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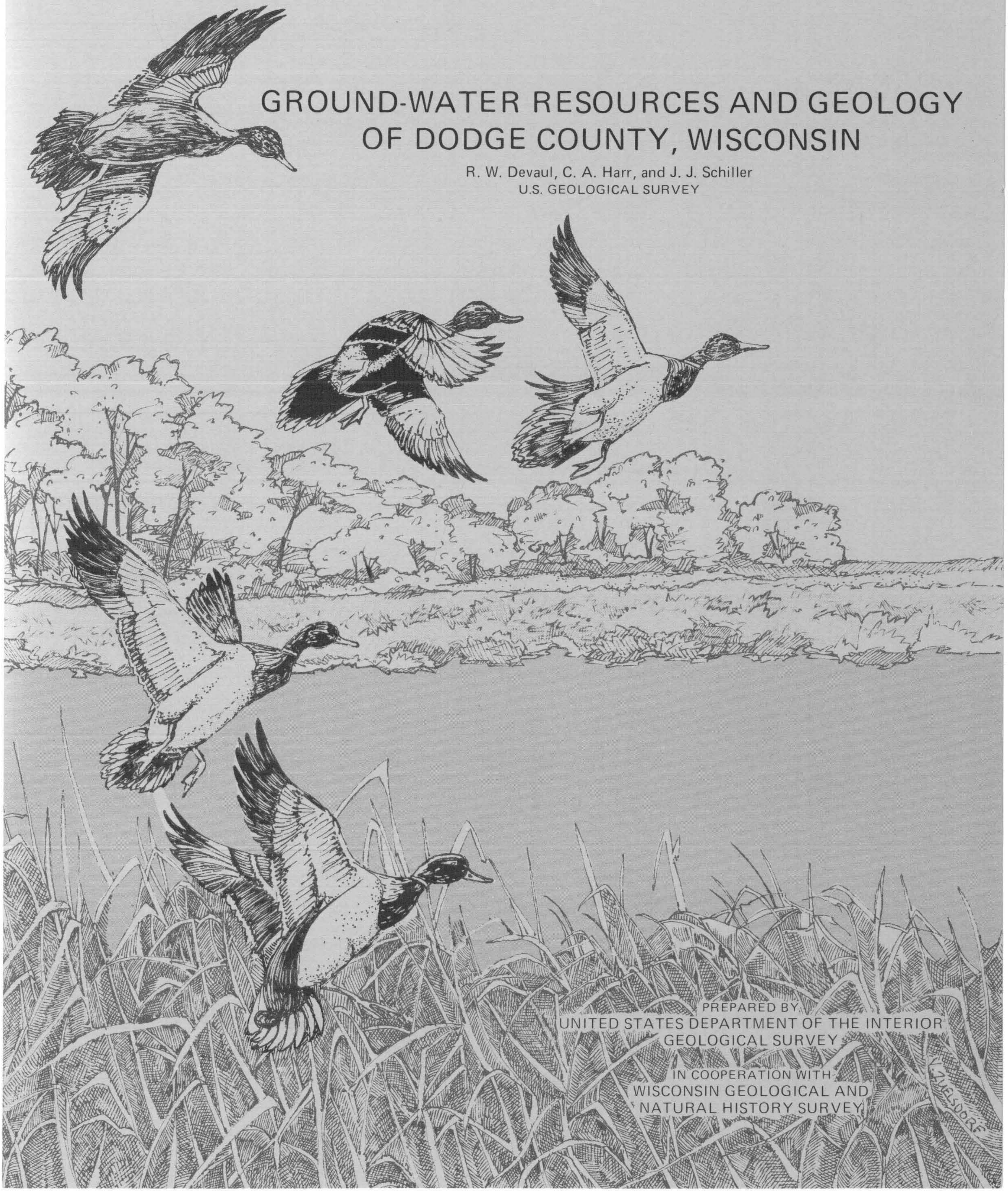
GROUND-WATER RESOURCES AND GEOLOGY OF DODGE COUNTY, WISCONSIN

R. W. Devaul, C. A. Harr, and J. J. Schiller
U.S. GEOLOGICAL SURVEY



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UNITED STATES DEPARTMENT OF THE INTERIOR
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IN COOPERATION WITH
WISCONSIN GEOLOGICAL AND
NATURAL HISTORY SURVEY

GROUND-WATER RESOURCES AND GEOLOGY OF DODGE COUNTY, WISCONSIN

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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.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
and
UNIVERSITY OF WISCONSIN–EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY
M. E. Ostrom, Director and State Geologist
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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
gallon per day (gal/d)	3.785	liter per day (L/d)
foot per day (ft/d)	0.3048	meter per day (m/d)

GROUND-WATER RESOURCES AND GEOLOGY OF DODGE COUNTY, WISCONSIN

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ABSTRACT

The ground-water resources of Dodge County were evaluated to aid planners in meeting the needs resulting from growth in population and industry. The sand-and-gravel, Silurian dolomite, Galena-Platteville, and sandstone aquifers are the principal sources of ground water. Probable well yields from the sand- and-gravel aquifer and the Galena-Platteville aquifer range from 100 to 500 gallons per minute. Probable well yields for the Silurian dolomite, which depend in part on the degree of fracturing, are about 100 gallons per minute. Probable well yields from the sandstone aquifer range from less than 100 to more than 1,000 gallons per minute.

Calcium and bicarbonate are the principal ions in ground water in Dodge County. The water is very hard, and the concentration of iron commonly exceeds the recommended limit for drinking water and the desirable concentration for water used for high-pressure boiler feed, some food processing, and leather finishing industries. The ground water generally is of suitable chemical quality for domestic, agricultural, and most industrial purposes.

In 1979, an average of about 13 million gallons of ground water was pumped daily for residential, industrial, commercial, irrigation, stock watering, and other purposes.

INTRODUCTION

Dodge County is in southeastern Wisconsin (fig. 1). The population of the county increased from 69,004 in 1970 to 75,064 in 1980 (oral commun., Demographic Services Section, Wisconsin Department of Administration, 1982). This growth in population has increased demands on the water resources of the county.

