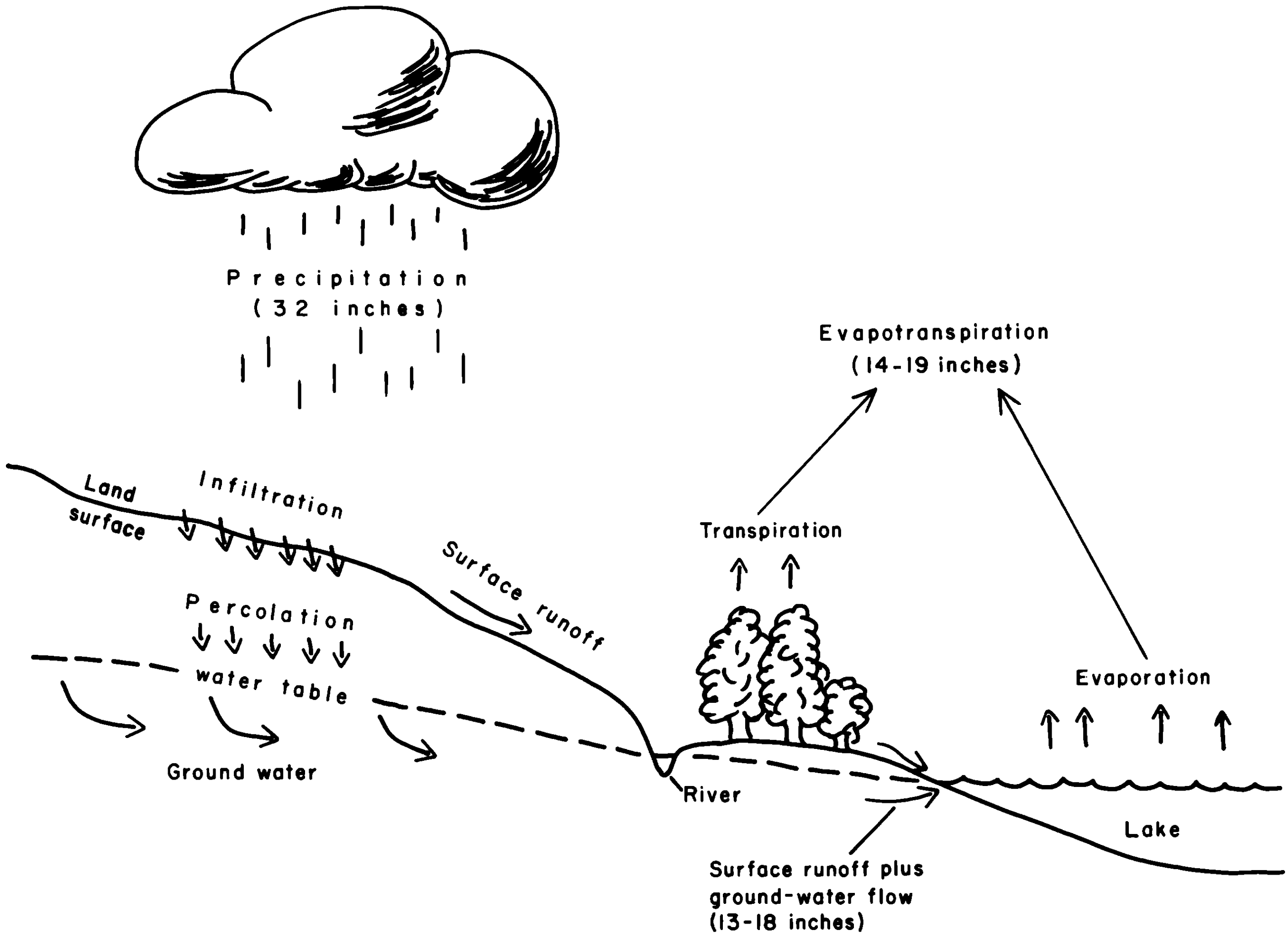


Figure 5.--Hydrologic cycle (values are annual mean).

Well-Numbering System

The well-numbering system for Michigan indicates the location of wells within a rectangular subdivision of land with reference to the Michigan base line and meridian. The first two segments of a well number designate township and range, the third segment designates the section and the fourth segment, a possible four-place alphabetic field A through D, designates successively smaller subdivisions of the section. Thus, a well designated as 48N 26E 16CCCB is located to the nearest 2.5 acres and within the shaded area in section 16 in figure 6.

For most wells, location is given only to the nearest 40-acre tract--for example, 16CC. If two or more wells are located in the same tract, a sequential number designation is added--for example, 26CC1, 26CC2, 26CC3, etc.

Township	Range	Section	Section ¼ ¼ ¼ ¼	Sequential number
48N	26E	16	C C C B	1

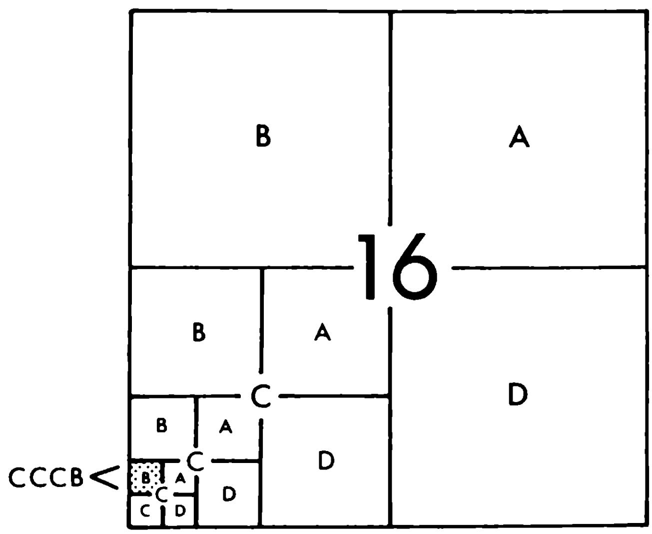


Figure 6.--Well-numbering system in Michigan.

INFILTRATION RATES

Infiltration rates range from very slow to very rapid (fig. 7). The rate at which water infiltrates depends on the composition of the surface materials. If materials are tight, infiltration is slow; if materials are open, infiltration is rapid. Where infiltration is very slow to slow, peak runoff is commonly high or, if the area is flat, wetlands are common.

Infiltration rates determine the quantity of ground-water recharge and are important in determining land use. Where rates are slow, recharge to the underlying ground-water reservoir is low and may not be sufficient to supply adequate water to wells. Areas of slow infiltration are, in many places, too waterlogged for farming unless drained. Furthermore, slow infiltration precludes use of septic tanks; thus, settlement of the area is not likely unless sanitary sewers and sewage treatment facilities are provided.

1/ Rates refer to inches per hour and generally can be correlated at:

Rate	Inches/hour
Very rapid	>10.0
Rapid	2.5 to 10.0
Moderate	0.8 to 2.5
Slow	0.2 to 0.8
Very slow	<0.2

