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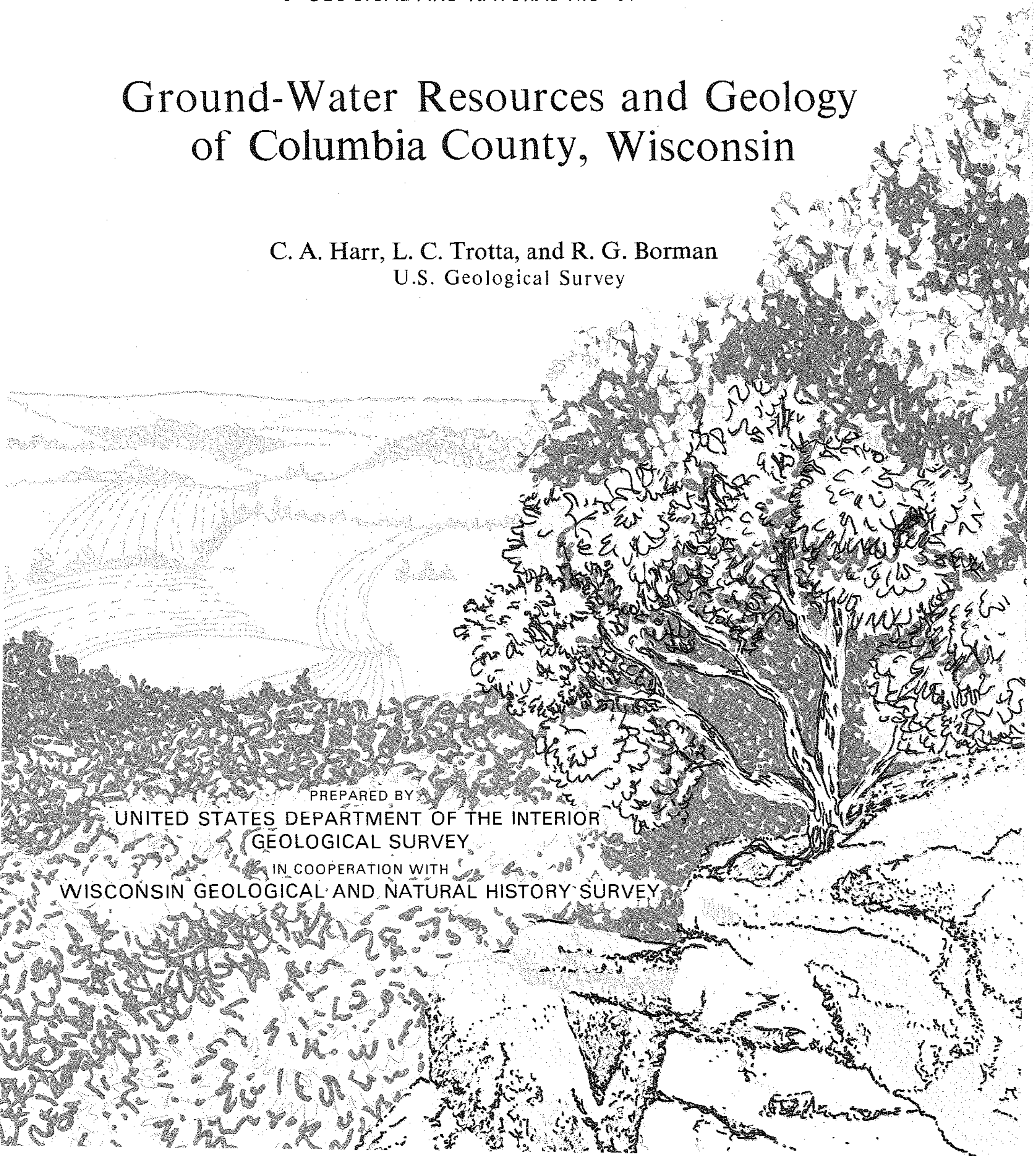
Ground-Water Resources and Geology of Columbia County, Wisconsin

C. A. Harr, L. C. Trotta, and R. G. Borman
U.S. Geological Survey



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This report is a product of the Geological and Natural History Survey Water Resources Program which includes: systematic collection, analysis, and cataloguing of basic water data; impartial research and investigation of Wisconsin's water resources and water problems; publication of technical and popular reports and maps; and public service and information. Most of the work of the Survey's Water Resources Program is accomplished through state-federal cooperative cost sharing with the U.S. Geological Survey, Water Resources Division.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

and

UNIVERSITY OF WISCONSIN–EXTENSION
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M. E. Ostrom, Director and State Geologist
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July, 1978

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FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply U.S. customary units	By	To obtain SI units
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	.06309	liter per second (L/s)
million gallon per day (Mgal/d)	.04381	cubic meter per second (m^3/s)
gallon per day (gal/d)	3.785	liter per day (L/d)
foot per day (ft/d)	.3048	meter per day (m/d)

Ground-Water Resources and Geology of Columbia County, Wisconsin

C. A. Harr, L. C. Trotta, and R. G. Borman

ABSTRACT

The increasing need for water of good quality in Columbia County, caused by a steadily increasing population, can be met from the sand-and-gravel and sandstone aquifers. As much as 15 gallons per minute can be obtained from wells almost everywhere. Yields of more than 1,000 gallons per minute are available from drift where it contains a sufficient thickness of saturated sand and gravel (the sand-and-gravel aquifer). The sandstone aquifer underlies nearly all the county except for areas west of the Wisconsin River and northwest of Pardeeville. It is more than 700 feet thick in the south-central part. The sandstone aquifer includes all bedrock younger than Precambrian age and is capable of yielding more than 1,000 gallons per minute to wells in about three-fourths of the county. It is the principal source of municipal-water supply.

The chemical quality of water from the two aquifers is similar. It is very hard (mean concentration of about 300 milligrams per liter as calcium carbonate), and much of it contains excessive amounts of iron and manganese. Concentrations of dissolved solids and chloride are higher in areas underlain by bedrock of Ordovician age than elsewhere.

About 5.0 million gallons per day of water was pumped in the county in 1974, 90 percent from the sandstone aquifer. About 45 percent of the total water pumped was for industrial and commercial purposes, 37 percent was for residential use, 16 percent for municipal use, and 2 percent for irrigation.

INTRODUCTION

Columbia County is in south-central Wisconsin (fig. 1). Portage, the county seat, is in the west-central part, on the Wisconsin River. The population increased from 36,708 in 1960 to 40,150 in 1970. Increasing population will require greater development of the water resources.

The purpose of this investigation is to describe the geology and the occurrence, movement, quality, and availability of ground water. The report is intended as an information base to aid planning, development, and manageme.. of the ground-water resource.

The project included collection and chemical analysis of ground-water samples and well-log, water-level, water-use, pumpage, and aquifer-test data for use in describing the hydrology and geology. Geology was studied only in enough detail to understand the ground-water hydrology.

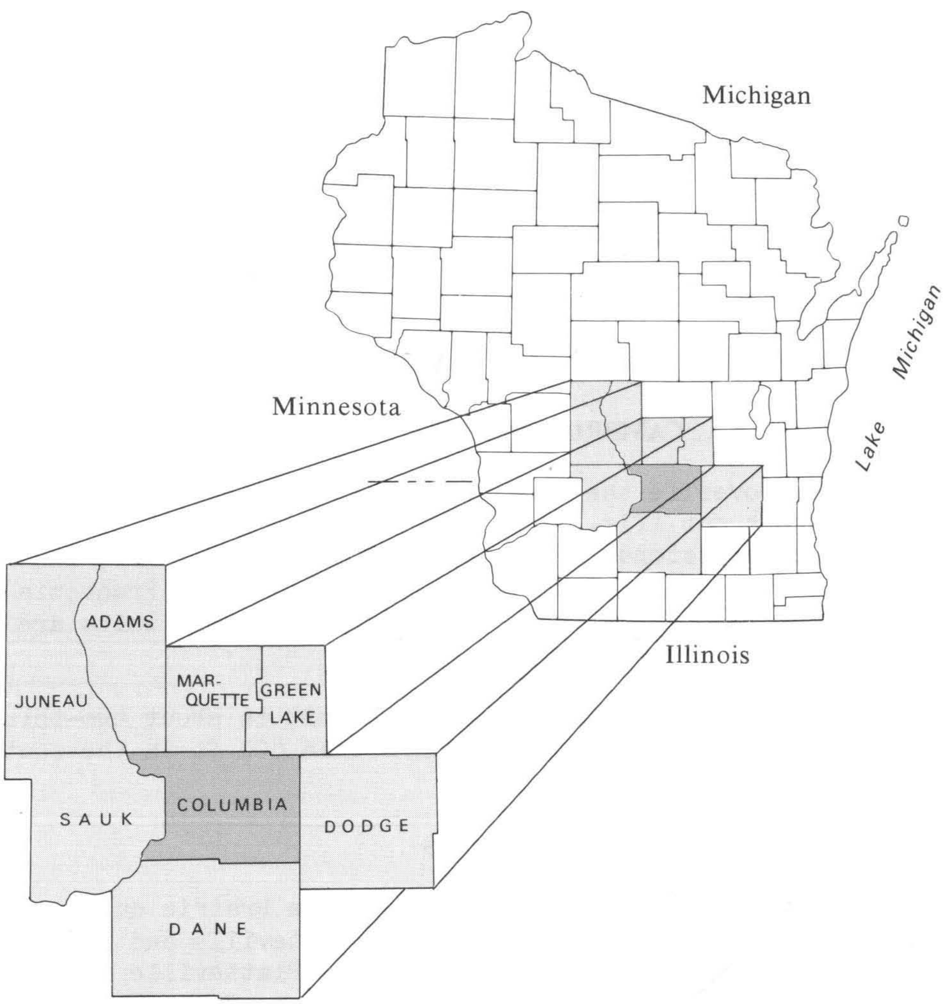


Figure 1. Location of Columbia County in Wisconsin.

This study was a cooperative project between the U.S. Geological Survey and the University of Wisconsin-Extension, Geological and Natural History Survey.

Thanks are given to the many municipal and county officials, State agencies, drillers, and individual well owners, who provided well and water information, and to the many others who allowed determination of water-level measurements and collection of water samples from their wells for chemical analyses. Special acknowledgment is made to the Wisconsin Department of Natural Resources for supplying well and pumpage records and to the Wisconsin Public Service Commission for pumpage records.

GEOLOGY

The materials that control the movement and storage of ground water in Columbia County range from the basement rocks of Precambrian age to the glacial deposits, alluvium, and soils of Quaternary age (table 1). Drift overlies the bedrock in most of the county. The bedrock, from oldest to youngest, consists of Precambrian crystalline rock; Cambrian sandstone; and Ordovician dolomite and sandstone (table 1). Many of these rocks underlie only parts of the county (figs. 2 and 4).

PRECAMBRIAN ROCKS

Igneous and metamorphic rocks of Precambrian age underlie all of Columbia County. They crop out northwest of Pardeeville and west of the Wisconsin River (fig. 2). They range in altitude from less than 250 ft in the southeast corner of the county (about 600 ft below the land surface) to more than 1,400 ft west of the Wisconsin River, where they crop out. The Precambrian rocks generally have low permeability and mark the lower limit of ground-water movement.