The purpose of this cooperative study between the U.S. Geological Survey and the University of Wisconsin-Extension, Geological and Natural History Survey, was to define the occurrence, movement, availability, quality, and use of ground water, and related geology in Dodge County. The study is intended to aid in the planning, development, and management of the ground-water resources.

The scope of the study included collection and analysis of ground-water samples and well logs; and water-level, water-use, pumpage, and aquifer-test data to describe the hydrogeology of the county.

The authors thank the many municipal and county officials, State agencies, water-well drillers, and individual well owners who assisted this study by providing well and water information and the many citizens who allowed access to their wells for measuring water levels or for collecting water sam-

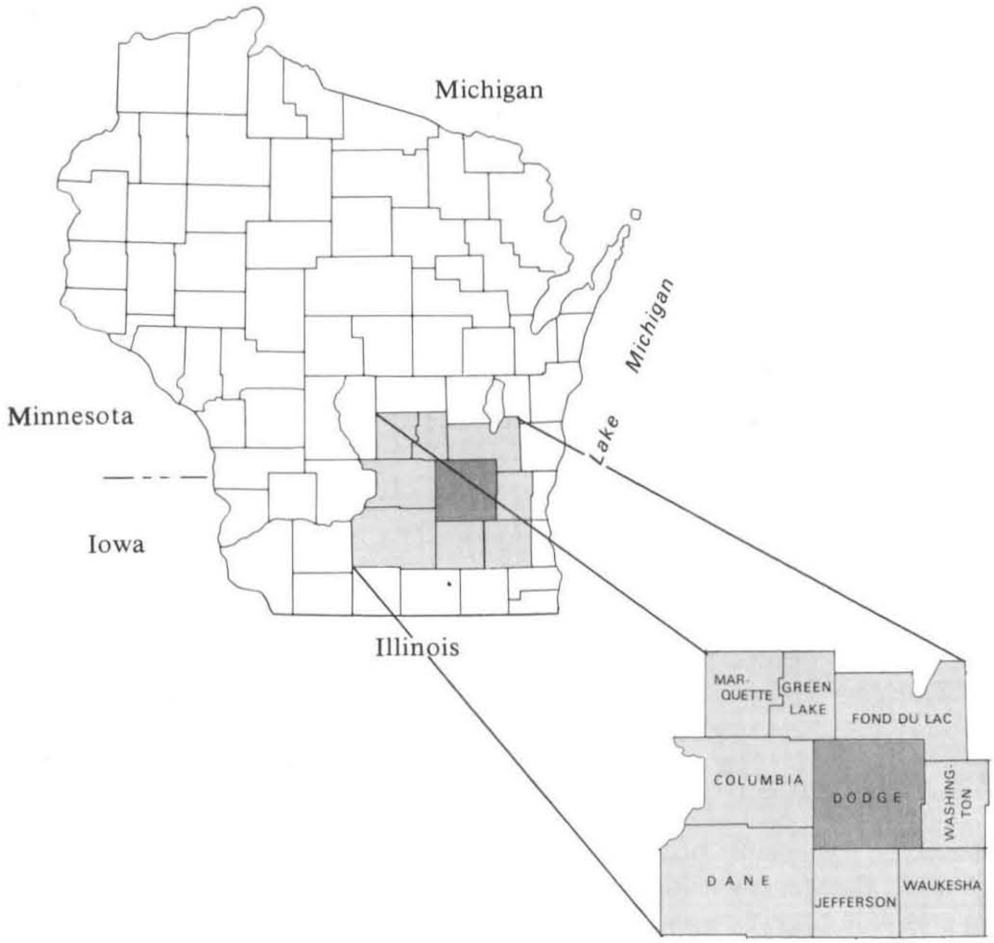


Figure 1. Location of Dodge County in Wisconsin.

ples for chemical analysis. The authors also thank the Wisconsin State Laboratory of Hygiene for several chemical analyses of ground water, and the Wisconsin Public Service Commission for pumpage records.

GEOLOGY

The rocks that control the movement and storage of ground water in Dodge County range from basement rock of Precambrian age to glacial and fluvial deposits of Quaternary age (table 1). The bedrock, from oldest to youngest, comprises Precambrian crystalline rocks, Cambrian sandstone, Ordovician dolomite, sandstone, and shale, and Silurian dolomite. The Cambrian, Ordovician and Silurian rocks are layered sedimentary beds that dip toward the east and southeast. Erosion of these rocks has left a bedrock surface in which the formations increase in age from east to west (fig. 2). Many of these rocks underlie only parts of the county.