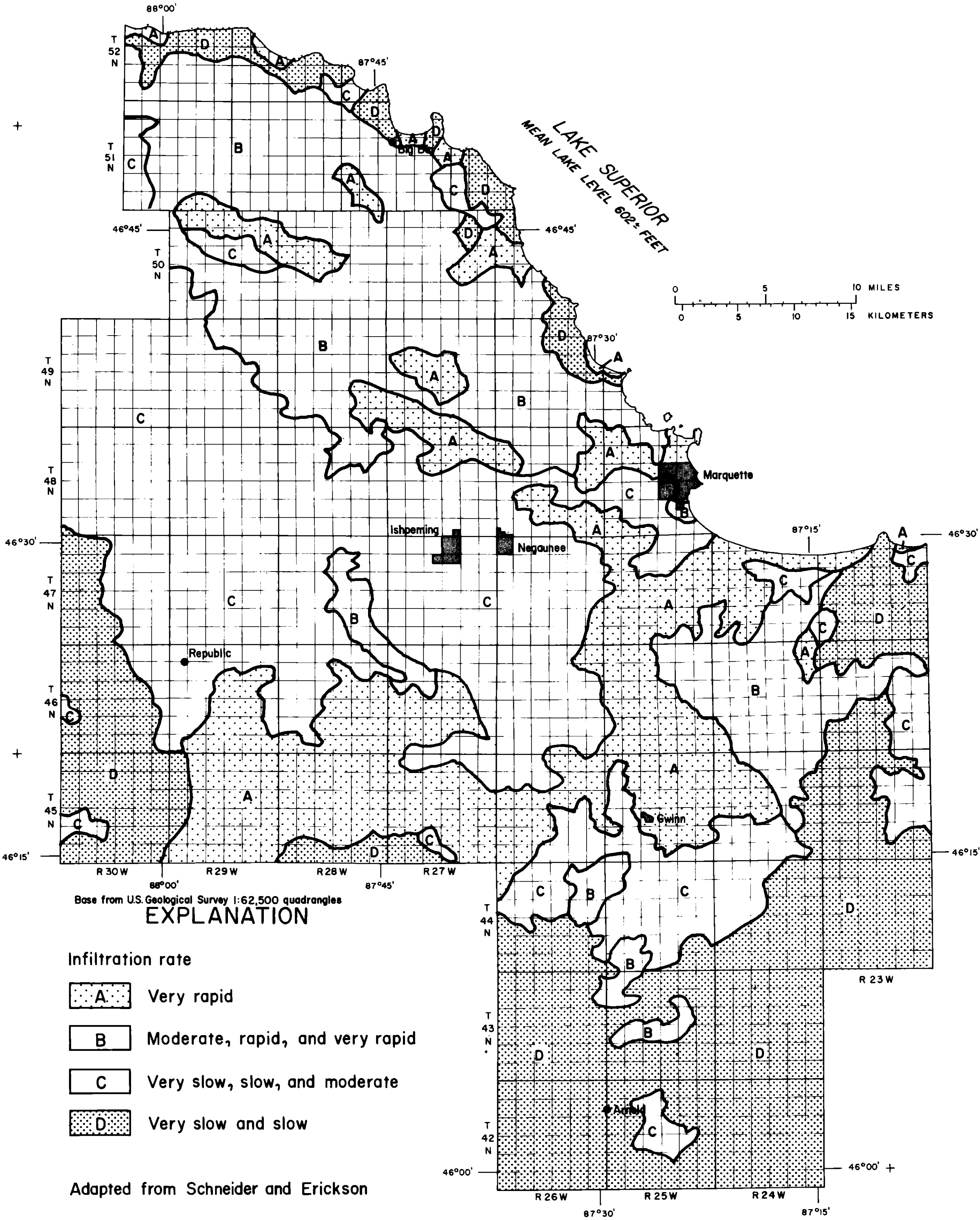


Figure 7.--Infiltration rates.

GEOLOGY

Bedrock and glacial deposits are the major rock types in Marquette County. Bedrock crops out in the central and northern part of the county and underlies glacial deposits elsewhere (fig. 8). Bedrock is composed of consolidated sedimentary, igneous, and metamorphic rocks. Glacial deposits are unconsolidated.

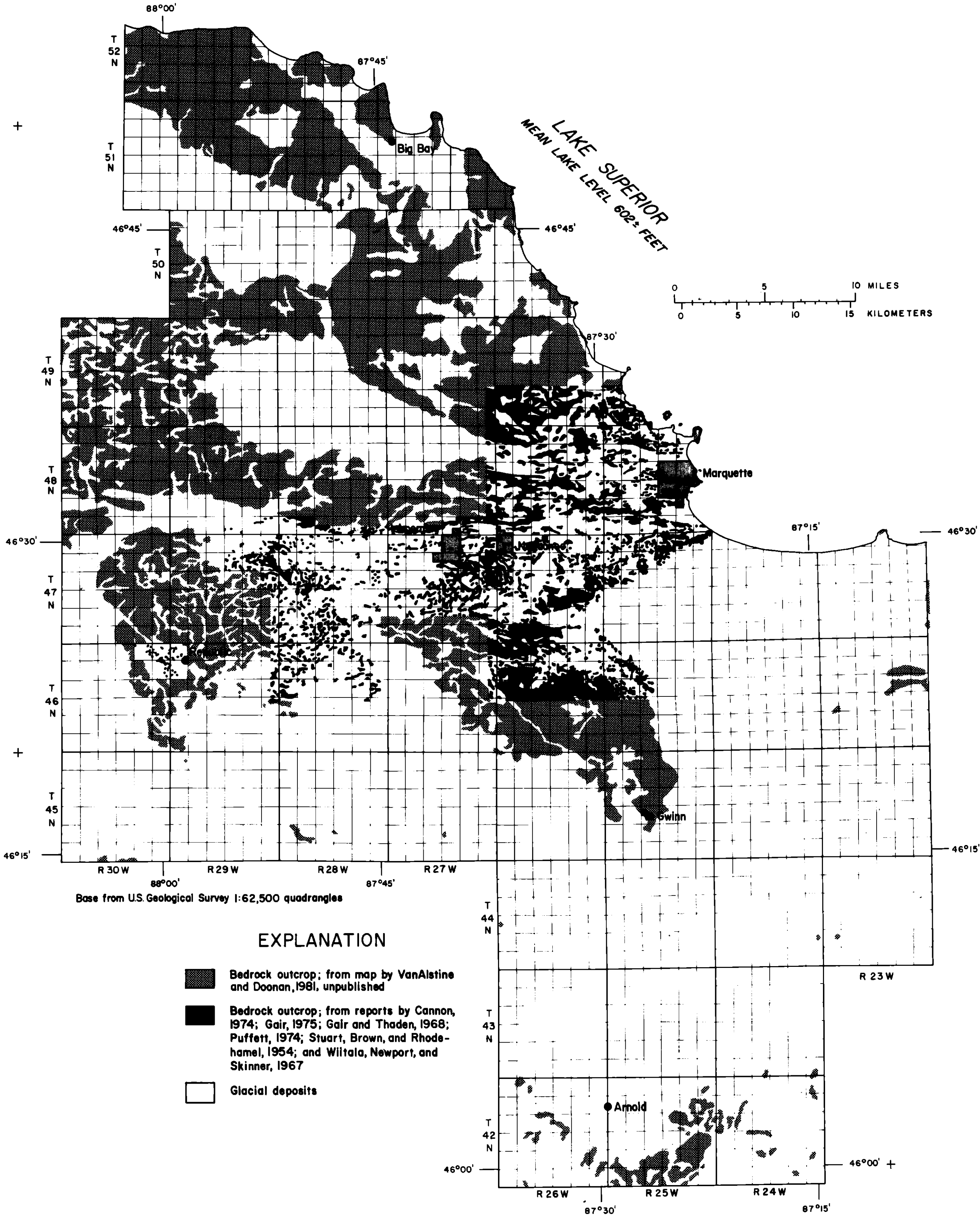


Figure 8.--Areal extent of bedrock outcrops and glacial deposits.

Bedrock

Bedrock in Marquette County consists of igneous and metamorphic rocks of Precambrian age and sedimentary rocks of Precambrian and Paleozoic age. Rocks of Precambrian age, occur in the central, northern, and western parts of the county (fig. 9). Sedimentary rocks, which overlie the older rocks, are found in the southern and eastern part and in a narrow zone along the shore of Lake Superior.

Metamorphic and igneous rocks of Precambrian age consist of quartzite, schist, gneiss, and metamorphosed volcanic and sedimentary rocks, iron-bearing rocks, granite, diorite, and basic igneous rocks. This rock complex has been folded and deformed. One large structural feature--the Marquette synclinorium--is composed of rocks that have been folded into a trough-shaped structure extending from Marquette westward to Baraga County. The snyclinorium contains most of the iron-bearing rocks mined in the county.

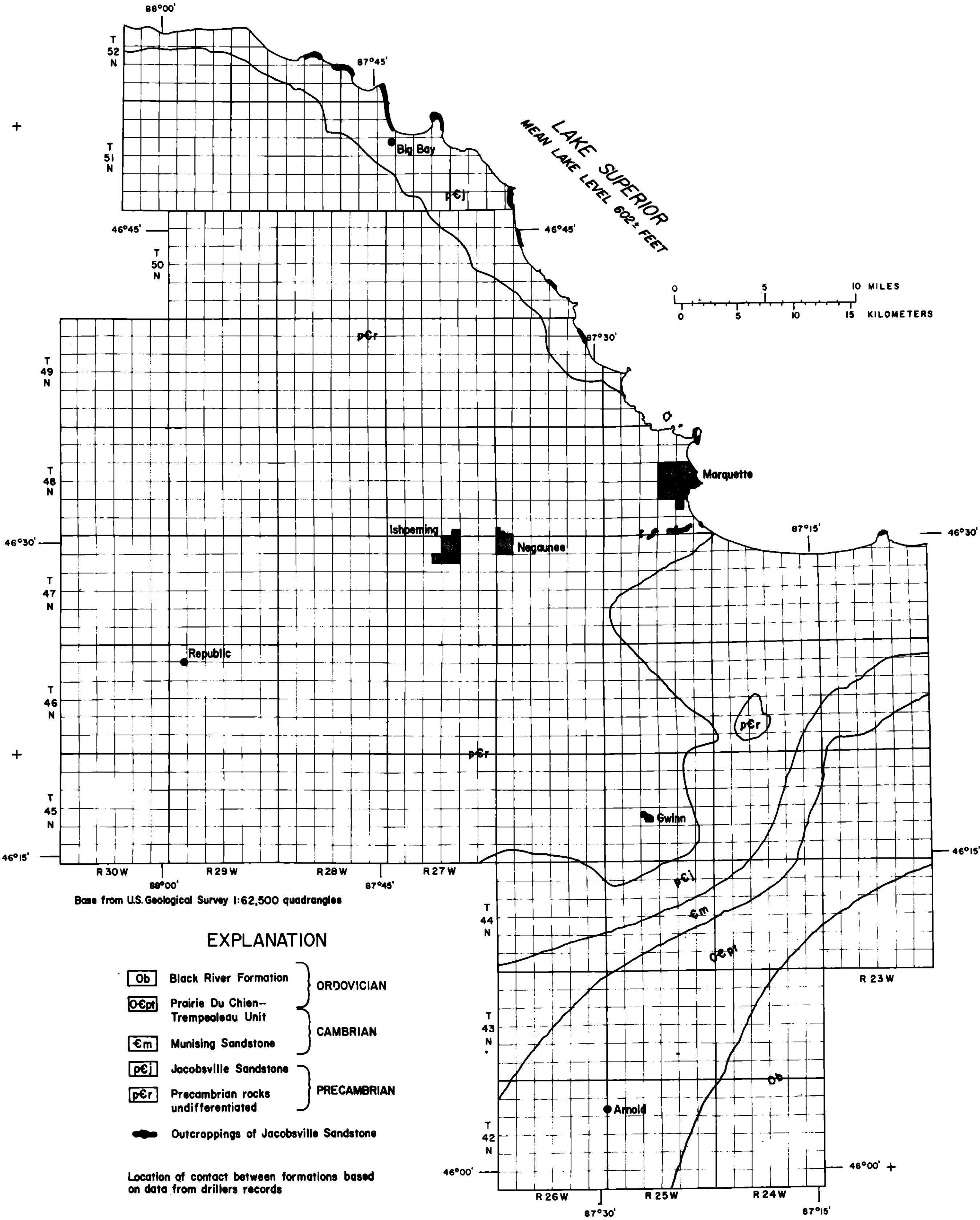


Figure 9.--Areal distribution of bedrock units.