CAMBRIAN ROCKS

Rocks of Cambrian age overlie the Precambrian rocks everywhere except where Precambrian rock crops out (fig. 2). The Cambrian rocks are primarily sandstone but include some siltstone, shale, and dolomite. They are, from oldest to youngest, the Mount Simon, Eau Claire, Galesville, and Franconia Sandstones, and the Trempealeau Formation. In this report these units are not differentiated and are called the "Cambrian sandstone".

The Cambrian sandstone is the uppermost bedrock unit in about two-thirds of the county (fig. 2). It thickens from zero to more than 800 ft in the south-central part of the county.

ORDOVICIAN ROCKS

Rocks of Ordovician age are, in ascending order, the Prairie du Chien Group (mostly dolomite), the St. Peter Sandstone, and the Platteville and Decorah Formation, and Galena Dolomite herein called the Galena-Platteville unit. The Prairie du Chien Group was eroded deeply before deposition of the St. Peter Sandstone. In places, where the entire Prairie du Chien Group was removed, the St. Peter Sandstone overlies the Cambrian sandstone. The Galena-Platteville unit is the uppermost bedrock in a few areas in the eastern half of the county (fig. 2).

Geology by L. C. Trotta (1976)

0 2 4 6 8 10 MILES

0 2 4 6 8 10 KILOMETERS

EXPLANATION

ORDOVICIAN

Galena Dolomite, Decorah, and Platteville Formations, undifferentiated
Mostly dolomite

St. Peter Sandstone
Mostly sandstone

Prairie du Chien Group
Mostly dolomite

CAMBRIAN

Trempleau Formation and Franconia, Galesville, Eau Claire, and Mount Simon Sandstones, undifferentiated
Mostly sandstone, some shale, siltstone and dolomite

PRECAMBRIAN

Crystalline Rock
Mostly quartzite and rhyolite

Figure 2. Bedrock geology.

Table 1.--Stratigraphy of Columbia County

System	Rock unit	Predominant lithology
QUATERNARY	Holocene deposits	Unconsolidated clay, silt, sand, gravel, and organic matter.
	Pleistocene deposits	Unconsolidated clay, silt, sand, gravel, cobbles, boulders, and organic matter.
ORDOVICIAN	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	Dolomite and some slightly shaly dolomite, light-gray to blue-gray.
	St. Peter Sandstone	Sandstone, dolomitic in some places, shaly at base in some places, white, light-gray, or pink, fine- to medium-grained.
	Prairie du Chien Group	Dolomite, tan, gray, or white; some sandstone and sandy dolomite.
CAMBRIAN	Trempealeau Formation	Sandstone, dolomitic, very fine- to medium-grained; dolomite interbedded with siltstone, light-gray.
	Franconia Sandstone	Sandstone, dolomitic, very fine- to medium-grained; siltstone, dolomitic.
	Galesville, Eau Claire, and Mount Simon Sandstones, undifferentiated	Sandstone, light-gray, fine- to coarse-grained, mostly medium grained.
PRECAMBRIAN	Precambrian rocks, undifferentiated	Crystalline rocks, mostly quartzite and rhyolite.

BEDROCK SURFACE

The topography of the bedrock surface (fig. 3) was formed by preglacial, glacial, and postglacial erosion. Most of the bedrock valleys were part of a preglacial drainage system. Streams occupying these bedrock valleys drained about three-fourths of the county toward the valley presently occupied by the Wisconsin River.

The bedrock surface ranges from about 500 ft above sea level in some valleys to about 1,400 ft on the bedrock high west of the Wisconsin River. The bedrock valleys that underlie and control present surface drainage are filled with drift which form important aquifers.

QUARTERNARY DEPOSITS

The unconsolidated deposits of Quaternary age that overlie bedrock in Columbia County are largely glacial sediments laid down by the Green Bay lobe during Wisconsin Glaciation, but they also include some alluvium and marsh deposits. Distinctive landforms (end moraine, ground moraine, outwash and lake plains) resulting from glaciation (fig. 4) are composed of sediment types determined by their mode of deposition.

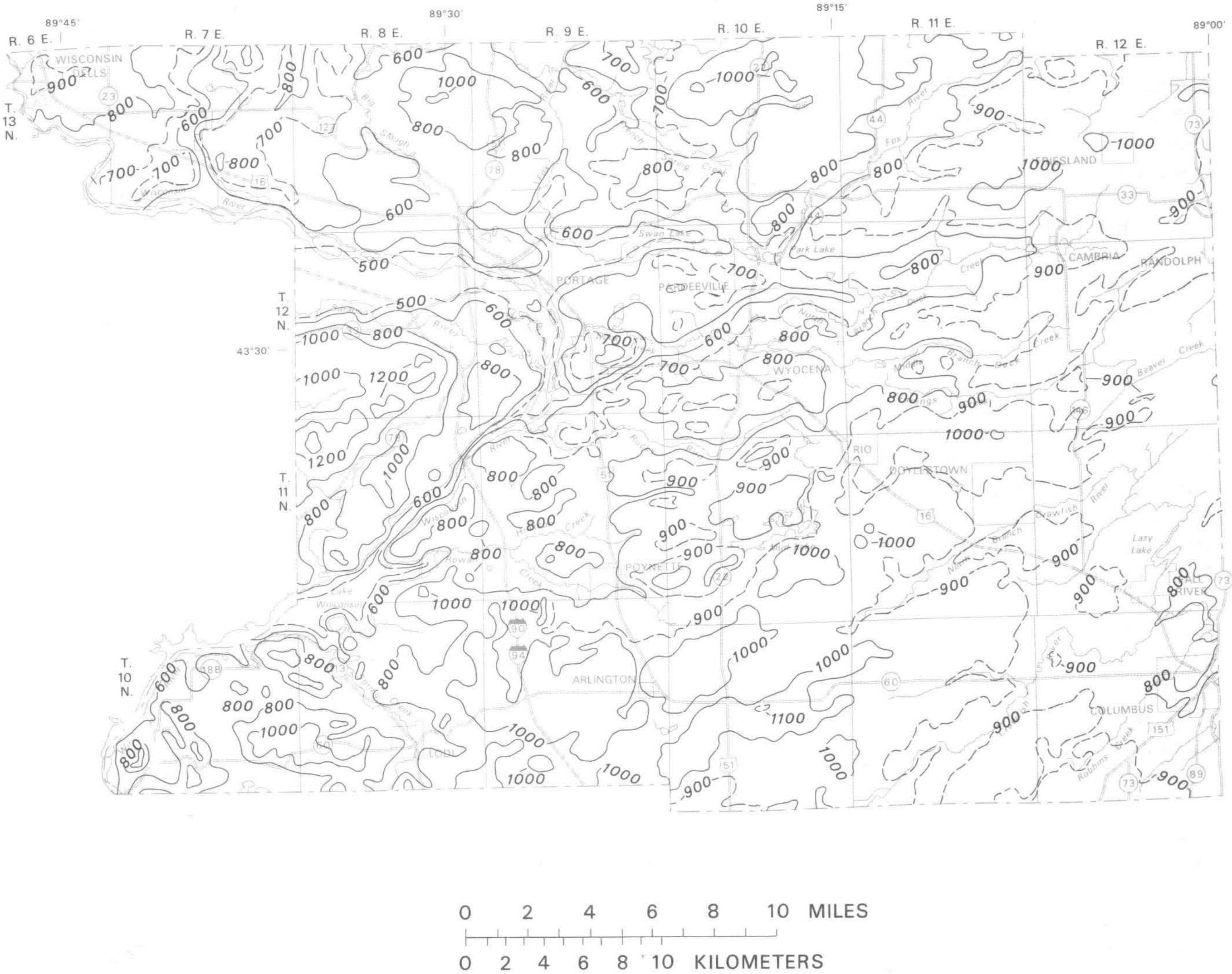
The end moraines were formed by deposition of unsorted material, ranging in size from clay to boulders and locally containing some stratified sand and gravel. They were deposited at the margin of the lobe during periods of standstill when the rate of melting equaled the rate of advance. The end moraines are typically ridges, with a rolling to hummocky surface and enclosed depressions or kettles. The end moraine in the northwest and southwest corners of the county marks the lobe's farthest advance (fig. 4). Several subparallel, discontinuous end moraines cross the county; the easternmost one trends approximately north-south through the center of the county.

The ground moraine (fig. 4) was deposited by glacial ice as a blanket of unsorted rock debris called till, ranging in size from clay to boulders. The ground moraine forms a gently undulating plain with moderate relief and no definite alinement. In some parts of the county, however, elongated hills of ground moraine, called drumlins, are alined in the direction of ice movement.

Outwash plains in the northwest and southwest corners of the county, consisting of stratified deposits of gravel, sand, silt, and clay, were laid down by water from the melting ice front. Lake-basin deposits in the area around Portage (fig. 4) are composed of sediment laid down in ephemeral fresh-water lakes.

Alluvium of Holocene age is found along streams in Columbia County and consists of unconsolidated materials laid down by running water and ranging in size from clay to gravel. Thin marsh deposits in low areas of Columbia County were formed by decaying vegetation and are primarily Holocene in age.

The unconsolidated deposits of Quaternary age range in thickness from zero in the few small areas of bedrock outcrops, mainly in the northwest part of the county, to more than 300 ft in the Wisconsin River valley and in a bedrock valley by Portage (fig. 5). The areas where bedrock crops out are too small to show in figure 5. Deposits of Quaternary age are thickest where glacial materials fill bedrock valleys.