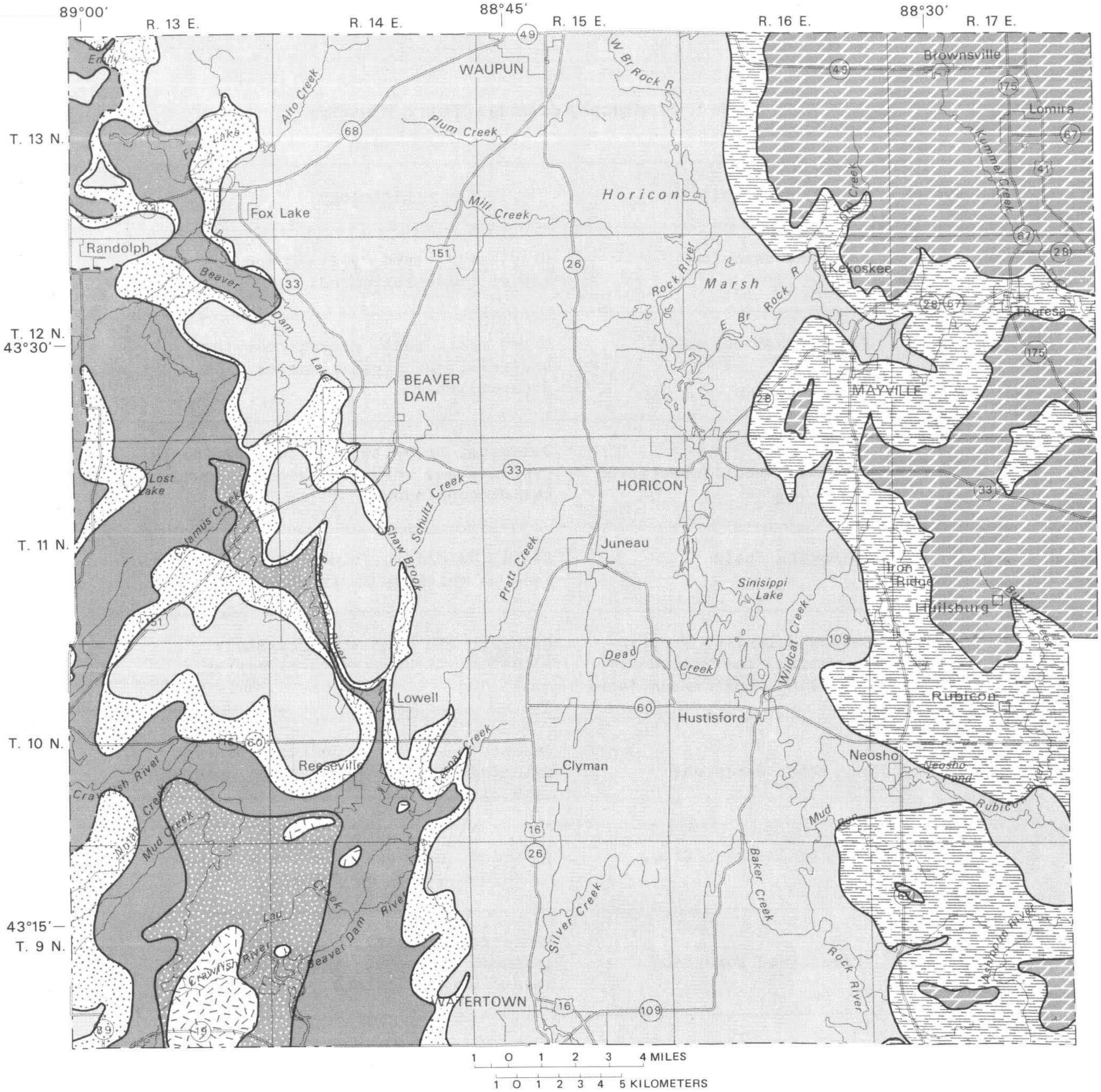
The bedrock is overlain by glacial drift throughout most of the county.

Precambrian Rocks

Crystalline rocks, mostly quartzite, of Precambrian age underlie all of Dodge County. Regionally, the Precambrian rock surface slopes to the east. Its altitude ranges from about 200 ft above mean sea level in the southwestern part of the county to about 250 ft in the northeastern corner of the county (about 1,280 ft below land surface). Smith and Hartnell (1978) show a ridge of the Precambrian rock surface extending eastward in an arc from near Portland, where the rocks crop out at an altitude of

Table 1. Stratigraphy of Dodge County, Wisconsin.

System	Rock unit	Lithology
Quaternary	Holocene deposits	Clay, silt, sand, gravel, and organic matter, unconsolidated.
	Pleistocene deposits	Clay, silt, sand, gravel, cobbles, boulders, and organic matter, unconsolidated.
Silurian	Dolomite, undifferentiated	Dolomite, brown to gray and gray shale. Crevices and solution channels abundant but discontinuous.
Ordovician	Maquoketa Shale	Shale, dolomitic, blue-gray; dolomitic beds as thick as 25 ft at the top.
	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	Dolomite and some slightly shaly dolomite, light-gray to blue-gray
	St. Peter Sandstone	Sandstone, fine- to medium-grained; dolomitic in places, shaly at base in some places, white, light-gray, or pink.
	Prairie du Chien Group	Dolomite, tan, gray, or white; some sandstone and sandy dolomite.
Cambrian	Trempealeau Formation	Sandstone, very fine- to medium-grained; dolomite, light-gray, interbedded with siltstone.
	Franconia Sandstone	Sandstone, very fine- to medium-grained; siltstone or dolomite; sandstone, dolomitic at base, medium- to coarse-grained.
	Galesville Sandstone	Sandstone, fine- to medium-grained, light gray.
	Eau Claire Sandstone	Sandstone, dolomitic, fine- to medium-grained, light-gray to light-pink; some shale beds.
	Mount Simon Sandstone	Sandstone, fine- to coarse-grained, mostly medium, white to light-gray; some dolomitic beds, some interbedded shale.
Precambrian	Precambrian rocks, undifferentiated	Crystalline rocks, mostly quartzite, light-gray to light-pink, micaceous; granite gneiss, gray or light pink, micaceous; native copper in places.



EXPLANATION

Contact
Dashed where approximate

SILURIAN

Dolomite, undifferentiated
Massive cherty dolomite, and silty, shaly dolomite

ORDOVICIAN

Maquoketa shale
Shale and shaly dolomite

Galena, Decorah, and Platteville Formations, undifferentiated
Cherty dolomite

St. Peter Sandstone
Mostly sandstone.

Prairie du Chien Group
Mostly dolomite

CAMBRIAN

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

PRE-CAMBRIAN

Crystalline rock

Figure 2. Bedrock geology.

860 ft, to the Huilsberg-Rubicon area, where the rock surface altitude is about 450 ft (about 560 ft below the land surface).

Cambrian Rocks

Sedimentary rocks of Cambrian age overlie the Precambrian rocks everywhere except in small areas in southwestern Dodge County and probably along the ridge of the Precambrian rocks, which may have stood above Cambrian seas. The Cambrian rocks predominantly very fine- to medium-grained sandstones, include some interbedded shale, dolomite, and siltstone. The Cambrian rocks, undifferentiated and called "Cambrian sandstone" in this report, consist of five formations--from oldest to youngest, the Mount Simon, Eau Claire, Galesville, and Franconia Sandstones, and the Trempealeau Formation (table 1).