Sedimentary rocks of Precambrian and Paleozoic age overlie the igneous and metamorphic complex in parts of the county. The oldest sedimentary rock, the Jacobsville Sandstone of Precambrian age (figs. 9 and 10), rests on the eroded surface of igneous and metamorphic rocks and consists of sandstone containing occasional beds of shale and conglomerate. It is generally red to red-brown and is mottled white. The reported maximum thickness of the Jacobsville Sandstone is about 600 ft.

Sedimentary rocks of Paleozoic age overlie the Jacobsville Sandstone in the southeastern part of the county. These rocks consist of several units, from oldest to youngest, as follows: Munising Sandstone, Trempealeau Formation, Prairie Du Chien Group, and the Black River Formation.

The Munising Sandstone of late Cambrian age consists of friable light-colored fine-to-medium grained sand. In many places, this unit is conglomeratic near its base. The thickness of the Munising ranges from a featheredge to 200 ft.

The Trempealeau Formation of late Cambrian age and Priarie Du Chien Group of early Ordovician age are similar in their lithologic and hydrologic characteristics and, in this report, are considered as a unit. The unit is a sequence of dolomite, dolomitic sandstone and lenses of quartz-rich sandstone; it is about 400 ft thick.

The Black River Formation of middle Ordovician age is the youngest bedrock. It consists of limestone, dolomite, and some thin beds of shale. Its maximum thickness is about 100 ft.

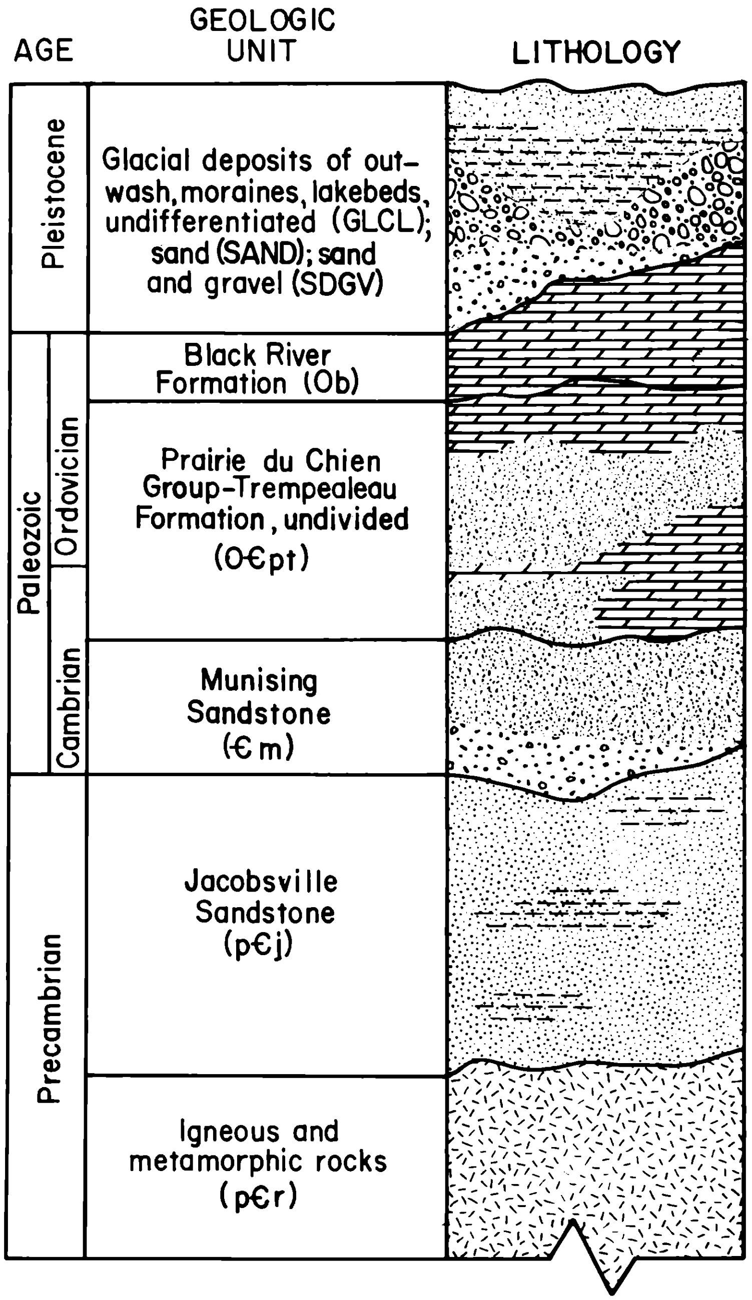


Figure 10.--Stratigraphic succession and lithology.

Glacial Deposits

Glacial deposits are the surficial material in much of Marquette County (fig. 11). In this report, the deposits are subdivided into outwash, moraines, and lakebeds.

Outwash is principally stratified sand and gravel deposited by glacial meltwater. The maximum thickness of outwash is about 300 ft.

Most moraines are an unstratified heterogeneous mixture of clay, silt, sand, gravel, and boulders; a few moraines, however, are stratified. In general, morainal material was deposited directly from glaciers without sorting by water. Moraines in some places are thin; in others they may be several hundred feet thick.

Lakebeds are generally stratified layers of fine sand, silt, and clay that were deposited in ponded water. They range from 10 to 30 ft thick in most places.

Glacial deposits range in thickness from a featheredge to nearly 500 ft (fig. 12). Deposits are thickest in areas where the bedrock altitude is low; especially in buried valleys such as that just south of Marquette (fig. 13).

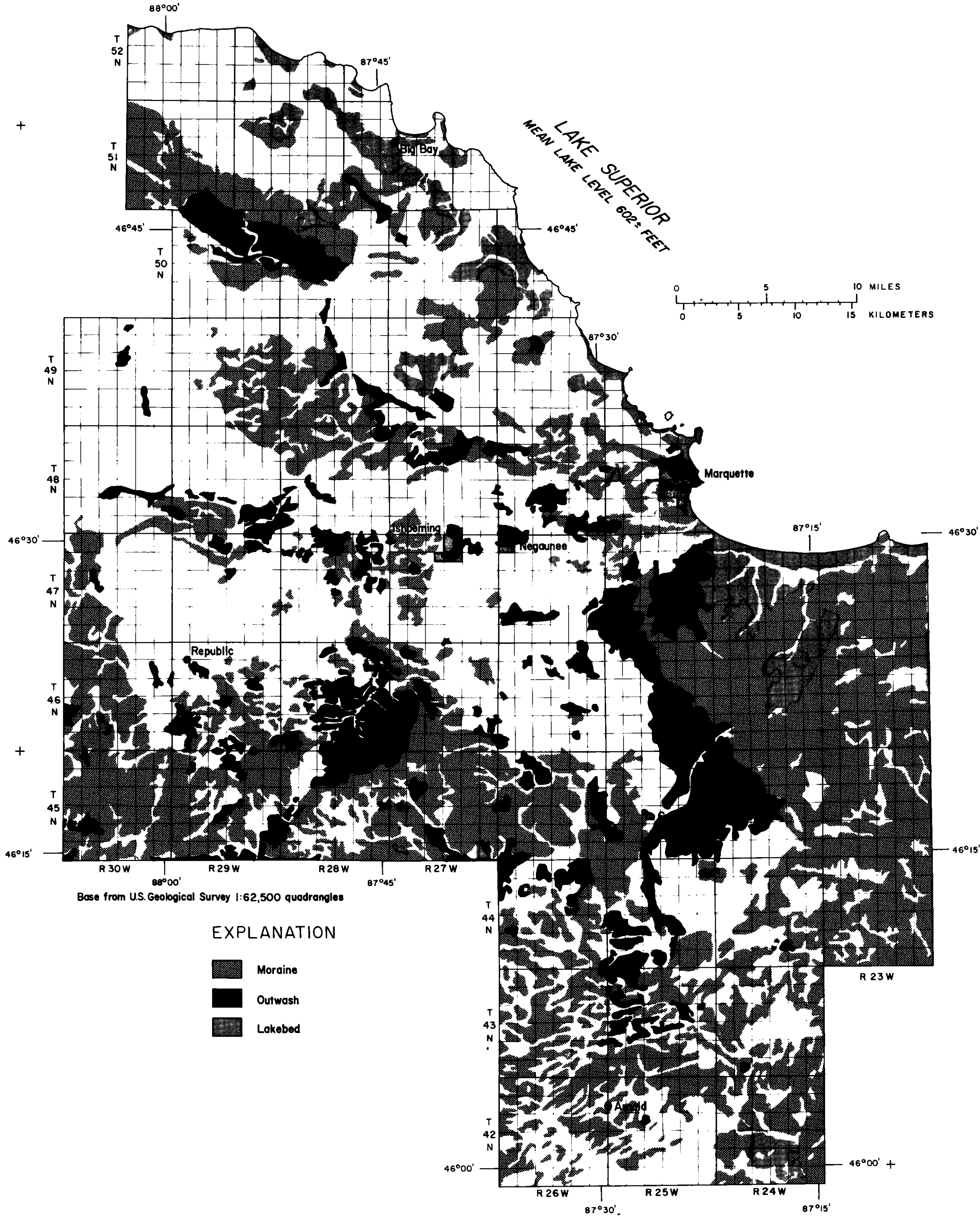


Figure 11.--Areal distribution of glacial features.