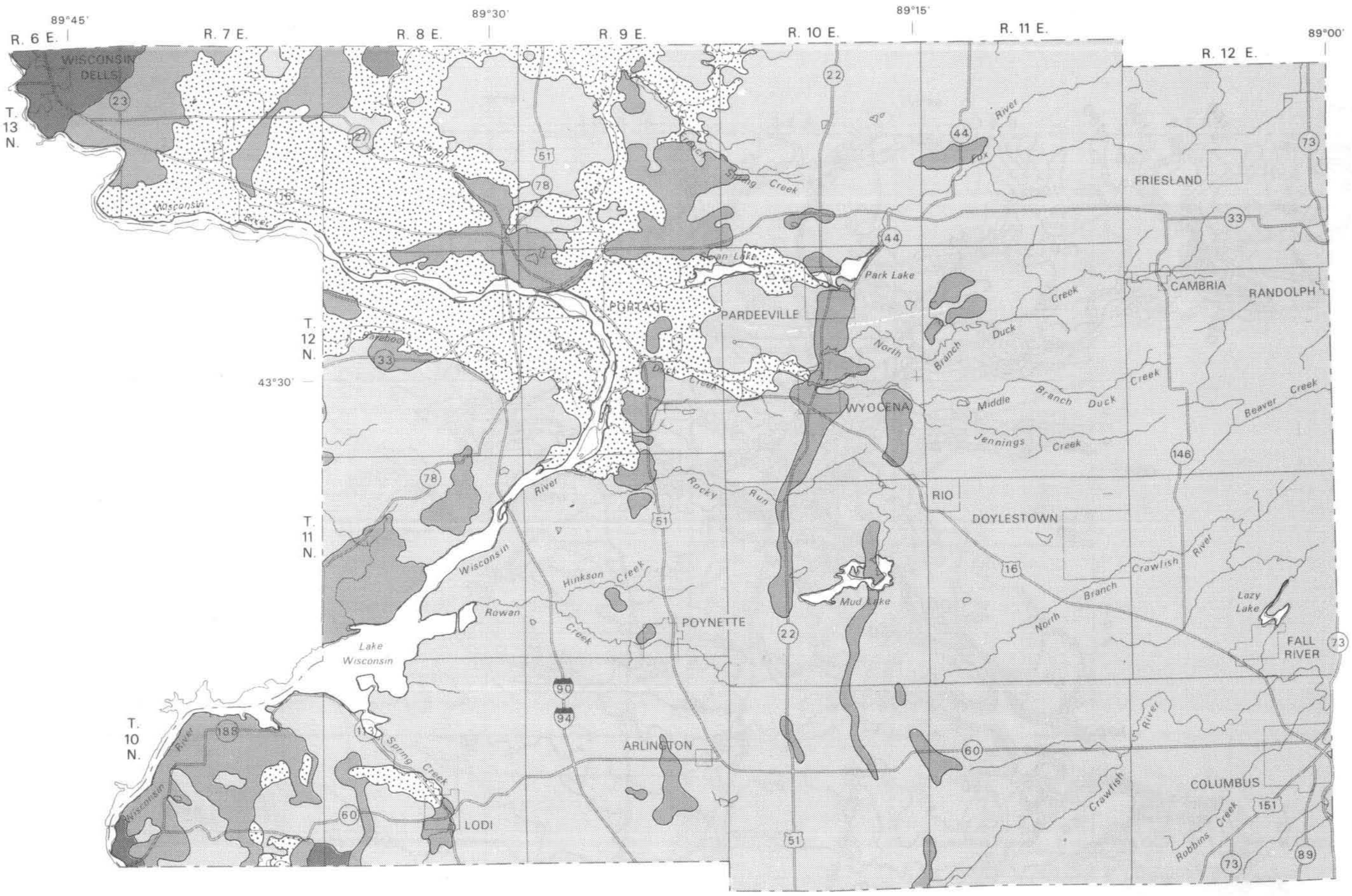
EXPLANATION

600

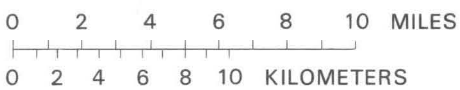
Bedrock contour

Shows altitude of bedrock surface. Contour interval 200 feet, with supplemental dashed 100 foot contours. Datum is mean sea level

Figure 3. Bedrock topography.



Geology from Hadley and Pelham (1976)



EXPLANATION

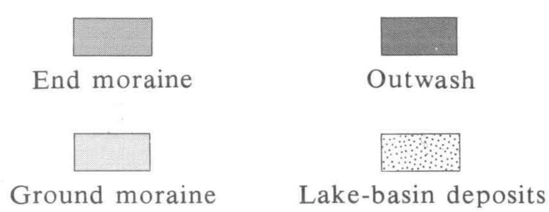
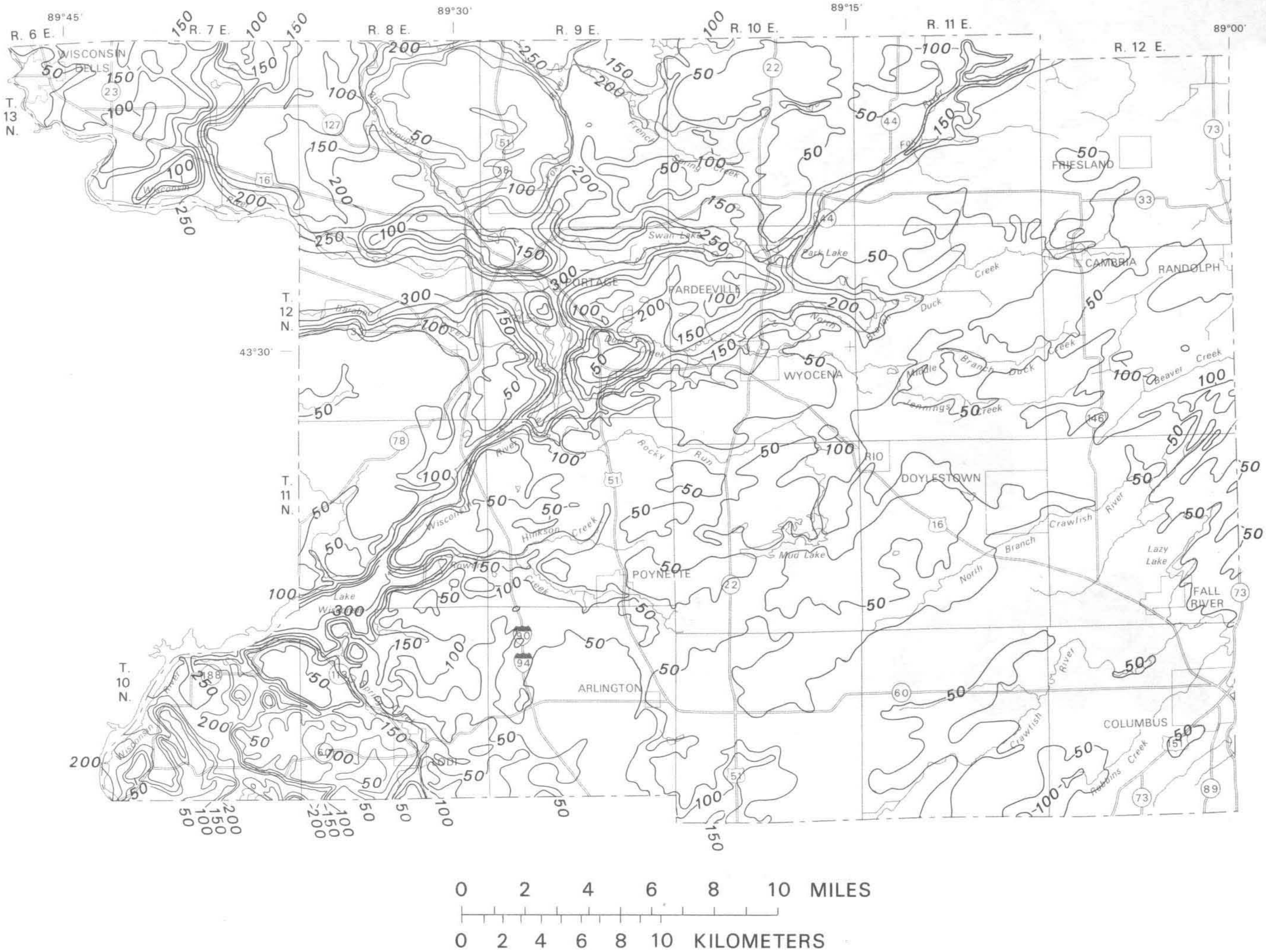


Figure 4. Glacial geology.



EXPLANATION

100

Line of equal thickness of unconsolidated materials

Interval 100 feet with supplemental 50 foot lines

Figure 5. Thickness of unconsolidated materials.

GROUND-WATER HYDROLOGY

PRINCIPAL AQUIFERS

The ground-water reservoir supplies potable water throughout Columbia County. The principal sources of ground water are the sand-and-gravel aquifer and the sandstone aquifer.

The sand-and-gravel aquifer consists of unconsolidated sand-and-gravel deposits in drift. These deposits occur over about half of the county, either at land surface or buried beneath less permeable drift.

The sandstone aquifer in Columbia County includes all rock of Cambrian and Ordovician age (table 1). The bottom of the sandstone aquifer is the surface of the Precambrian rocks. The aquifer is nearly continuous throughout the county and includes, from oldest to youngest, sandstones of Cambrian age and the Prairie du Chien Group, St. Peter Sandstone, and Galena-Platteville unit of Ordovician age. The Cambrian sandstones yield most of the water from this aquifer. The Prairie du Chien Group, St. Peter Sandstone and Galena-Platteville unit are important sources for domestic supply, primarily in the eastern third of the county. Precambrian rocks, where fractured, yield some water to wells. They are tapped only where the sand-and-gravel and sandstone aquifers are absent, and yield only enough water for domestic supplies.

WATER TABLE

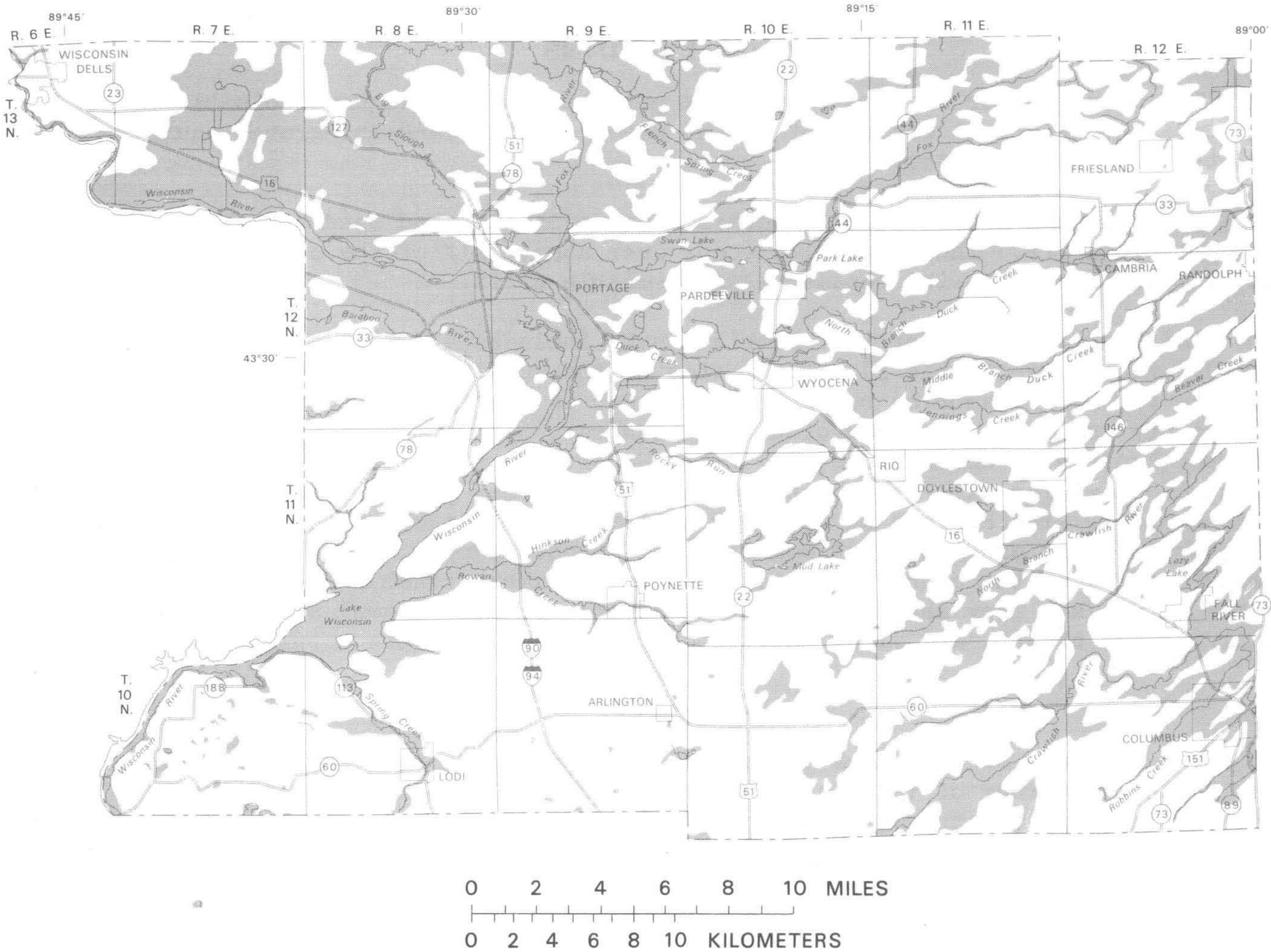
The altitude of the water table (pl. 1) ranges from less than 740 ft in the southwest corner of the county to more than 1,250 ft west of the Wisconsin River. In about two-thirds of the county the water table lies within the drift.