The Cambrian sandstone is overlain by younger rocks in all but small areas in southwestern and west-central Dodge County, where it is the uppermost bedrock unit (fig. 2). The sandstone thickens from zero near Portland to more than 500 ft in the northeastern part of the county.

Ordovician Rocks

Sedimentary rocks of Ordovician age overlie the Cambrian sandstone in all but small areas in southwestern and west-central Dodge County (fig. 2). They are the uppermost bedrock unit in most of the county. The Ordovician rocks include, from oldest to youngest, the Prairie du Chien Group; St. Peter Sandstone; Platteville and Decorah Formations and Galena Dolomite, undifferentiated; and the Maquoketa Shale. The Prairie du Chien Group, Platteville and Decorah Formations and Galena Dolomite are predominantly dolomite but contain some sandstone, sandy dolomite, and shaly dolomite. The St. Peter Sandstone is fine- to medium-grained sandstone, dolomitic in places, and shaly at the base in some places. The Maquoketa Shale is a blue-gray dolomitic shale.

Silurian Rocks

Undifferentiated dolomite of Silurian age is the uppermost bedrock unit and is present in only parts of the eastern third of Dodge County (fig. 2).

Bedrock Surface

The topography of the bedrock surface (fig. 3) was formed by preglacial and glacial erosion. The altitude of the bedrock surface ranges from less than 700 ft above mean sea level in bedrock valleys underlying the Beaverdam, Crawfish, and E. Branch Rock Rivers to more than 1,100 ft at bedrock highs of the Silurian dolomite in the eastern part of the county. Bedrock crops out at several places in southwestern Dodge County (fig. 3).

Quaternary Deposits

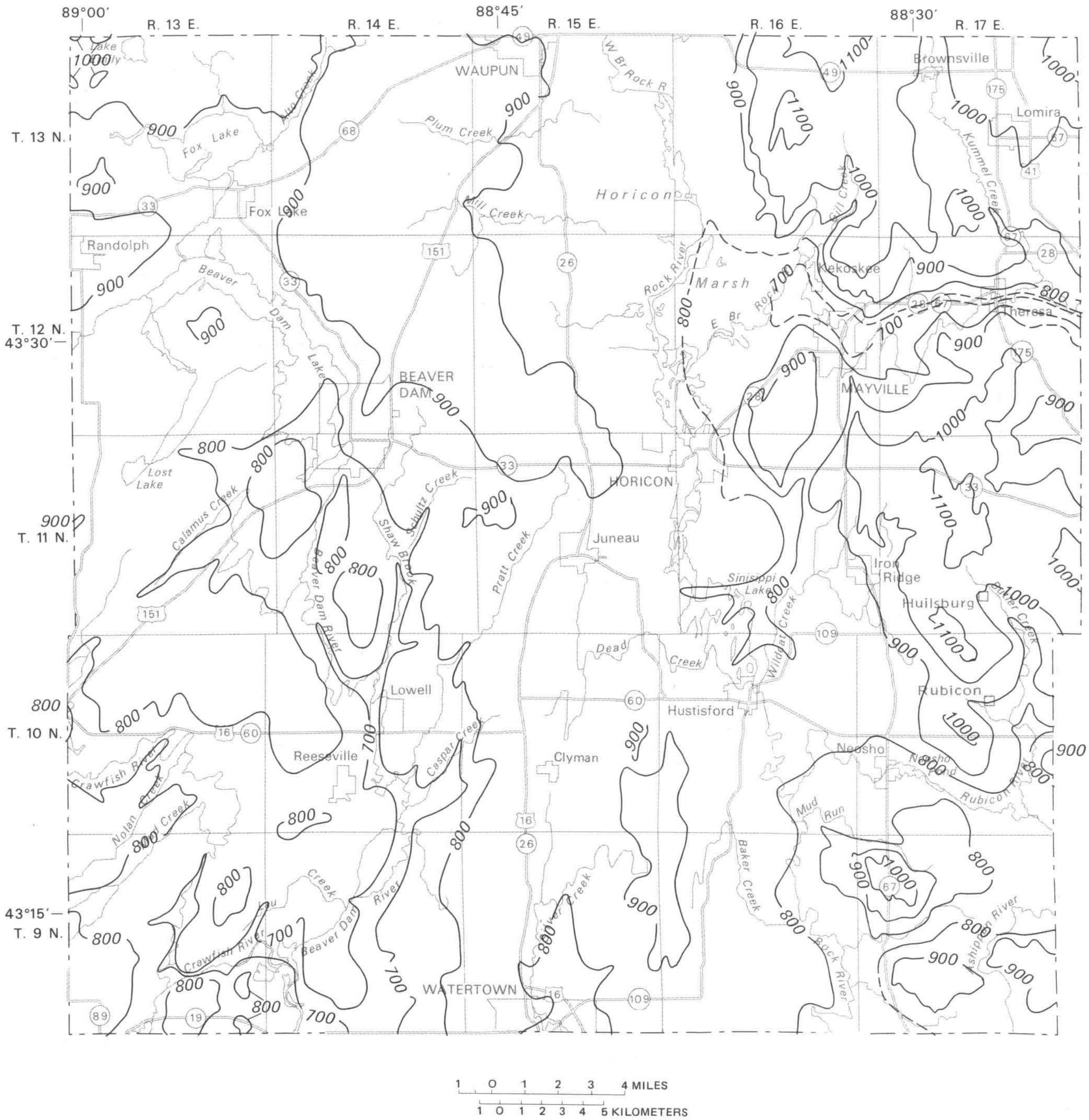
Unconsolidated deposits of Quaternary age overlie the bedrock throughout Dodge County except at a few sites where bedrock crops out at the surface. Most of these deposits are of glacial origin but some are stream-alluvium and lake-basin deposits (fig. 4). Their mode of deposition determines the grain size and sorting, as well as the resultant glacial landforms.

The end moraines in northern and southwestern Dodge County (fig. 4) were formed by deposition at the margins of the Green Bay ice lobe. The end moraine in the southeast is part of the Kettle Moraine formed by deposition between margins of the Green Bay and Lake Michigan lobes. The end moraines are composed of unsorted material (till), ranging in size from clay to boulders and locally containing some stratified sand and gravel. The Kettle Moraine typically contains more stratified sand and gravel than the end moraines of the Green Bay lobe. End moraines commonly are topographic ridges of rolling to hummocky surfaces and closed depressions or kettles.