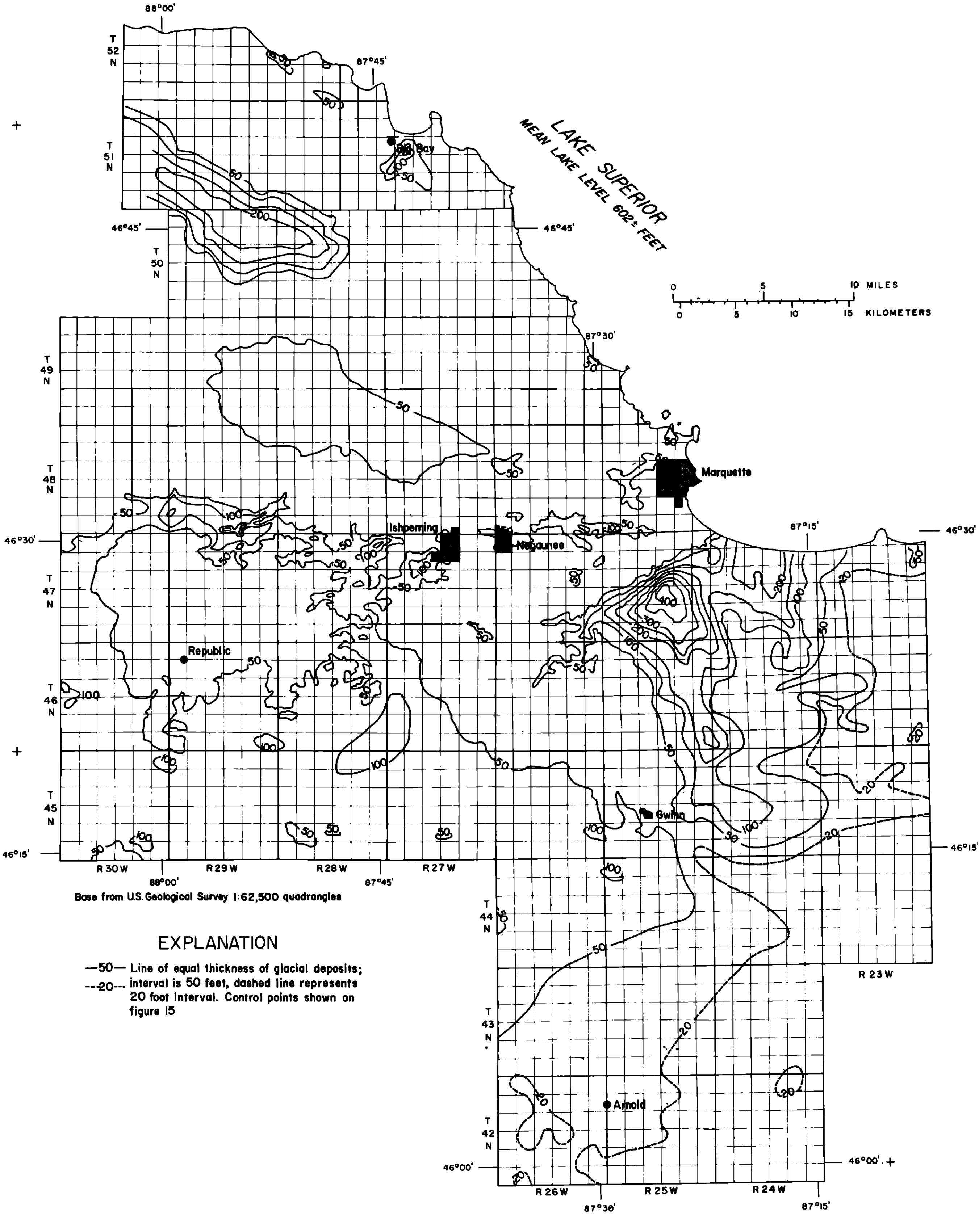


Figure 12.--Thickness of glacial deposits.

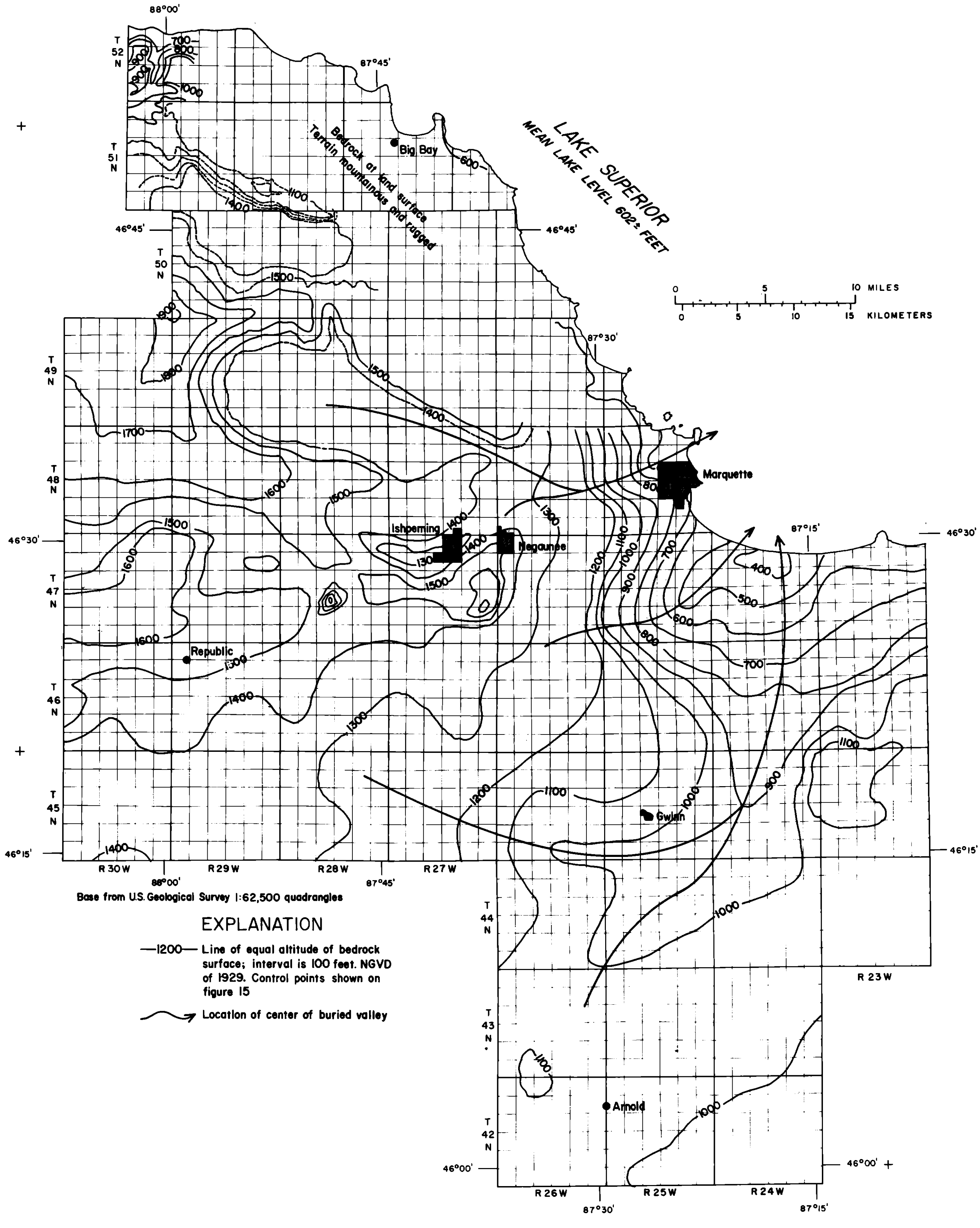


Figure 13.--Altitude of bedrock surface.

WATER SUPPLIES

Water for public and rural supplies is derived from lakes and aquifers (table 2). Most water for industrial supplies is from lakes or streams. The source at any site depends on the quantity and quality of water needed and what is available.