The water table generally has a shape similar to the land surface but has less relief. Where the land surface is high (hills), the water table is deep, and where the land surface is low (stream valleys), the water table is shallow. Areas where the depth to water below land surface is less than 10 ft are shown in figure 6.

RECHARGE AND MOVEMENT

The source of all ground water is precipitation. Between 1 and 10 in of precipitation annually infiltrates and recharges the ground-water reservoir. The amount of infiltration depends mainly on the type of rock material at the land surface. In areas covered by clayey till, recharge is lowest. It is greater in silty, sandy till and is greatest where sand and gravel are at the surface.

The general direction of ground-water flow within the drift or the shallow bedrock can be determined from the water-table contours (pl. 1). Ground water flows in the direction of decreasing head and moves approximately at right angles to the water-table contours. Movement is from recharge areas to discharge areas such as streams, lakes, and wetlands.



EXPLANATION

Area where depth to water is less than 10 feet

Figure 6. Areas where the depth to water is less than 10 feet.

Local, semiconfining layers form barriers to ground-water interchange between and within aquifers. For example, in the area southeast of Lake Wisconsin, clay confines ground water moving northwest toward the lake. As a result, many wells that penetrate the aquifer below the clay flow at the land surface.

GROUND-WATER AVAILABILITY

Large supplies of ground water for industrial, irrigation, and municipal use are available from the sand-and-gravel aquifer in the Wisconsin River valley and from the sandstone aquifer throughout most of the county. Small supplies for domestic use are available almost everywhere in the county.

THE SAND AND GRAVEL AQUIFER

The sand-and-gravel aquifer is made up of the permeable sediments within the saturated unconsolidated materials. The saturated thickness of unconsolidated materials, including the sand-and-gravel aquifer and impermeable clay and silt, ranges from zero in about one-third of the county to more than 300 ft in the Wisconsin River valley and in a bedrock valley east of Portage (fig. 7).

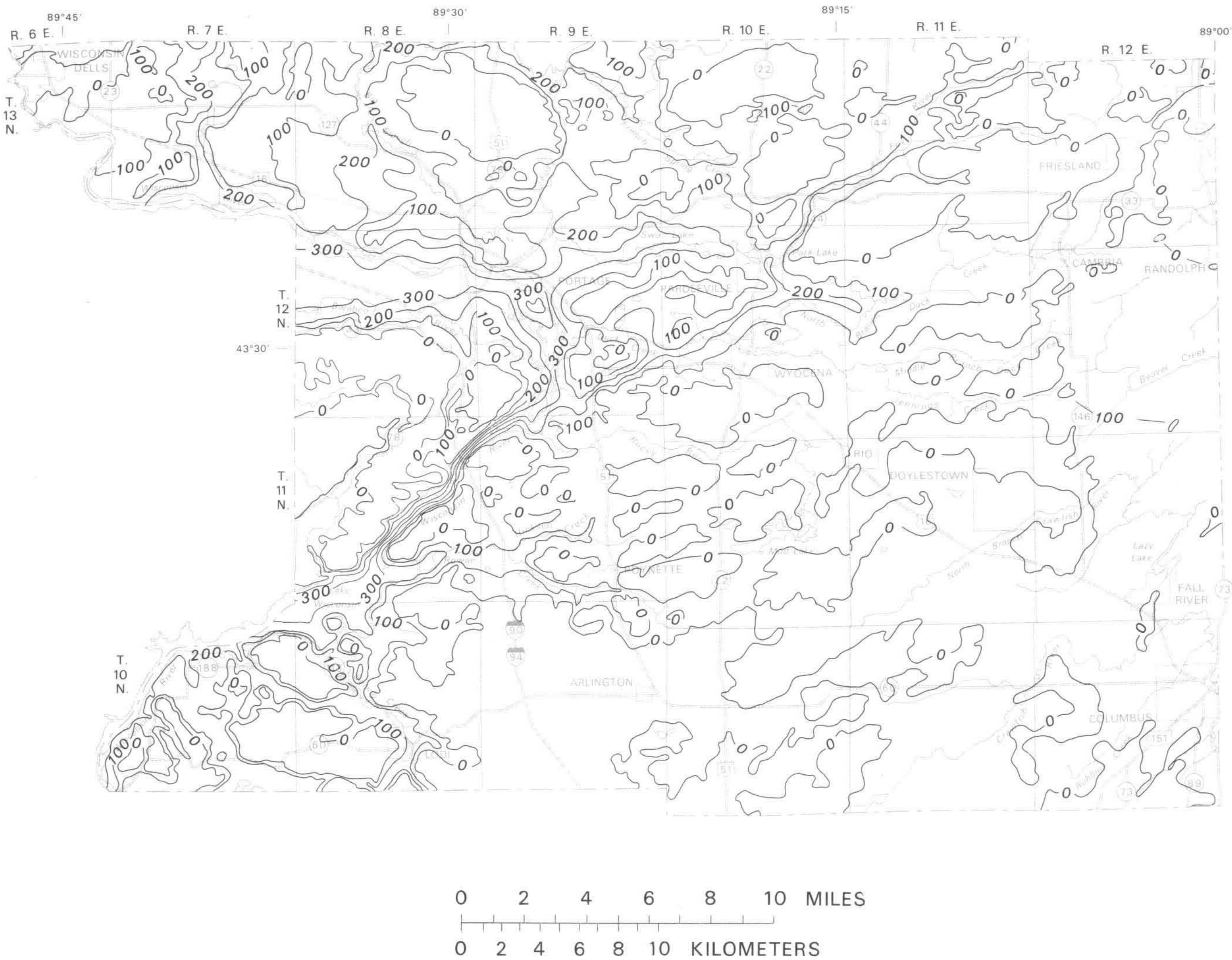
Water-bearing sand and gravel fills many bedrock valleys in the western half of the county. The aquifer may extend from the surface downward or be buried below relatively impermeable materials. Few high-capacity wells (capable of yielding at least 70 gal/min) have been developed in the sand and gravel. These few are screened, gravel packed, and about 100 ft deep. The highest well yield reported is 1,000 gal/min.

The saturated thickness of the sand-and-gravel aquifer ranges from 0 to more than 200 ft (fig. 8). This thickness includes all saturated, permeable, unconsolidated material between the land surface and the bedrock. It includes material at the surface, overlain by impermeable deposits, or occurring in beds separated by relatively impermeable deposits. All materials designated in well records as sand-size or larger are included.

The sand-and-gravel aquifer can yield more than 1,000 gal/min, enough to meet industrial or municipal demands, from thick, saturated parts of the aquifer in western Columbia County (fig. 9). Yields sufficient for domestic purposes are available elsewhere.

Figure 9 shows the probable well yields from the sand-and-gravel aquifer, based on the hydraulic conductivity and saturated thickness of the aquifer. The hydraulic conductivity was estimated from lithologic and specific-capacity data for 70 wells and ranges from 3 ft/d to more than 1,700 ft/d. It also is based on the following assumptions: the well is fully penetrating and screened in all parts of the aquifer, the well has an effective radius of 1 ft, well loss is negligible, and drawdowns do not exceed two-thirds of the saturated thickness of the aquifer.

The map is generalized and should be used with caution. To attain these yields wells may have to penetrate and be screened through the entire saturated



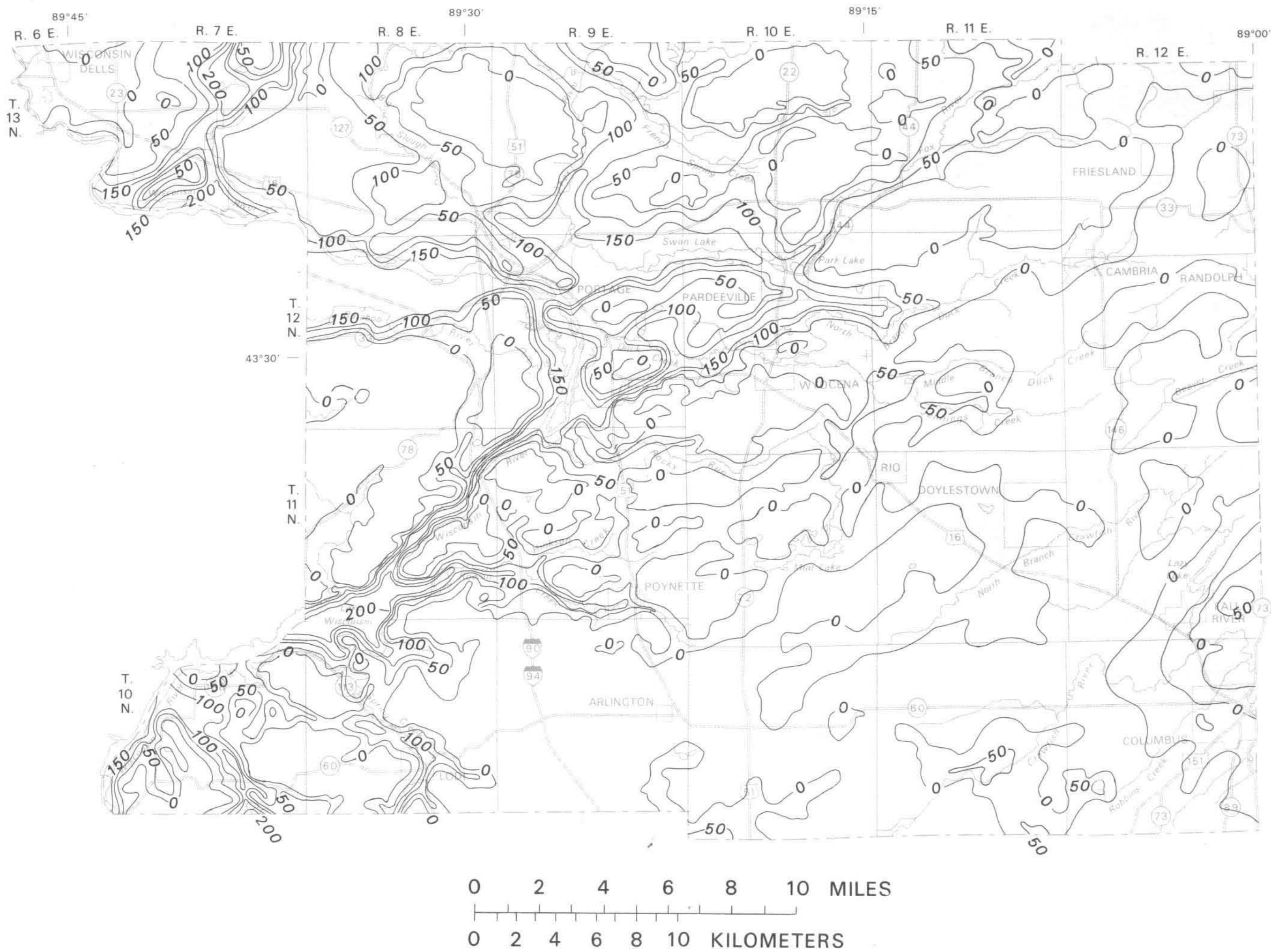
EXPLANATION

——— *100* ———

Line of equal saturated thickness of unconsolidated materials

Interval 100 feet

Figure 7. Saturated thickness of unconsolidated materials.