The extensive ground moraine was deposited under moving glacial ice or as a residue from melting ice. It is composed of unsorted till ranging in size from clay to boulders. The surface of the ground moraine is gently undulating with elongated hills (drumlins) aligned in the direction of ice movement.

Outwash consisting of stratified clay, silt, sand, and gravel was deposited by water from the melting glacial front (fig. 4). Clay and silt compose the lake-basin deposits in the Horicon Marsh area.

Alluvium of Holocene age, ranging in size from clay to gravel, was deposited by running water along



EXPLANATION

——*800*——

Bedrock contour

Shows altitude of bedrock surface.
Dashed where approximate.
Contour interval 100 feet.
Datum is sea level.

Figure 3. Bedrock topography.

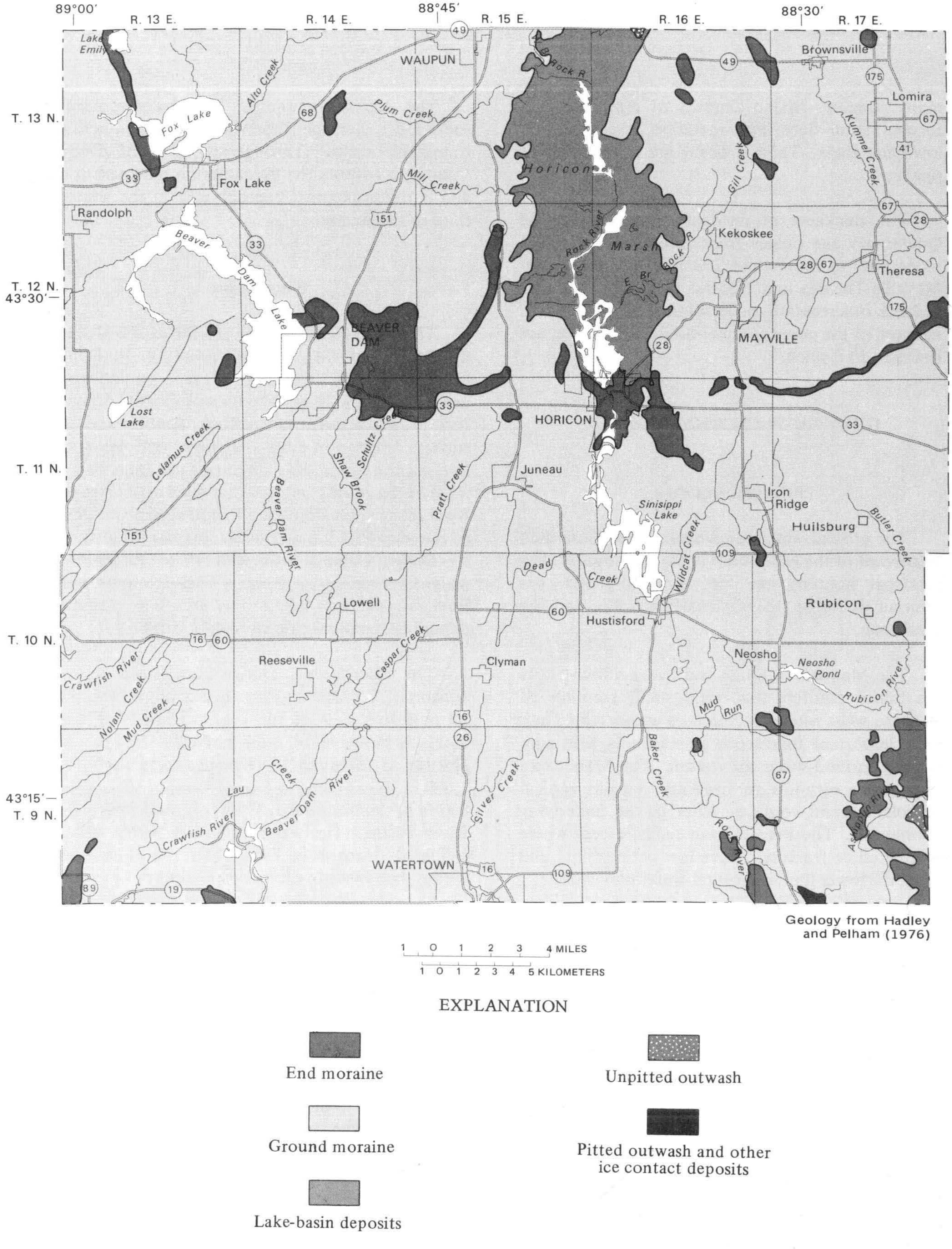


Figure 4. Glacial geology.

many streams. Marsh deposits of Holocene age, formed from decaying vegetation, are found in low-lying areas. These deposits are not mapped in this report.

The thickness of unconsolidated deposits of Quaternary age ranges from zero, where bedrock crops out, to more than 200 ft in the Kekoskee-Mayville-Theresa and Neosho areas (fig. 5). The bedrock outcrops are too small to show on figure 5. In most of the county, unconsolidated deposits are less than 50 ft thick.

GROUND-WATER HYDROLOGY

Principal Aquifers

The ground-water reservoir supplies more than 98 percent of the water used in Dodge County. The principal aquifers are the sand-and-gravel, the Silurian dolomite, the Galena-Platteville, and the sandstone.

The Maquoketa Shale and Precambrian rocks are minor aquifers that yield small amounts of water to wells where fractured or weathered. Their most important function is as confining beds controlling ground-water movement. The Maquoketa Shale has a very low permeability; it limits vertical percolation and confines water in the underlying formations. The Precambrian rocks, except where weathered or fractured, have low permeability and mark the lower limit of ground-water movement.

The sand-and-gravel aquifer underlies about half of the county. It consists of discontinuous lenses and layers within the glacial drift that occur at the land surface or are buried beneath less permeable drift.