Individual household needs, whether rural or in small towns without public supplies, are usually obtained from aquifers. These reservoirs, in general, are easily accessible, and most wells tapping them yield from 5 to 50 gal/min. Hilly and mountainous areas may, in places, be underlain by no aquifers and water may have to be obtained from other sources.

Public supplies tap both lakes and aquifers. The greatest use of water for public supplies is in Marquette. Here, an average of 3.5 million gal/d is pumped from Lake Superior to supply the city. The greatest use of ground water is at Sawyer Air Force Base, where, on the average, 1.3 million gal/d is pumped. Several townships also pump considerable quantities.

Table 2.--Source of water supplies

Community, township, or site	Altitude (feet above NGVD of 1929)	Population[1/] (1970)	Source of water[2/]	Aquifer[3/] and well depths (feet)
Alder	650	U, K	N	
Arnold	1,030	U, K	N	
Austin	1,150	U	Pa	
Beacon	1,720-1,745	U;270	Pb	
Beverly Hills	1,380-1,420	U	Pc	
Bay Cliffs Camp	690	-	W,Pd	p€j, 683
Big Bay	685	U;185	W,Pe	SDGV, 156
Birch	625	U, K	N	
Brookton Corners	905	U, K	N	
Buckroe	634	U, K	N	
Camp Fleetwood	1,400	U, K	N	
Carlshend	1,150	U	N	
Champion	1,600-1,740	U;500	W	GLCL, 110
Clarksburg	1,530	U, K	N	
Diorite	1,565	U;190	W,Pf	GLCL, 38, 49
Dukes	1,090	U, K	N	
Eagle Mills	1,280	U, K	N	
Forsyth Township	-	-	W,M	SDGV, 40-103
Green Garden	780-800	U, K	N	
Greenwood	1,500	U;355	W,Pf	GLCL, 30-97
Gwinn	1,090-1,110	1,054	Pa	
Harvey	650	U	N	
Homeier	680	U, K	N	
Humboldt	1,537	U	N	
Huron Mountain	620	U	W	SDGV, 55-200
Ishpeming	1,450-1,500	8,245	Sa	
Ishpeming Township	-	-	W,Pg	SDGV, 49-59
Lake Angeline	1,440-1,460	U, K	Pc	
Lawson	1,080	U, K	N	
Little Lake	1,125	U;135	N	
Mangum	660	U, K	N	
Maple Grove	1,110	U, K	N	
Marquette	605-750	21,967	Sb	
Mashek	1,020-1,040	U, K	N	
McFarland	1,085	U, K	N	
Michigamme	1,560-1,650	U;180	N	
National Mine	1,400-1,500	U;370	N	
Negaunee	1,340-1,400	5,248	Sc	
New Dalton	850-970	U, K	N	
New Swanzy	1,110	U	Pa	
North Lake	1,540	U	Pc	
Northland	1,100-1,160	U, K	N	
Palmer	1,310	U;765	W,Ph	SDGV, 34, 38
Park Hill	1,490-1,540	U;270	Pi	
Princeton	1,160-1,220	U	Pa	

Table 2.--Source of water supplies--Continued

Community, township, or site	Altitude (feet above NGVD of 1929)	Population[1/] (1970)	Source of water[2/]	Aquifer[3/] and well depths (feet)
Republic	1,490-1,540	U;510	Pi	
Republic Township	-	-	W,Sd	SDGV, 47-68
Salisbury	1,420-1,460	U, K	Pc	
Sand River	620	U, K	N	
Sands	1,200	U	N	
Sands Station	1,195	U, K	N	
Sawyer AFB	1,100-1,180	6,679	W	SDGV, 79-144
Selma	1,070	U, K	N	
Skandia	900	U	N	
Snowville	1,565	U, K	N	
South Republic	1,490	U	N	
Trowbridge Park	680-900	U;1,100	N	
Watson	1,005	U, K	N	
West Ishpeming	1,460	U;1,700	Pc	
Witch Lake	1,490	U;15	N	
Yalmer	780	U, K	N	

1/ U - Unincorporated, approximate population shown for some communities.

K - No distinct settlement; only a few homes, small store, bar, or other buildings.

2/ M - Public supply from mine shaft.

N - No public supply.

P - Purchased water:
- a - from Forsyth Township
- b - from Champion
- c - from Ishpeming Township
- d - partial supply from Powell Township
- e - Powell Township owns and operates well
- f - Ely Township owns and operates wells
- g - some from city of Ishpeming
- h - Richmond Township owns and operates wells
- i - from Republic Township

S - Public supply from surface water:
- a - from Lake Sally
- b - from Lake Superior
- c - from Teal Lake
- d - some from Perch Lake

W - Public supply from wells.

3/ GLCL - Glacial deposits, undifferentiated.
SDGV - Sand and gravel.
p€j - Jacobsville Sandstone

No aquifer given if community has no public supply.

QUALITY OF WATER

The quality of water in most places in Marquette County is good. Dissolved-solids concentration of water from streams and wells is generally low (table 3). Values much higher than those in table 3 probably result from man's activities. Grannemann (1979) found that surface water is generally of the calcium-magnesium bicarbonate type.

Of the ground-water analyses in table 3, only a few show values for dissolved solids. A reasonable estimate of dissolved solids is obtained by multiplying specific conductance by 0.6. On this basis, dissolved-solids concentrations range from 35 to 720 milligrams per liter (mg/L).

Quality of water from glacial deposits is generally better than that from bedrock, as indicated by its lower dissolved-solids concentration. However, iron and manganese are high. Quality of water from bedrock varies widely. Water from shallow depth and from sandstone may have dissolved solids as low as 80 mg/L; whereas, water from depths greater than 1,000 ft and from the igneous-metamorphic complex of Precambrian age generally has dissolved solids of more than 1,000 mg/L (Grannemann, 1979).

Table 3.--Quality of water from selected streams and wells (analyses by U.S. Geological Survey; results in milligrams per liter; constituents are dissolved)

STREAMS

Gaging stations[a/]	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	pH (units)	Hardness (at $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids (residue at 180°C)	Iron (Fe) (µg/L)	Manganese (Mn) (µg/L)
04044400	55	182	7.2	83	17	3.6	2.4	1.0	78	19.6	6.0	0.0	123	--	--
04044574	--	142	7.5	70	--	--	--	--	83	5.6	1.5	--	93	--	--
04057800	109	63	6.8	30	9	1.8	1.1	.8	34	9.5	.9	.2	68	--	--
04058100	309	84	7.2	40	10	3.4	1.0	.8	34	8.8	1.9	.1	66	725	80
04058200	9	144	7.3	71	--	--	--	--	88	10.0	2.8	--	120	--	--
04058400	35	185	7.5	95	31	6.4	4.3	1.7	74	30.0	5.7	--	148	--	--
04058500	114	143	7.4	64	18	4.9	4.7	1.0	48	19.4	3.1	.1	108	441	35
04059000	1,122	187	7.8	90	22	8.8	4.0	1.0	102	11.4	3.3	.1	123	368	17
04062300	941	57	7.0	22	5	1.5	1.6	.4	22	8.2	1.5	.2	41	--	--

WELLS

Location	Depth (ft)	Aquifer[2/]	Date	Specific conductance (micromhos per cm at 25°C)	pH (units)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids 3/ (residue at 180°C)	Iron (Fe) (μg/L)	Manganese (Mn) (μg/L)
42N 24W 25BC1	105	Ob	09-16-70	520	7.6	--	81	26	--	--	349	13	2.0	--	--	--	--
42N 26W 05BCA1	38	OЄpt	09-09-70	420	8.0	--	70	16	--	--	293	6.0	.0	--	--	--	--
44N 23W 30ACC1	40	Ob	09-18-70	540	7.4	--	84	24	--	--	349	14	14	--	--	--	--
44N 26W 12DDD1	34	SAND	10-21-70	100	6.7	--	11	4.4	--	--	49	6.6	1.0	--	--	--	--
45N 23W 23AAA1	38	OЄpt	09-18-70	320	7.7	--	42	19	--	--	190	16	13	--	--	--	--
45N 24W 20DBB1	30	GLCL	10-19-70	60	8.6	--	12	2.4	--	--	39	6.6	1.0	--	--	--	--
45N 28W 03DA1	40	SDGV	08-28-73	123	6.7	57	12	6.6	1.2	0.5	61	9.6	3.0	--	65	--	--
45N 30W 26DDD1	137	pЄr	10-15-70	1,200	8.2	--	69	30	--	--	322	64	200	--	--	--	--
46N 23W 07CCB1	101	pЄj	10-02-70	600	7.0	--	69	36	--	--	268	13	68	--	--	--	--
46N 23W 30DAD1	85	Єm	10-01-70	220	7.4	--	30	18	--	--	155	10	2.0	--	--	--	--
46N 25W 11CB1	189	SDGV	07-26-63	77	7.4	36	12	1.4	1.5	.7	44	2.2	1.5	--	48	--	--
46N 25W 36BC1	135	SDGV	07-10-67	260	7.7	134	41	7.8	2.1	.9	162	4.8	4.0	0.2	154	1,500	520
46N 26W 31CC1	32	SDGV	09-10-63	212	6.6	99	28	7.0	3.1	1.4	90	30	.0	--	126	--	--
46N 28W 1BD1	97	pЄr	08-28-63	136	8.5	64	15	6.3	1.6	1.2	47	4.8	8.5	--	69	230	--
46N 30W 22AB1	51	GLCL	10-09-70	160	7.9	--	18	9.7	--	--	102	.0	1.0	--	--	--	--
47N 23W 03ABD1	50	pЄj	10-06-70	180	6.7	--	20	6.3	--	--	98	.0	21	--	--	--	--
47N 24W 21DDA1	125	GLCL	10-21-70	240	7.8	--	34	7.3	--	--	149	7.4	1.0	--	--	--	--
47N 26W 25AA1	35	SDGV	07-24-63	363	6.5	161	43	13	7.7	3.3	92	84	12	--	217	1,600	--
47N 28W 15AC1	72	SAND	07-08-64	110	9.7	36	10	2.5	3.7	2.3	18	7.6	.0	--	64	--	--
47N 29W 34CB1	23	SDGV	08-28-63	151	6.6	56	13	5.8	2.2	1.2	85	1.6	2.0	--	94	660	--
48N 26W 23ACA1	40	GLCL	10-16-70	140	8.1	--	20	2.9	--	--	76	25	3.0	--	--	--	--
48N 29W 19CD1	127	SDGV	07-08-64	148	8.1	72	23	3.5	2.3	1.1	86	5.2	1.8	--	100	--	--
49N 26W 12CC1	66	pЄj	10-13-70	300	7.9	--	32	11	--	--	171	.0	4.0	--	--	--	--
50N 26W 19BB1	99	pЄj	10-13-70	280	6.2	--	31	6.3	--	--	49	10	23	--	--	--	--
51N 27W 01CAC1	126	pЄj	10-14-75	200	7.1	--	23	10	--	--	117	7.4	.0	--	--	--	--
51N 28W 01BA1	55	SDGV	10-08-70	200	7.5	108	31	7.8	--	--	132	.0	.0	--	--	5,000	--
51N 28W 21DB1	200	pЄj	10-08-70	140	7.7	--	24	3.4	--	--	95	.0	2.0	--	--	--	--