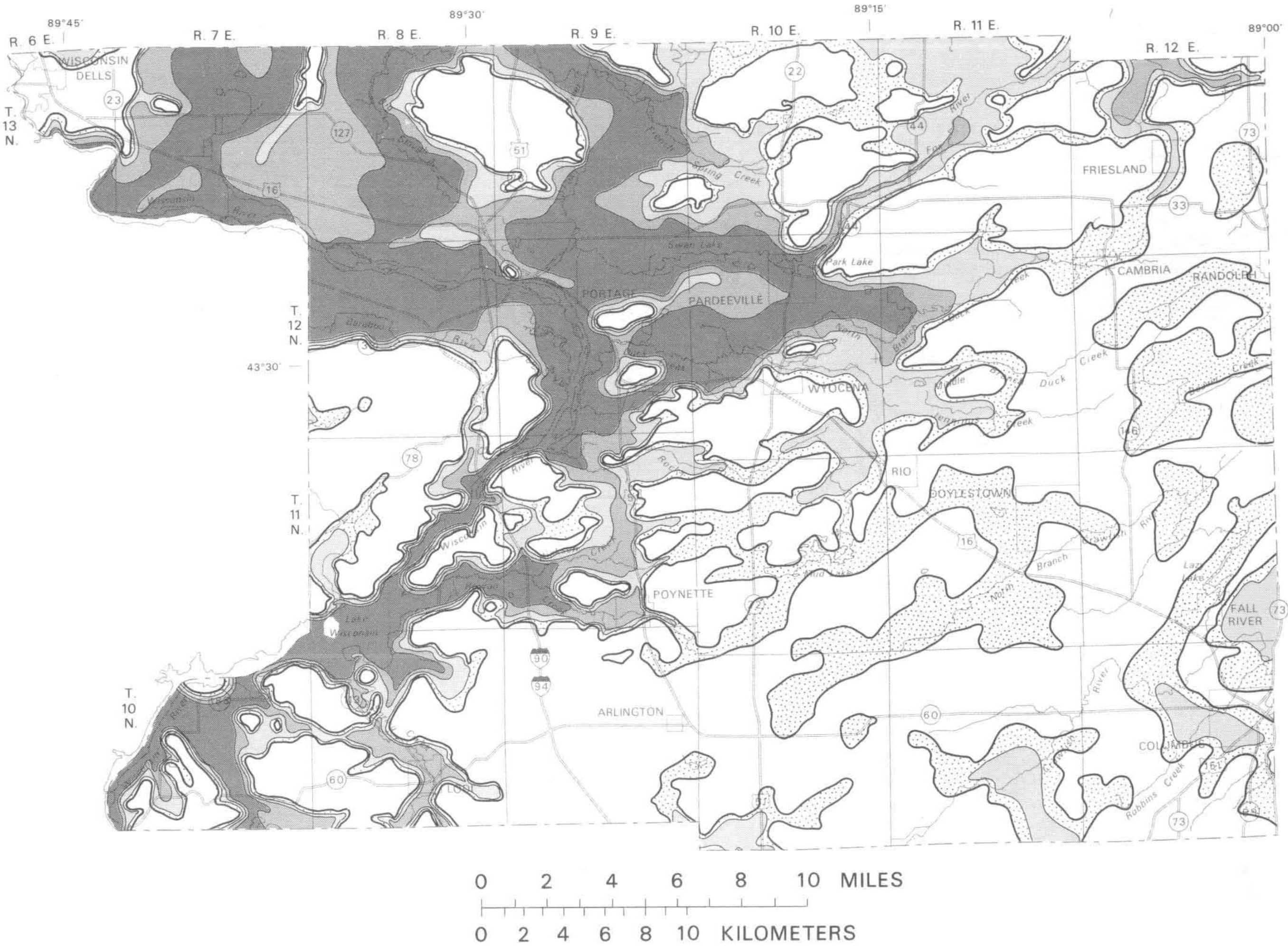
EXPLANATION

150

Line of equal saturated thickness of the sand-and-gravel aquifer

Interval 50 feet

Figure 8. Saturated thickness of the sand-and-gravel aquifer.



EXPLANATION

Probable well yields

Chances of more than 100 gallons per minute are poor

Chances of 500-1000 gallons per minute are good

Chances of 100-500 gallons per minute are good

Chances of more than 1000 gallons per minute are good

Boundary of saturated sand-and-gravel aquifer

Figure 9. Probably well yields from the sand-and-gravel aquifer.

thickness of sand and gravel (which may not be economically feasible to attain the yields indicated). Large-diameter wells may be required, especially for yields of more than 500 gal/min, and recharge may limit the ability of a well or well field to provide sustained yields at that level. In areas with less than 50 ft of saturated sand and gravel and in some small tributary valleys, probable well yields are mapped as less than 100 gal/min.

Wells finished in saturated unconsolidated deposits where sand and gravel are absent may yield some water, but sustained yields of more than a few gallons per minute are unlikely.

THE SANDSTONE AQUIFER

The sandstone aquifer underlying most of southern Wisconsin is an important source of water throughout its area. In Columbia County it is the principal source for most municipal, industrial, and private domestic supplies. Municipal or industrial wells pump between 150 and 1,000 gal/min, one well is reported to yield 1,850 gal/min. Domestic wells generally are pumped at less than 20 gal/min.

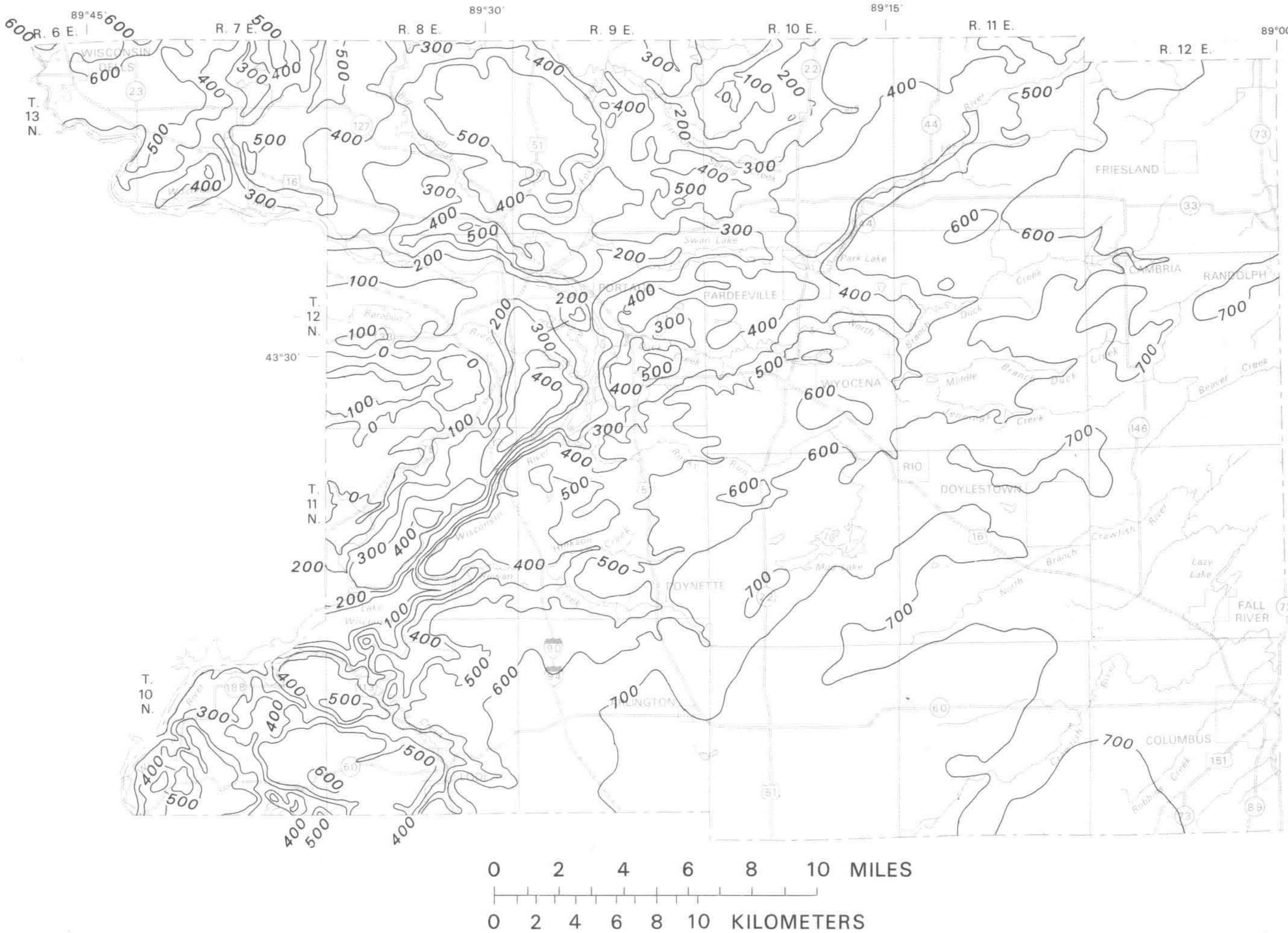
The saturated thickness of the sandstone aquifer ranges from zero west of the Wisconsin River and northwest of Pardeeville, where the aquifer is absent, to more than 700 ft in the south-central part of the county (fig. 10). Sharp decreases in saturated thickness occur where a valley is cut into the bedrock surface, or over highs in the Precambrian surface.

Large well yields can be developed from the sandstone aquifer because of its great saturated thickness and large head, greater than 700 and 750 ft, respectively, in the south-central part of the county (fig. 11).

Figure 12 shows the probable well yields from the sandstone aquifer, based on the hydraulic conductivity, which ranges from 0.1 to 160 ft/d, and on the saturated thickness of the aquifer. It also is based on the following assumptions: the well is fully penetrating and open to the entire thickness of aquifer, the well has an effective radius of 0.5 ft, well loss is negligible, and drawdowns do not exceed 40 percent of the available head. The ability of a well to provide sustained yields of more than 500 gal/min may be limited by available recharge.

GROUND-WATER QUALITY

Ground water in Columbia County is of good chemical quality for most uses. However, concentrations of nitrate nitrogen in water from some wells exceed the National Academy of Sciences, National Academy of Engineering (1972) recommended limit of 10 mg/L (milligrams per liter) for drinking water. The water is very hard, with a mean hardness of about 300 mg/L as calcium carbonate, and requires softening for some purposes. Concentrations of iron and manganese were highly variable. The mean concentrations of total and dissolved iron were about 600 μg/L (micrograms per liter) and 150 μg/L, respectively, as compared to mean concentrations of total and dissolved manganese of 40 μg/L and 50 μg/L, respectively, and exceed drinking water standards set by the National Academy of Sciences, National Academy of Engineering in 1972.