The Silurian dolomite aquifer includes rocks of the Silurian System and overlies the Maquoketa Shale. It is present in parts of the eastern third of the county.

The Galena-Platteville aquifer includes rocks of the Galena Dolomite, Decorah and Platteville Formations. It is the uppermost bedrock unit in the middle third of the county overlying the sandstone aquifer. It is overlain by the Maquoketa Shale in eastern Dodge County.

The sandstone aquifer includes Ordovician rocks older than the Platteville Formation, and all Cambrian rocks. Throughout most of Dodge County, it overlies the Precambrian basement rock and is the uppermost bedrock unit in the western third of the county.

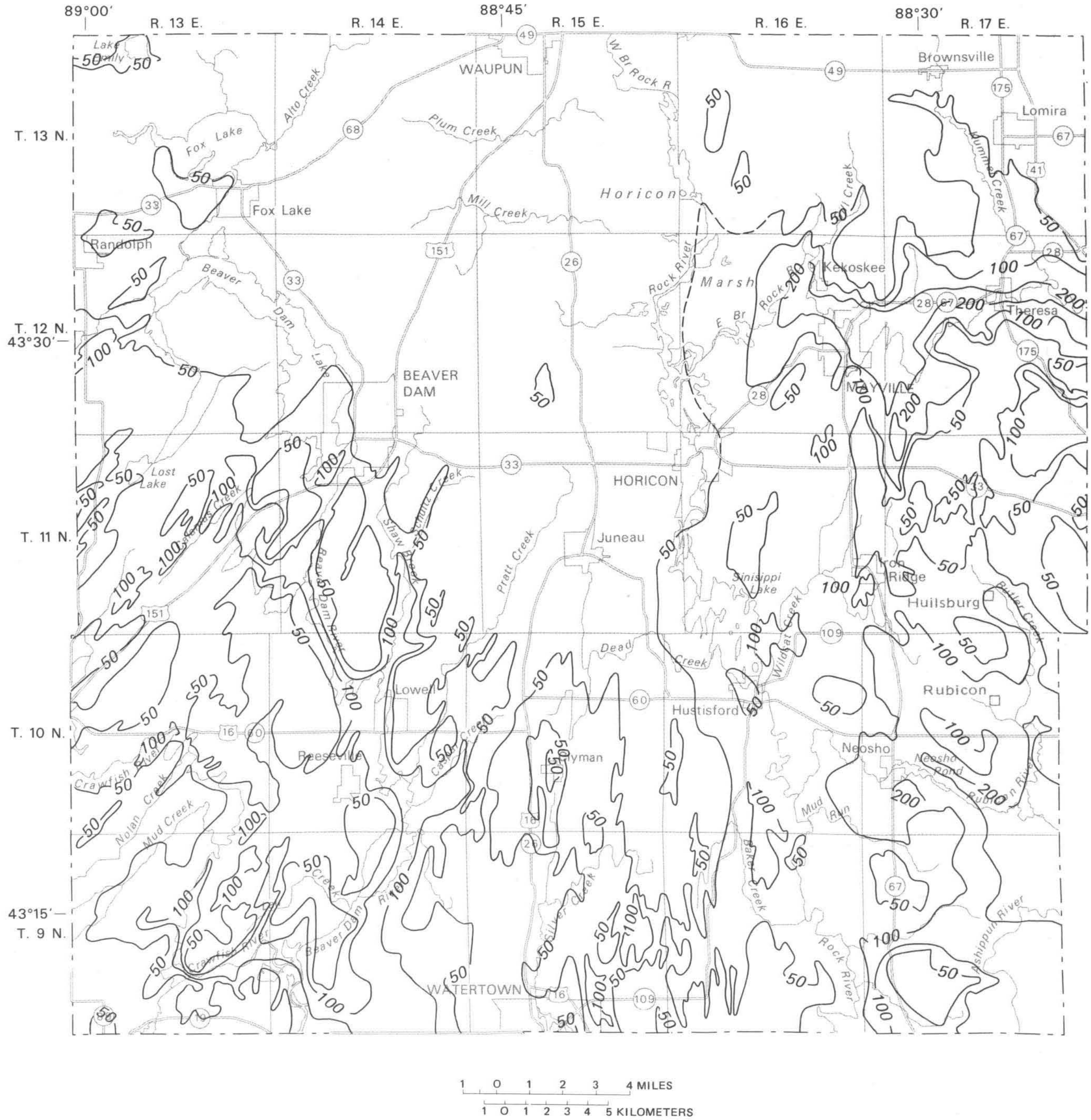
Water Table

The water-table map (pl. 1) shows the altitude of the top of the zone of saturation in Dodge County in 1977. The map is based on the static water levels in wells open to unconsolidated deposits and to the uppermost bedrock aquifer and the surface altitude of lakes, streams, and wetlands. Because the water table fluctuates less than 10 ft in most of the county, many water-level measurements from other years were used to add significant detail to the map that has a contour interval of 20 ft. In six Dodge County wells with 15 to 26 years of water-level records, maximum fluctuations of water level ranged from 8.3 to 12.7 ft. The maximum annual fluctuations ranged from 3.5 to 11.2 ft.

The water table in Dodge County is a subdued version of the land surface. It is shallow (less than 10 ft during part of the year) in low-lying areas along streams, lakes, and wetlands (fig. 6). The altitude of the water table ranges from more than 1,080 ft in east-central Dodge County to less than 800 ft in the Maunesha, Crawfish, and Beaverdam River basins. The water table lies within unconsolidated deposits in about half the county and within shallow bedrock in the remainder.

Recharge and Movement

The source of ground water is precipitation. One to 10 in. of the average annual 31 in. of precipitation is estimated to be recharged to the ground-water reservoir in Dodge County; the amount depending on the permeability of soil and rock material at the land surface. Recharge is least in areas of either peat or muck soils or soils developed on lake clay or clayey till, greater in areas of silt loam soils developed on loess or sandy silty drift, and greatest in areas of loam soils developed on outwash or sandy drift or on sand and gravel. Recharge is also high in areas where fractured dolomite is overlain with thin surficial deposits.