FOOTNOTES:

1/ Additional data in U.S. Geological Survey's annual series of basic records reports titled "Water Resources Data for Michigan."

2/ GLCL - Glacial deposits, undifferentiated
SAND - Sand
SDGV - Sand and gravel
Ob - Black River Formation
OЄpt - Prairie Du Chien Group - Trempealeau Formation, undivided
Єm - Munising Sandstone
pЄj - Jacobsville Sandstone
pЄr - Precambrian igneous and metamorphic rocks, undifferentiated

Age shown in figure 10.

3/ Estimate dissolved solids from specific conductance by the formula: Dissolved Solids = Specific Conductance x 0.6.

SURFACE-WATER RESOURCES

Streams in Marquette County flow to Lake Superior and Lake Michigan. The Carp, Dead, Iron, and Chocolay Rivers and minor streams in the northern part of the county flow to Lake Superior. And, although the county borders on Lake Superior, more than 50 percent of the flow is south in the Escanaba and Michigamme Rivers to Lake Michigan.

Several years of discharge record for the Carp River indicates that the average flow in its basin is 1.2 $ft^3/s/mi^2$ (table 4). Because no other streamflow data are available and because of similarities in hydrologic conditions, this value is assumed for about 500 mi^2 in the northern part of the county (area A, fig. 14). Thus, an average discharge of 600 ft^3/s may be estimated.

In the Chocolay River area (area B, fig. 14), only a few miscellaneous measurements, other than those on Cherry Creek (table 4, gaging station 04044583), have been made. Some tributaries to the Chocolay River, such as Cherry Creek, are ground-water fed and have high yields per square mile. The infiltration rate in that part of the basin is high, tending to reduce peak runoff. An assumed runoff of 1.2 $ft^3/s/mi^2$ indicates a discharge of about 250 ft^3/s for the 200 mi^2 Chocolay River area.

The flow from the northern part of the county and the Chocolay River area is the total flow to Lake Superior from Marquette County. On the basis of the above estimates, it is 850 ft^3/s.

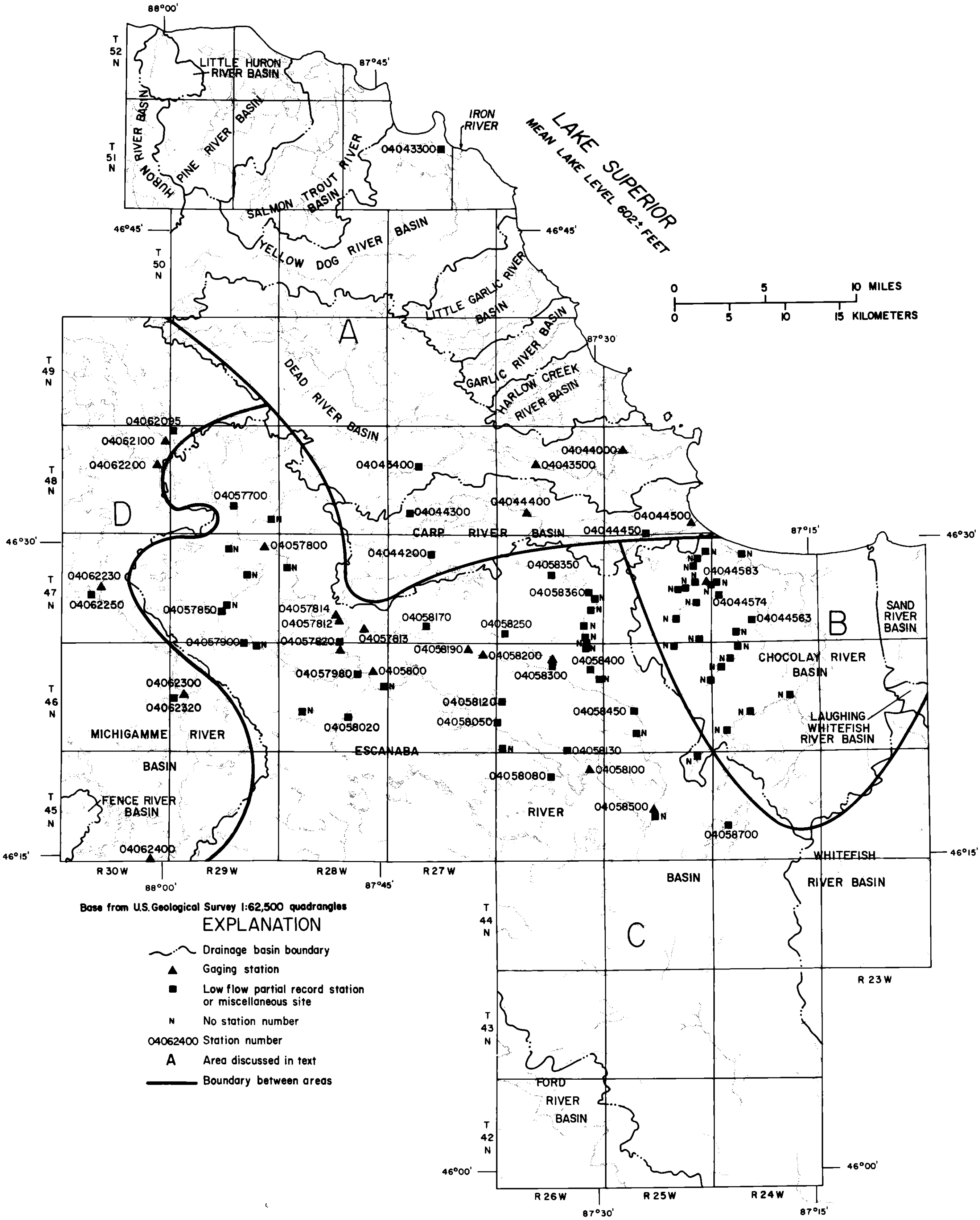


Figure 14.--Sites where streamflow data have been collected.

Table 4.--Discharge and drainage for selected sites on streams

River basin	Gaging stations a/	Drainage area (mi²)	Discharge (ft³/s/mi²)	Average (ft³/s)	Maximum discharge (ft³/s)	Minimum discharge (ft³/s)	Number of years of record
Carp	04044400	51	1.2	60	351	3.7	17
Chocolay	04044583	4.5	4.2	18.7	37	18	5
Escanaba	04057800	46	1.3	60	1,640	4	19
	57820	73	1.1	82	1,060	8.6	6
	58000	128	1.1	142	1,090	12	21
	58100	210	1.0	218	2,580	2.2	17
	58130	14	-	-	166	3.6	4
	58200	24	-	-	860	.4	19
	58300	14	-	-	600	.5	13
	58400	38	.9	33	458	3.7	14
	58500	124	.9	111	2,390	19	23
	59000	870	1.0	888	10,500	90	37
Michigamme	04062100	67	1.7	115	3,060	3.6	7
	62200	133	1.6	211	3,610	.7	17
	62230	194	1.5	282	3,180	2.8	11
	62300	240	1.3	322	3,030	7	14
	62400	316	1.3	422	4,360	23	14

River basin	Partial record and miscellaneous sites a/	Drainage area (mi²)	Highest measurement made (ft³/s)	Lowest measurement made (ft³/s)
Iron	04043300	88	144	51.5
Dead	04043400	12	22	6
	43500	138	806 b/	39 c/
	44000	158	2,340 c/	37 c/
Carp	04044200	16	48	3.9
	44300	5	8	2.5
	44450	7	14	12.2
	44500	86	219 c/	30 c/
Chocolay	04044563	17	29	26.1
	44574	9	13	11.6
Escanaba	04057700	24	35	.6
	57850	11	15	.1
	57900	34	31	2.2
	57980	51	70	4.4
	58020	20	19	3
	58050	179	212	34.9
	58080	12	16	3.7
	58120	8	8	.5
	58170	9	6	.5
	58250		5	1.6
	58350	10	5 d/	3.5 d/
	58360	15	58	5
	58450	97	81	16.5
	58700	10	5	.1
Michigamme	04062095	19	50	3.7
	62250	31	43	8.5
	62320	23	18	2.2

a/ Specific locations given in U.S. Geological Survey annual report "Water Resources Data for Michigan."

b/ Estimate from rating curve.

c/ Daily mean.

d/ Includes mine pumpage.