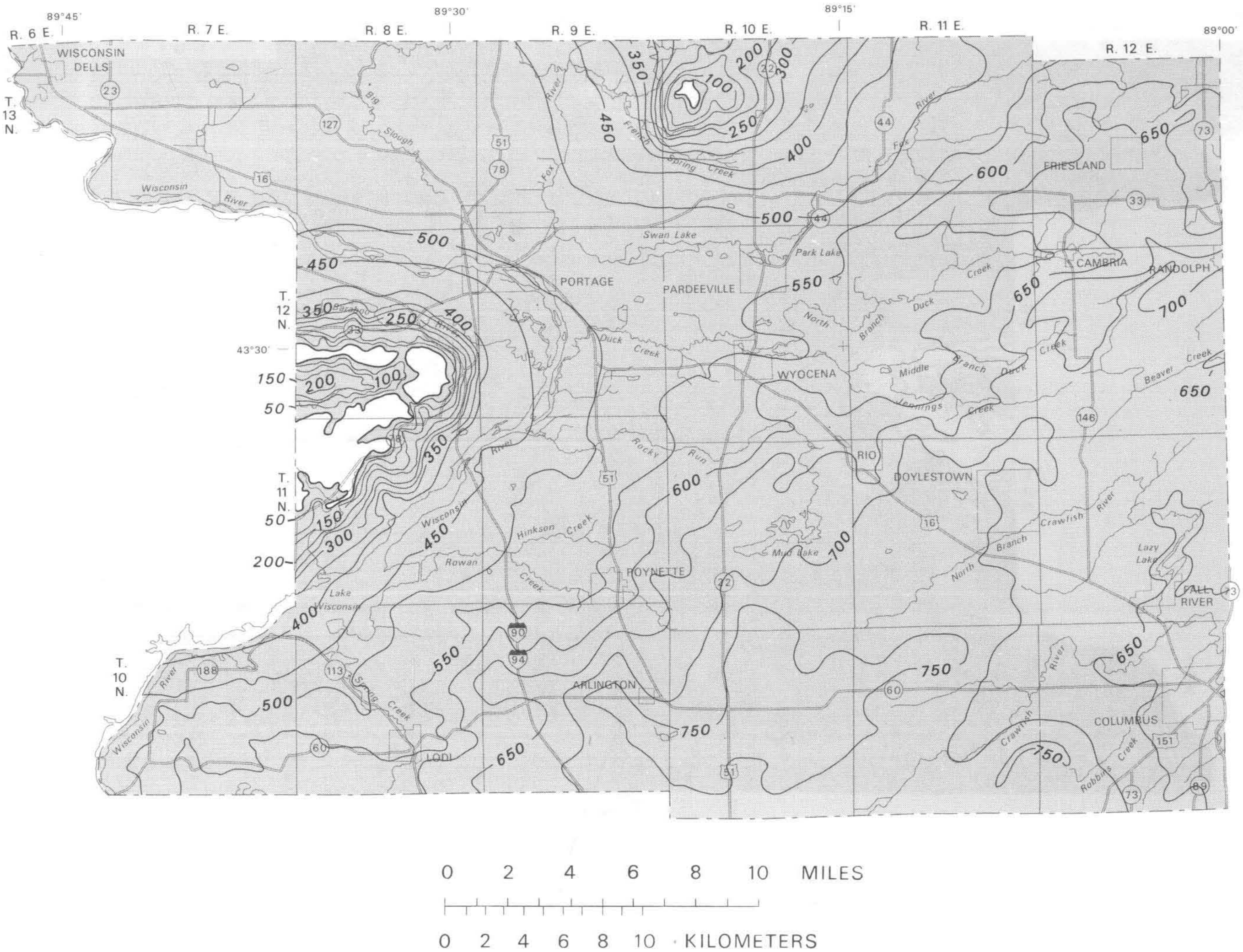
EXPLANATION

——— 500 ———

Line of equal saturated thickness of the sandstone aquifer

Interval 100 feet

Figure 10. Saturated thickness of the sandstone aquifer.



EXPLANATION

——— 600 ———

Line of equal total head

Shows total head above the base of the sandstone aquifer in 1974. Interval 50 feet

Area of saturated sandstone aquifer

Figure 11. Total head for the sandstone aquifer.

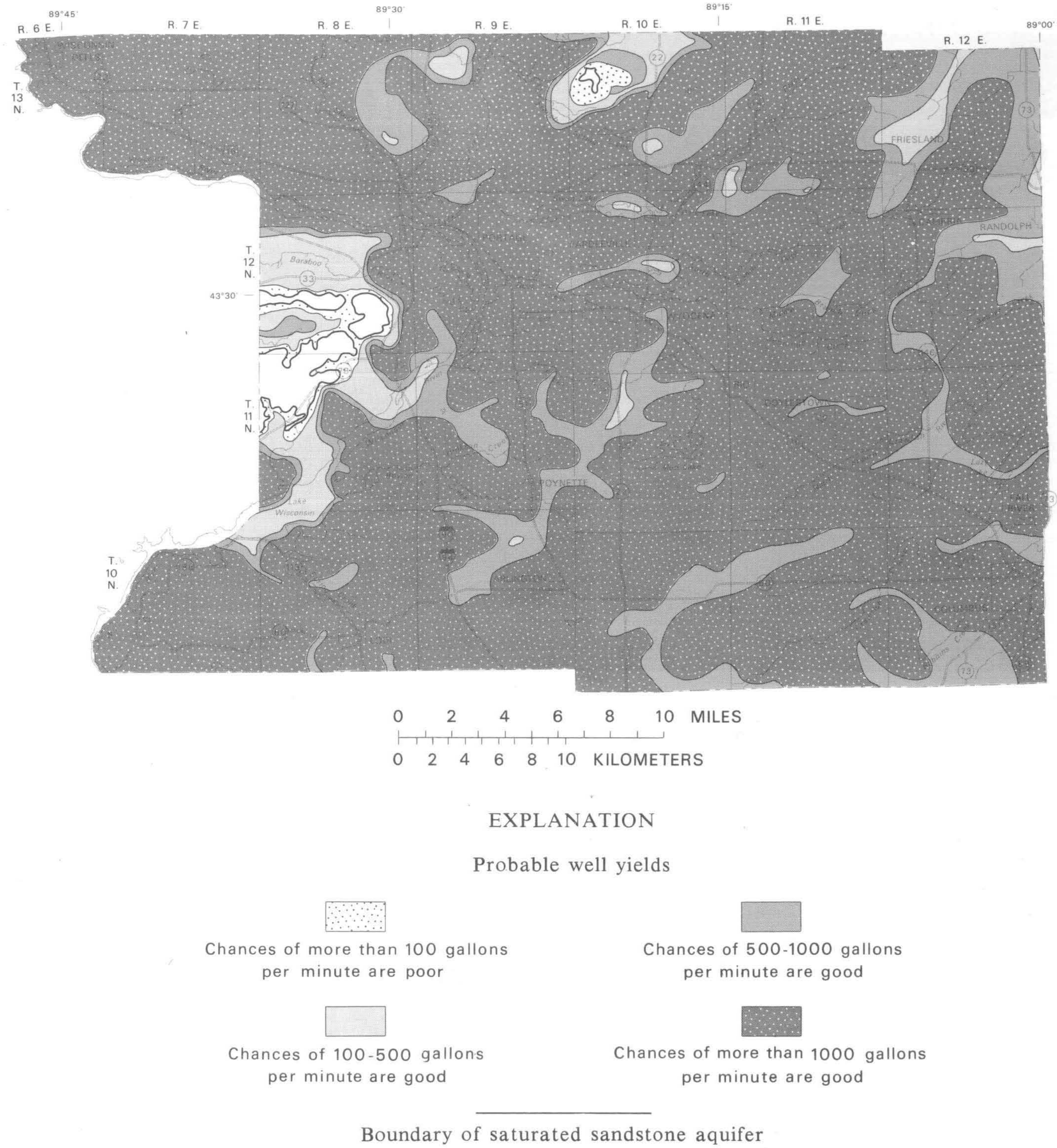


Figure 12. Probable well yields from the sandstone aquifer.

The ground water is of relatively uniform chemical character, reflecting, in part, the chemical composition of the rocks with which it is in contact. Calcium and magnesium make up about 50 and 45 percent, respectively, of the principal cations. Bicarbonate makes up 84 percent of the anions. The remaining cations and anions in solution are sodium, 4 percent; sulfate, 6 percent; chloride, 5 percent; and nitrate nitrogen, 4 percent. The chemical analyses of water from 95 randomly selected wells are summarized in table 2. Water samples were collected and analyzed according to U.S. Geological Survey methods (Brown and others, 1970). The mean concentration of total iron was more than four times that of dissolved iron. The difference probably was owing to the presence of iron coatings on sand grains in the sample or finely divided iron scale from well casings.

Mean concentrations of all constituents reported, except silica (17 mg/L), total iron (about 670 μg/L) and ammonium nitrogen (0.20 mg/L), were less in water from the sand-and-gravel aquifer than in water from the sandstone aquifer, based on seven samples collected from wells tapping the sand-and-gravel aquifer. High concentrations of ammonium nitrogen, a product of anaerobic microbial decomposition of organic wastes, are associated with seepage from septic tanks, cesspools, barnyards, and with other sources of organic wastes. Although concentrations of the principal cations and anions in solution in water from the sand-and-gravel aquifer are less, generally, than in water from the sandstone aquifer, the chemical characteristics of water from the two aquifers are similar, as shown by the modified Stiff diagrams in figure 13.

The dissolved-solids concentration in the ground water ranges from 93 to 810 mg/L; the mean concentration is 335 mg/L. Figure 14 shows that water with dissolved-solids concentrations greater than 400 mg/L occurs in the eastern and south-central parts of the county, an area underlain mostly by dolomitic rocks of Ordovician age. Ground water with dissolved-solids concentrations less than 400 mg/L occurs generally in the area underlain by Cambrian sandstone. There was little correlation (correlation coefficient 0.17) between dissolved-solids concentration and depth of well.

The hardness of ground water ranged from 73 mg/L in the Wisconsin Dells area to 630 mg/L near Cambria. The mean concentration was about 300 mg/L. Figure 15 shows that hardness greater than 400 mg/L occurs generally in the area underlain by rocks of Ordovician age. The correlation between hardness of ground water and depth of well was poor (correlation coefficient 0.19).

Concentrations of chloride in ground water ranged from 0.1 to 190 mg/L, with a mean of 11 mg/L. Concentrations of chloride greater than 10 mg/L were found near Arlington, Doylestown, and Cambria, as shown in figure 16. As with dissolved-solids concentration and hardness of water, the highest chloride concentrations seem to be related to rocks of Ordovician age. The mean chloride concentration of ground water from the sand-and-gravel aquifer (1.8 mg/L) is much lower than from the sandstone aquifer (12 mg/L). Although the data are few, this difference suggests that the source of the chloride is the rocks composing the sandstone aquifer.