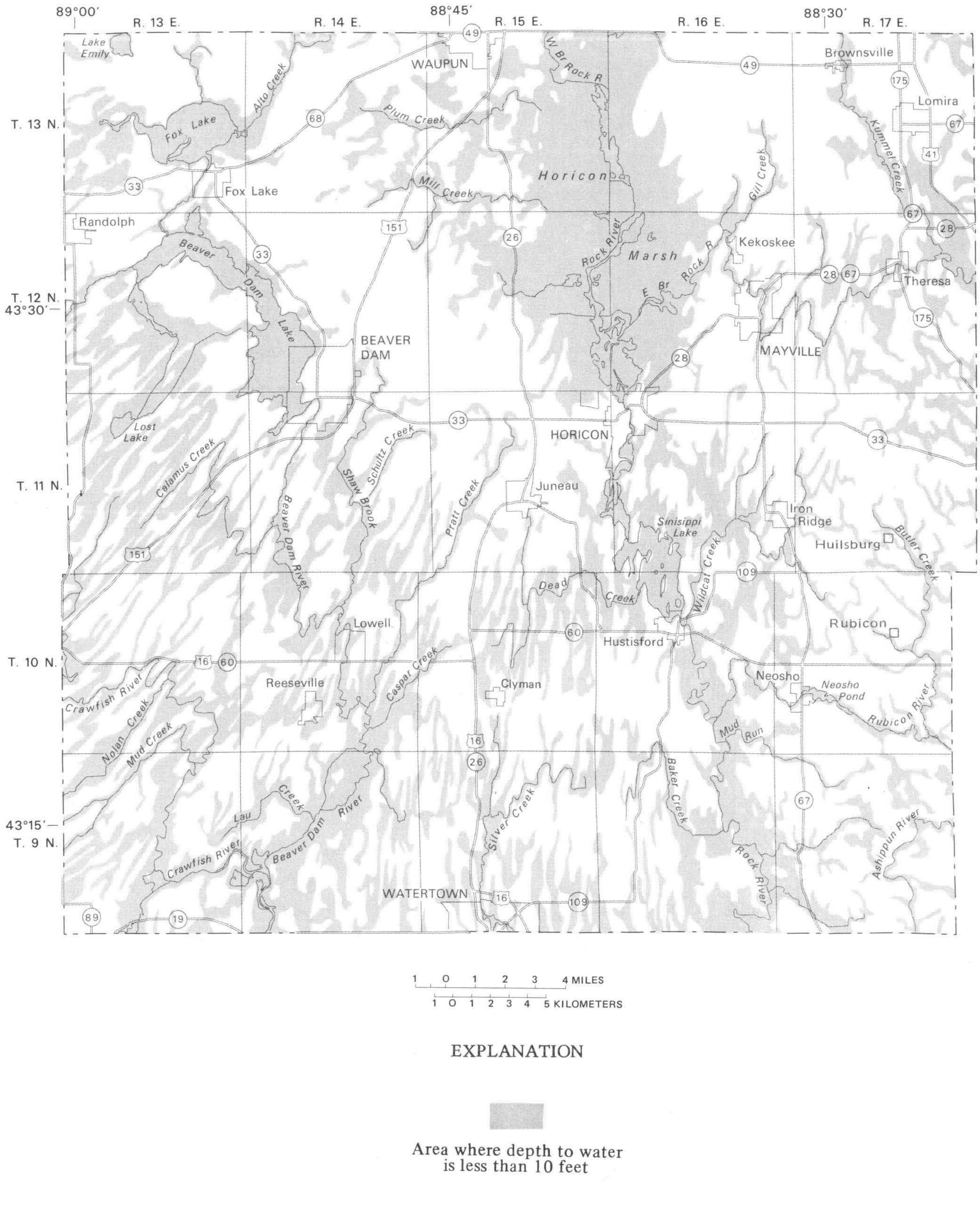
EXPLANATION

——— 50 ———

Line of equal thickness of unconsolidated materials

Dashed where approximate. contour interval 100 feet with supplemental 50-foot contour.

Figure 5. Thickness of unconsolidated deposits.



EXPLANATION

Area where depth to water is less than 10 feet

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

Ground water moves in two systems in Dodge County: a water-table system and an artesian system. The general direction of ground-water flow in saturated unconsolidated deposits and bedrock under water-table conditions can be determined from the water-table contours shown on plate 1. The ground water flows at approximately right angles to the contours in the direction of decreasing head; from areas of recharge to areas of natural discharge such as streams, lakes, and wetlands.

Ground water in the Galena-Platteville and sandstone aquifers underlying the Maquoketa Shale in eastern Dodge County (fig. 2) is under artesian conditions. The principal source of recharge to the aquifers is downward leakage through unconsolidated deposits west of the Maquoketa Shale, but some recharge is by leakage through the Maquoketa Shale. The movement of ground water in these aquifers is generally eastward toward Washington County and northward toward Fond du Lac County.

GROUND-WATER AVAILABILITY

Ground water is available throughout Dodge County, but individual well depths and yields differ widely. Small yields of water for domestic use, about 15 gal/min, can be obtained almost everywhere in the county. Records of 884 wells were used to define ground-water availability. Of these wells, 112 are completed in the sand-and-gravel aquifer, 91 in the Silurian dolomite aquifer, 279 in the Galena-Platteville aquifer, 340 in the sandstone aquifer, 46 in the Maquoketa Shale, and 16 in the Precambrian. The wells in the sand-and-gravel aquifer range from 33 to 243 ft; in the Silurian dolomite aquifer, from 60 to 220 ft; in the Galena-Platteville aquifer, from 52 to 495 ft; and in the sandstone aquifer from 53 to 1,409 ft. Depth of domestic wells ranges from 33 to 678 ft, and average 143 ft, most are completed in the sand-and-gravel aquifer, or in the uppermost bedrock aquifer.