Computation of flow from Marquette County to Lake Michigan is backed by reliable and lengthy data from site 04059000 on the Escanaba River and site 04062400 on the Michigamme River. Data from these sites indicate the average flows to be 1.0 $ft^3/s/mi^2$ and 1.3 $ft^3/s/mi^2$, respectively. Assuming the size of drainage for the Escanaba River area (area C, fig. 14) to be 900 mi^2 and that for the Michigamme River part of the county (area D) to be 250 mi^2, the total flow to Lake Michigan is 1,225 ft^3/s.

Combined runoff from the county, based on the estimates for the four areas discussed above, is about 2,100 ft^3/s.

GROUND-WATER RESOURCES

Evaluation of ground-water resources depends primarily on available well data (table 5) and an understanding of geologic conditions. In some areas, as shown on figure 15, data are abundant, and reasonable assessments are possible. However, much of the county is devoid of wells and ground-water conditions can only be estimated.

In areas having thin glacial deposits underlain by sedimentary bedrock, such as in the southeastern part of the county, estimates of ground-water conditions can be based on the generalized water-bearing characteristics of bedrock. For this part of the county (area A, fig. 15), the characteristics are as follows:

Jacobsville Sandstone. Yields small quantities of water to wells; sufficient for domestic use if no other source is available. In a few places, water may be high in chloride.

Munising Sandstone. A good aquifer; yields of 10 to 50 gal/min can be expected. In some places may yield more than 100 gal/min to large diameter wells.

Prairie du Chien-Trempealeau unit. Beds of sandstone yield as much as 50 gal/min; whereas, beds of limestone and dolomite, in most places yield only sufficient water for domestic supplies.

Black River Formation. In most places, can be expected to yield sufficient water for domestic supplies. Where fractures have been enlarged by solution action, may yield up to 30 gal/min to wells.

The only place, other than the southeast, where sedimentary bedrock is near land surface, is in a strip along Lake Superior north of Marquette. In this strip, the Jacobsville Sandstone is the principal source of water. Because weathered zones provide increased storage capacity, yield from some wells is as high as 30 gal/min.

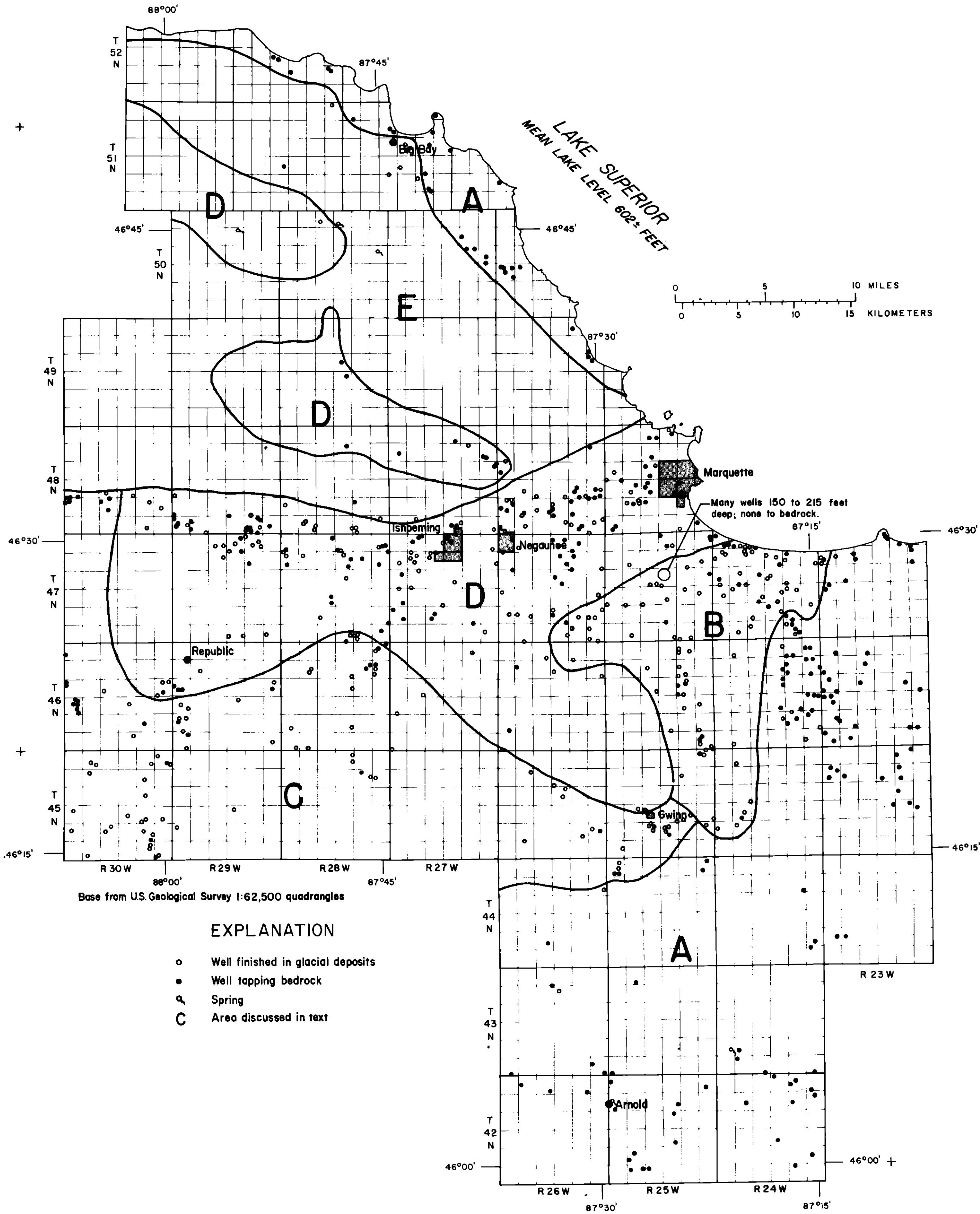


Figure 15.--Sites where ground-water and geologic data have been collected.

Table 5.--Yield of selected wells[1/]

Well number	Aquifer[2/]	Yield (gal/min)	Specific capacity (gal/min/ft drawdown)
42N 24W 2BD1	Ob	12	1
42N 25W 1AD1	O€pt	30	3
42N 26W 4DD1	O€pt	5	<1
43N 24W 33DC1	Ob	6	<1
43N 25W 31CC1	O€pt	8	<1
44N 23W 30AC1	Ob	5	2
44N 24W 25DB1	Ob	6	<1
44N 25W 6AC1	GLCL	5	<1
44N 26W 28DA1	p€j	10	20
45N 23W 14BB1	O€pt	6	1
45N 24W 20CD1	GLCL	6	1
45N 25W 27BD1	GLCL	10	3
45N 26W 25BB1	GLCL	10	1
45N 28W 11AD1	GLCL	6	1
45N 30W 13CA1	GLCL	25	6
45N 30W 26DD2	p€r	5	<1
46N 23W 18DD1	€m	15	2
46N 24W 12BA1	p€j	5	<1
46N 28W 15AB1	GLCL	20	2
46N 29W 18BD1	p€r	32	16
46N 29W 18DB1	GLCL	97	6
46N 30W 26CA1	p€r	12	<1
47N 23W 7CC1	GLCL	5	<1
47N 24W 15CB1	GLCL	50	5
35BA1	p€j	10	<1
47N 26W 29BC2	GLCL	203	41
47N 27W 8BB1	GLCL	90	3
47N 28W 12CA2	GLCL	50	1
48N 25W 18DC1	p€r	20	<1
18CC1	GLCL	10	2
48N 26W 7DC1	GLCL	16	3
48N 28W 32DA2	GLCL	20	1
48N 29W 30CC5	p€r	35	1
31CB1	GLCL	40	40
48N 30W 21CA1	GLCL	2	<1
49N 26W 12CC1	p€j	3	<1
50N 26W 19BB1	p€j	12	1
50N 27W 14AB1	p€j	30	1
51N 27W 14AA1	p€j	30	3

1/ From Doonan and Van Alstine, 1981.