Nitrate nitrogen concentrations in ground water sampled for this study ranged from 0.00 to 17 mg/L, with a mean concentration of 3 mg/L. Concentrations of nitrate nitrogen greater than 2.0 mg/L occurred throughout the county;

Table 2.--Summary of chemical analyses of water from selected wells in Columbia County, Wisconsin

{Chemical analyses in milligrams per liter, except iron and manganese which are in micrograms per liter}

Constituent	Number of analyses	Maximum	Minimum	Median	Mean[1]	Standard deviation
Dissolved silica (SiO_2)	95	28	7.9	16	15.8	3.4
Total iron (Fe)	72	6,000	20	100	603 (300)	1,125
Dissolved iron (Fe)	22	1,400	0	10	149 (300)	331
Total manganese (Mn)	73	350	0	10	37.8 (50)	57.7
Dissolved manganese (Mn)	23	200	0	20	52.4 (50)	77.6
Dissolved calcium (Ca)	95	120	16	60	63.0	18.7
Dissolved magnesium (Mg)	95	81	8.0	32	34.2	11.4
Dissolved sodium (Na)	95	96	.8	3.0	6.2	12.5
Dissolved potassium (K)	95	85	.4	.9	2.1	8.6
Ammonium nitrogen (N)	73	3.2	.00	.01	.08	.38
Bicarbonate (HCO_3)	95	517	85	293	318	87.0
Dissolved chloride (Cl)	95	190	.1	2.6	10.9 (250)	27.9
Dissolved sulfate (SO_4)	95	160	.8	15	19.4 (250)	22.9
Dissolved fluoride (F)	95	.4	.0	.1	.13 (1.2)	.08
Nitrate nitrogen (N)	95	17	.00	1.8	3.48 (10)	3.9
Nitrite nitrogen (N)	95	.04	.00	.00	.001	.006
Organic nitrogen (N)	73	.93	.00	.06	.08	.12

Table 2.--Summary of chemical analyses of water from selected wells in Columbia County, Wisconsin--Continued

{Chemical analyses in milligrams per liter, except iron and manganese which are in micrograms per liter}

Constituent	Number of analyses	Maximum	Minimum	Median	Mean[1]	Standard deviation
Total phosphorus (P)	95	0.23	0.00	0.01	0.02	0.03
Hardness, as $CaCO_3$	95	630	73	290	297	93.6
Noncarbonate hardness, as $CaCO_3$	95	220	0	26	37.3	38.0
Dissolved solids						
Residue on evaporation @ 180°C	95	810	93	309	335 (500)	131
Sum of constituents	95	759	88	305	325	118
Specific conductance (micromhos/cm @ 25°C)	94	1,400	134	555	581	208
pH (units)	95	8.0	6.9	7.4	7.3	.24
Temperature, degrees Celsius	94	13.0	8.5	10.5	10.7	.90

[1]Number in parentheses is the recommended limiting concentration in drinking water (NAS, NAE, 1972).

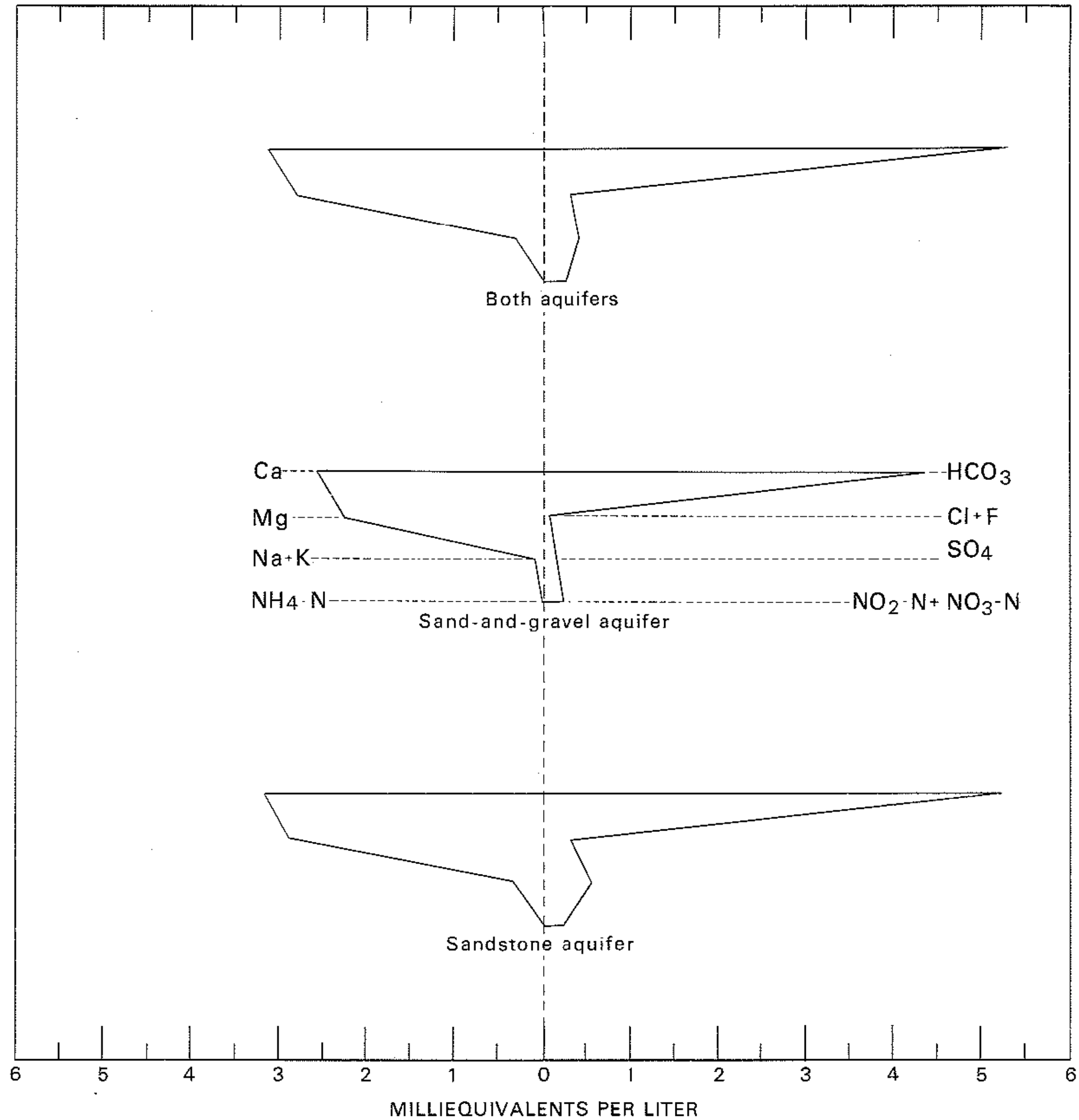
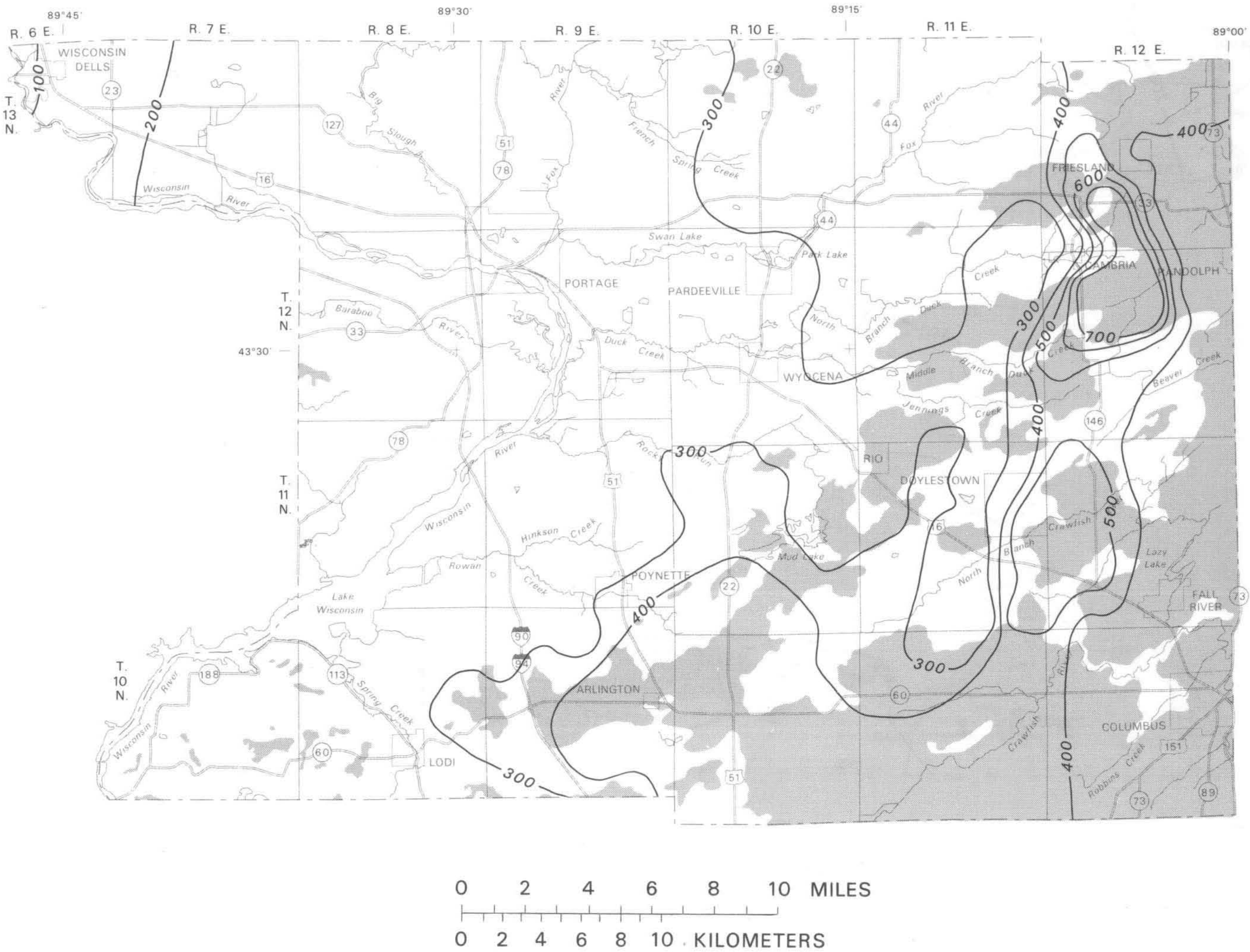


Figure 13. Modified Stiff diagrams showing the mean chemical character of ground water.



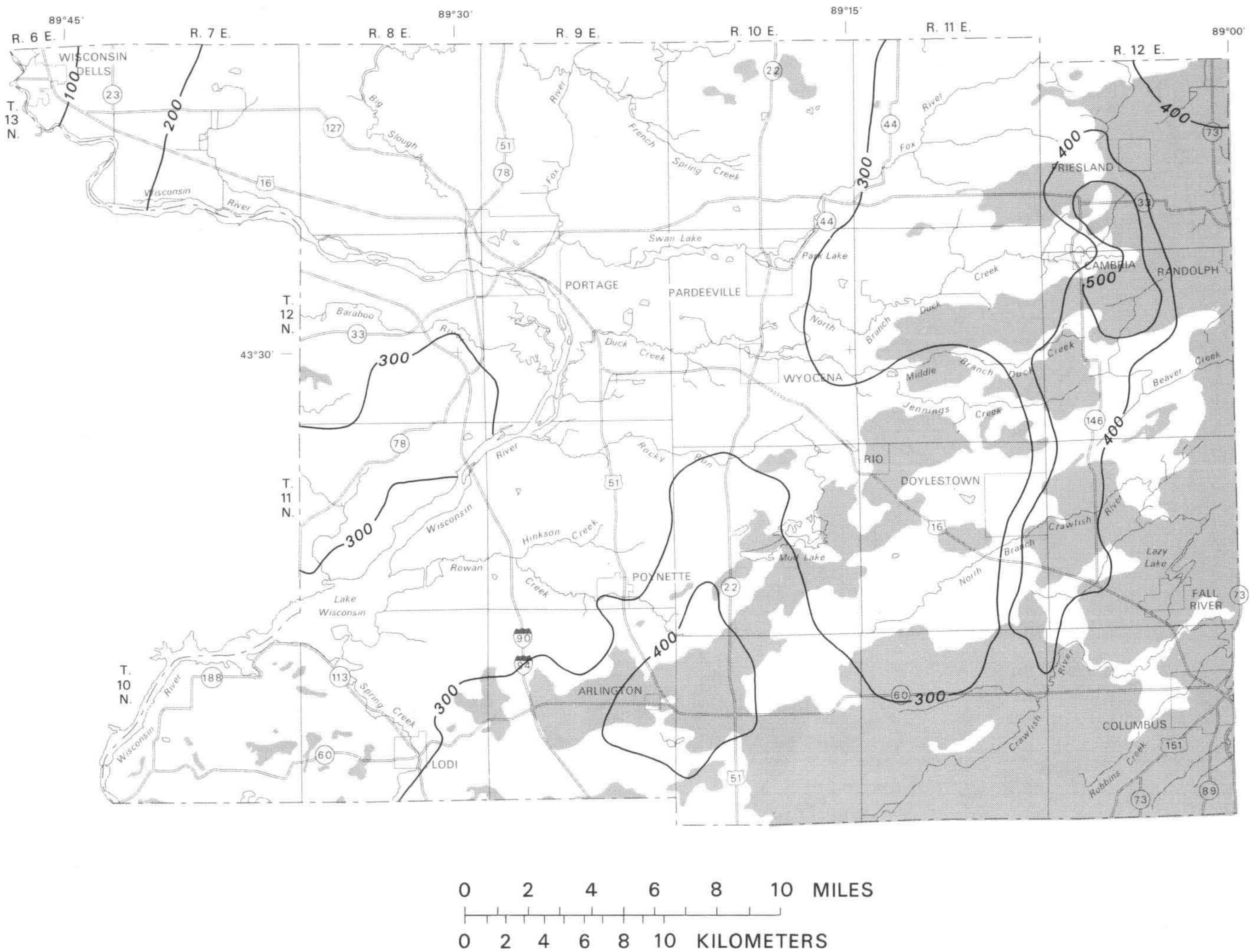
EXPLANATION

——— 500 ———

Line of equal dissolved-solids concentration, 1975
(residue on evaporation at 180°C)
Interval 100 milligrams per liter

Area of bedrock of Ordovician age

Figure 14. Distribution of dissolved solids in ground water.



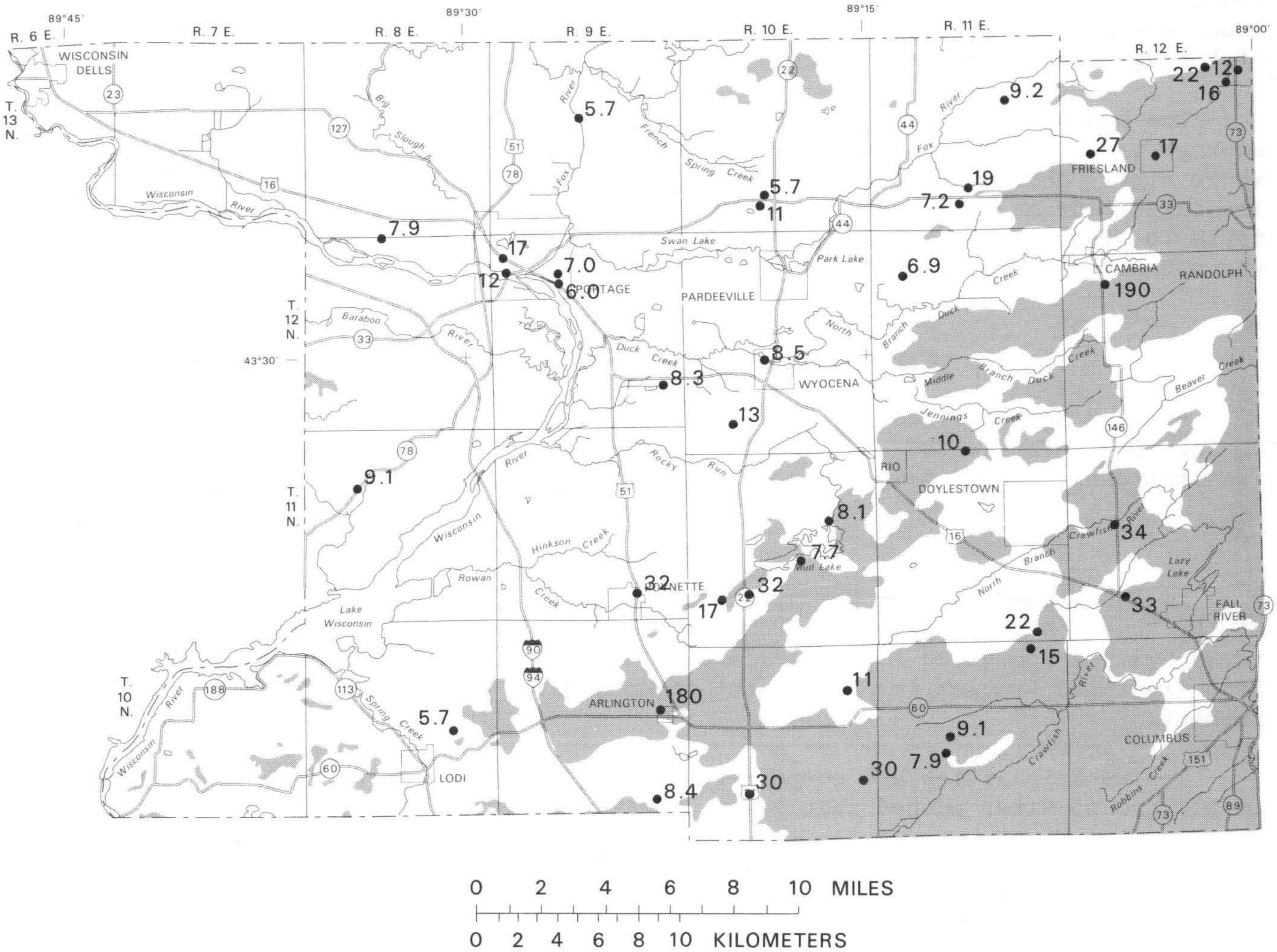
EXPLANATION

—————— 400 ——————

Line of equal hardness as calcium carbonate, 1975
Interval 100 milligrams per liter

[grey shading] Area of bedrock of Ordovician age

Figure 15. Distribution of hardness in ground water.



EXPLANATION

•9.1

Well

Number is chloride concentration in milligrams per liter, 1975

Area of bedrock of Ordovician age

Figure 16. Distribution of chloride in ground water.

concentrations greater than 10 mg/L, the recommended limit for drinking water (National Academy of Sciences, National Academy of Engineering, 1972) were found south of Doylestown, in the Marcellon area, southwest of Wyocena, north of Portage, and near North Leeds.

The potential for ground-water pollution from sources such as road-salt storage areas, septic tanks, barnyards, and others may be greater in areas where highly permeable sand and gravel are exposed at the land surface, where fractured bedrock is exposed or is thinly mantled with drift, or where the depth to water is less than 10 ft (fig. 6). However, ground-water pollution was not detected in this study.

GROUND-WATER PUMPAGE AND USE

About 5 Mgal/d of water was pumped from the aquifers in Columbia County during 1974. This water was used for residential, industrial, commercial, institutional, and municipal purposes, and for irrigation.

PUMPAGE

In 1974, pumpage from the sandstone aquifer (4.52 Mgal/d) made up 90 percent of the county's total pumpage. Pumpage from the sand-and-gravel aquifer (0.49 Mgal/d) accounted for 10 percent of the total. Some water is pumped from fractured Precambrian rocks, but it amounts to only a small fraction of a percent.

Ten municipalities and corporations pumped 3.67 Mgal/d in 1974, or 73 percent of all ground water pumped that year. Their average daily pumpages were:

Organization	1974 pumpage (Mgal/d)
City of Portage	1.00
City of Columbus	.66
Martin-Marietta Corp., Portage	.47
City of Wisconsin Dells	.45
City of Lodi	.26
Del Monte Corp., Arlington	.23
Michigan Fruit Canners, Inc., Cambria	.16
Village of Pardeeville	.16
Village of Fall River	.14
Village of Cambria	.14
TOTAL	3.67

USE

The amount of ground water used daily in 1974 for residential, commercial, industrial, institutional, and municipal purposes, and for irrigation is shown below.

Use	Amount used (Mgal/d)	Percent
Residential, public supply	1.15	23
Residential, private supply	.67	14
Commercial, public and private supply	.77	15
Industrial, public and private supply	1.52	30
Irrigation, private supply	.10	2
Institutional, private supply	.01	0
Municipal	.79	16
TOTAL	5.01	100

Residential water use includes all household uses in single-and multiple-family dwellings. In addition, it includes farm uses such as stock watering and equipment washing. Public-supply residential use is water used in dwellings on a public or private water-distribution system serving five or more homes. Water used in homes and farms with their own source of supply is considered private-supply residential use. Residential use by aquifer is tabulated below.

	Residential use	
Aquifer	Public supply (Mgal/d)	Private supply (Mgal/d)
Sand and gravel	0.17	0.09
Sandstone	.98	.58
TOTAL	1.15	.67

Commercial use refers to water used by businesses that do not fabricate or make a product; filling stations, retail stores, resorts, and restaurants are examples.

Industrial use refers to water used in plants that manufacture or fabricate products. In addition to use in the actual fabrication of a product, industrial water may be used for cooling, sanitation, air-conditioning, or irrigating the grounds of the plant. Industrial water use made up 30 percent of the ground water used in Columbia County in 1974.

Irrigation water is used for sprinkling golf courses and irrigating crops. Some public-supply water is used for lawn sprinkling, but this is considered municipal use.

Institutional water is used in the maintenance and operation of institutions such as schools, hospitals, rest homes, and prisons. Private-supply institutional use is the only type tabulated. Water for institutions served by public supplies is included under municipal water use. Self-supplied institutions accounted for only 0.2 percent of the ground water used in Columbia County in 1974.

Municipal water use is water pumped by municipalities but not sold to customers. It is used for flushing water lines, fire fighting, and sprinkling; in municipal buildings and institutions; and includes water lost in the distribution system. In 1974, 16 percent of the ground water pumped in the county was for municipal use.

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