2/ GLCL - Glacial deposit, undifferentiated
Ob - Black River Formation
O€pt - Prairie du Chien Group - Trempealeau Formation, undivided
€m - Munising Sandstone
p€j - Jacobsville Sandstone
p€r - Precambrian igneous and metamorphic rocks, undifferentiated

Glacial deposits are the principal source of water where they are more than 50 ft thick and underlain by sedimentary bedrock, as in area B (fig. 15). In places in this area, glacial deposits yield as much as 200 gal/min. In some places, wells are finished in bedrock and have production characteristics similar to equivalent bedrock units in area A.

Where glacial deposits are more than 50 ft thick but are underlain by igneous and metamorphic rocks, as in area C, the best sources of water are the glacial deposits. These deposits can be expected to yield from 10 to 50 gal/min in some places. Igneous and metamorphic rocks, if weathered, may yield some water to wells but barely enough for domestic supplies.

Glacial deposits in area D range from a featheredge to over 100 ft in thickness and are underlain by igneous and metamorphic rocks. In this area, it is difficult to predict ground-water occurrence and conditions except on a well-to-well basis. If glacial deposits are thick and composed of sand and gravel, good yields can be expected. If, however, the deposits are thin, the chances of obtaining even domestic supplies are poor. Evaluation is difficult because the altitude of the bedrock surface is quite variable. In many places, bedrock may be exposed, and only a few hundred feet away it may be buried beneath 100 or more feet of glacial deposits. Test drilling is necessary to determine the availability of ground water accurately.

Area E is mountainous and is composed of igneous and metamorphic rocks. The area is poor for obtaining ground-water supplies, although occasional depressions filled with sandy material may yield a few gallons per minute to wells.

SEWAGE AND REFUSE DISPOSAL

Populated areas (fig. 1), outcropping bedrock (fig. 8), and streams (fig. 14) and their floodplains are generally unsuitable for sewage and refuse disposal. Wetlands, their areal extent shown on figure 16, are also unsuitable. As can be seen from these figures, a large part of Marquette County falls into one or more of the above categories. Areas of igneous and metamorphic bedrock outcrops can be used effectively for disposal if leachate can be contained. Otherwise, the leachate will flow rapidly to nearby streams.

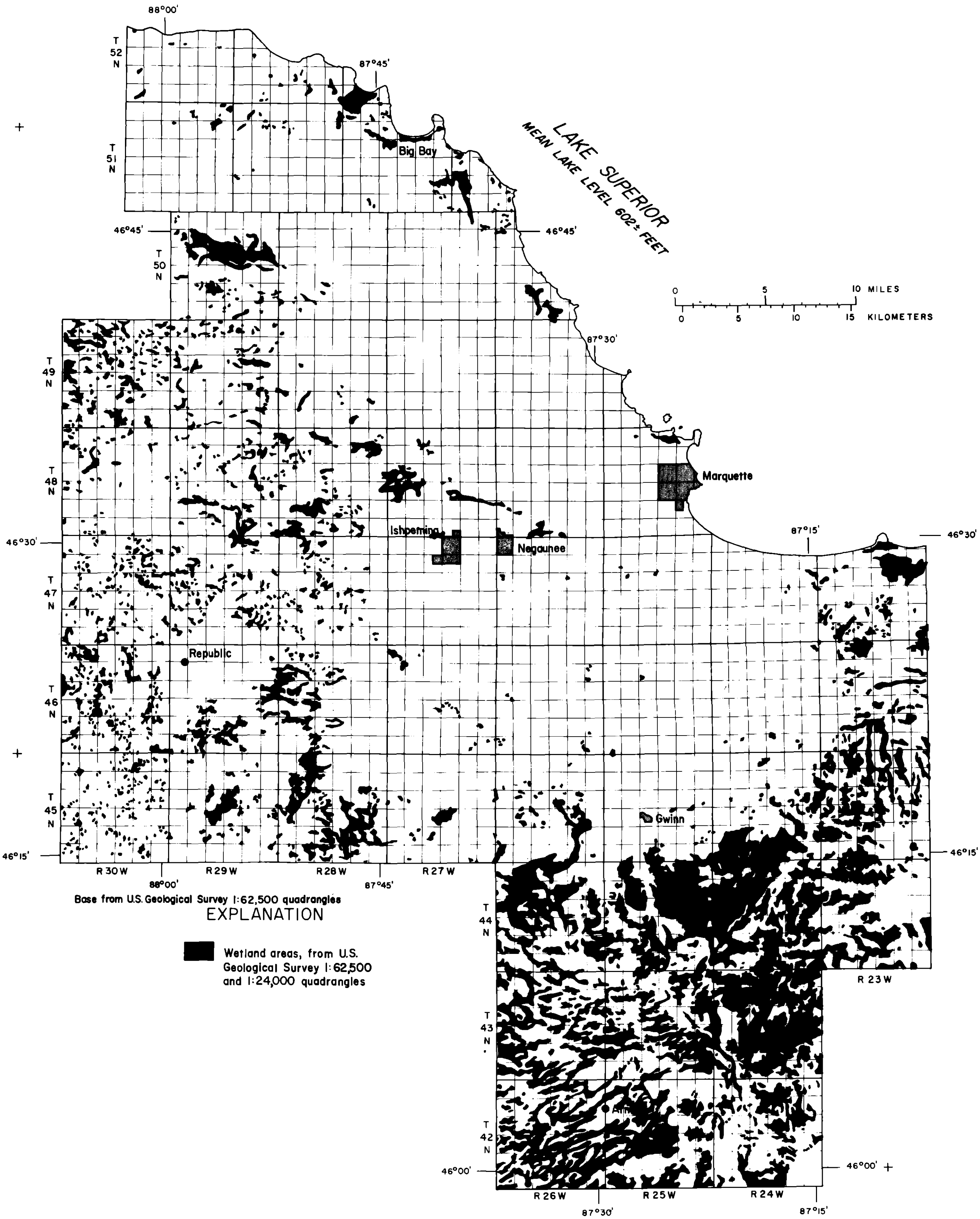


Figure 16.--Wetlands.

SELECTED REFERENCES

Boyum, B. H., 1964, The Marquette mineral district, Michigan: Cleveland-Cliffs Iron Company, 29 p.

Case, J. E., and Gair, J. E., 1965, Aeromagnetic map of parts of Marquette, Dickinson, Baraga, Alger and Schoolcraft Counties, Michigan, and its geologic interpretation, Map GP-467, 3 sheets.

Doonan, C. J., and Van Alstine, J. L., 1981, unpublished report, Ground water and geology of Marquette County, Michigan: Michigan Geological Survey Water Investigation 12, 53 p., 8 figs.

Gair, J. E., 1975, Bedrock geology and ore deposits of the Palmer Quadrangle, Marquette County, Michigan; with a section on the Empire Mine (by Tsu-ming Ham): U.S. Geological Survey Professional Paper 769, 159 p., 70 figs., 8 plates, 38 tables, 125 refs.

Gair, J. E., and Thaden, R. E., 1968, Geology of the Marquette and Sands Quadrangles, Marquette County, Michigan: U.S. Geological Survey Professional Paper 397, 77 p., 31 figs., 7 plates, 14 tables, 78 refs.

Gere, M. A., Jr., (compiler), 1978, Michigan mineral producers, 1977, Michigan Department of Natural Resources, Geological Survey Division, Eleventh Annual Director.

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.

----- 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.

Hamblin, W. K., 1958, The Cambrian sandstones of northern Michigan: Michigan Geological Survey Pub. 51, 149 p., 89 figs.

Leverett, F., 1929, Moraines and shore lines of the Lake Superior Region: U.S. Geological Survey Professional Paper 154a, 72 p.

Marquette County Planning Commission, 1975, Marquette County Comprehensive plan: 234 p.

Martin, H. M., (compiler), 1936, The centennial geological map of the Northern Peninsula of Michigan: Michigan Geological Survey Publication 39, series 33.

----- 1955, Map of the surface formations of the Northern Peninsula of Michigan: Michigan Geological Survey Publication 49.

Peterson, E. C., and Middlewood, E., 1978, Minerals in the economy of Michigan: U.S. Bureau of Mines, State Mineral Profile 7, 14 p.

Puffett, W. P., 1974, Geology of the Negaunee Quadrangle, Marquette County, Michigan: U.S. Geological Survey Professional Paper 788, 53 p., 24 figs.

Segerstrom, K., 1964, Negaunee moraine and the capture of the Yellow Dog River, Marquette County, Michigan: U.S. Geological Survey Professional Paper 501-C, p. C126-129.

Schneider, I. F., and Erickson, A. E., (no date), Water holding capacity and infiltration rates of soils in Michigan: Michigan State University Soils Science Dept. Agriculture Project 413, 6 sheets, 5 maps.

State of Michigan, Planning and Policy Analysis Division, 1974, Population projections for the counties of Michigan: Michigan Department of Management and Budget report, 119 p.

Stuart, W. T., Brown, E. A., and Rhodehamel, E. C., 1954, Ground-water investigations of the Marquette iron-mining district: Michigan Department of Conservation, Geological Survey Division Technical Report 3, 91 p.

U.S. Public Health Services, 1962, Drinking water standards, 1962: U.S. Public Health Service Publication 956, 61 p.

Wiitala, S. W., Newport, T. G., and Skinner, E. L., 1967, Water resources of the Marquette Iron Range Area, Michigan: U.S. Geological Survey Water-Supply Paper 1842, 142 p., 40 figs.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981—751-214