Large supplies of water for industries and municipalities are available from the sandstone and sand-and-gravel aquifers, but the availability from each aquifer differs areally. High-capacity wells finished in the sandstone aquifer also may be open to the Galena-Platteville aquifer in many areas. Moderately large supplies may also be obtained from the Galena-Platteville aquifer.

The Precambrian rocks and Maquoketa Shale are used to a small extent as aquifers, providing quantities of water sufficient only for domestic supplies.

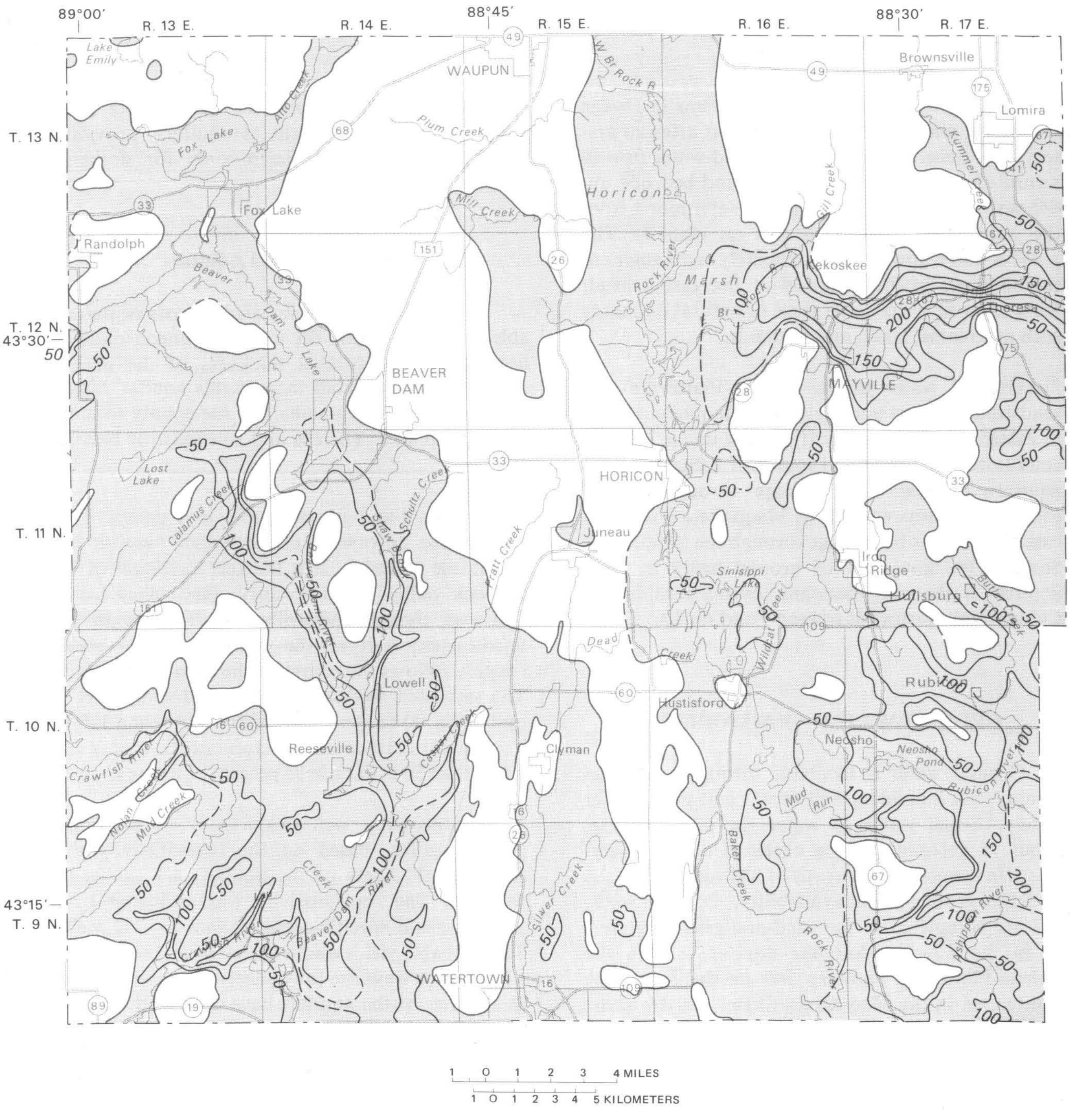
Sand-and-Gravel Aquifer

The sand-and-gravel aquifer consists of permeable sediments within the saturated unconsolidated deposits. The saturated thickness of the unconsolidated deposits that include this aquifer ranges from zero in about one-half of the county to more than 200 ft near Theresa and southeast of Neosho (fig. 7).

The sand-and-gravel aquifer may extend from the surface downward or be buried beneath impermeable material. It is thickest in several of the bedrock valleys of the county. One valley trends east-west through Mayville and Theresa in the northeastern part of the county; another valley roughly follows the course of the Beaverdam River. The saturated thickness of the sand-and-gravel aquifer (fig. 8) ranges from zero to more than 100 ft. The aquifer is absent in 46 percent of the county and is less than 50 ft thick in 95 percent of its area.

The probable well yields from the sand-and-gravel aquifer, based on the transmissivity and saturated thickness of the aquifer, are shown on figure 9. The transmissivity was estimated from lithologic and specific-capacity data for 112 wells. The probable yields also were based on the assumption that the wells are fully penetrating and screened in all parts of the aquifer, have an effective radius of 1 ft, that well loss is negligible, and that drawdowns do not exceed two-thirds of the saturated thickness of the aquifer.

The sand-and-gravel aquifer can yield as much as 500 gal/min from thick, saturated parts in eastern Dodge County (fig. 9). However, only one high-capacity well (capable of yielding more than 70 gal/min) has been developed in the sand-and-gravel aquifer. This well is 10 in. in diameter, screened, gravel packed, 106 ft deep, and was tested at 475 gal/min. Of the 112 domestic or stock wells inventoried in the sand-and-gravel aquifer, all except 1 terminated in an open-end casing. One was terminated with a 2-ft screen. The yields of the low-capacity wells ranged from 5 to 70 gal/min, and the average yield was about 15 gal/min. All except 10



EXPLANATION

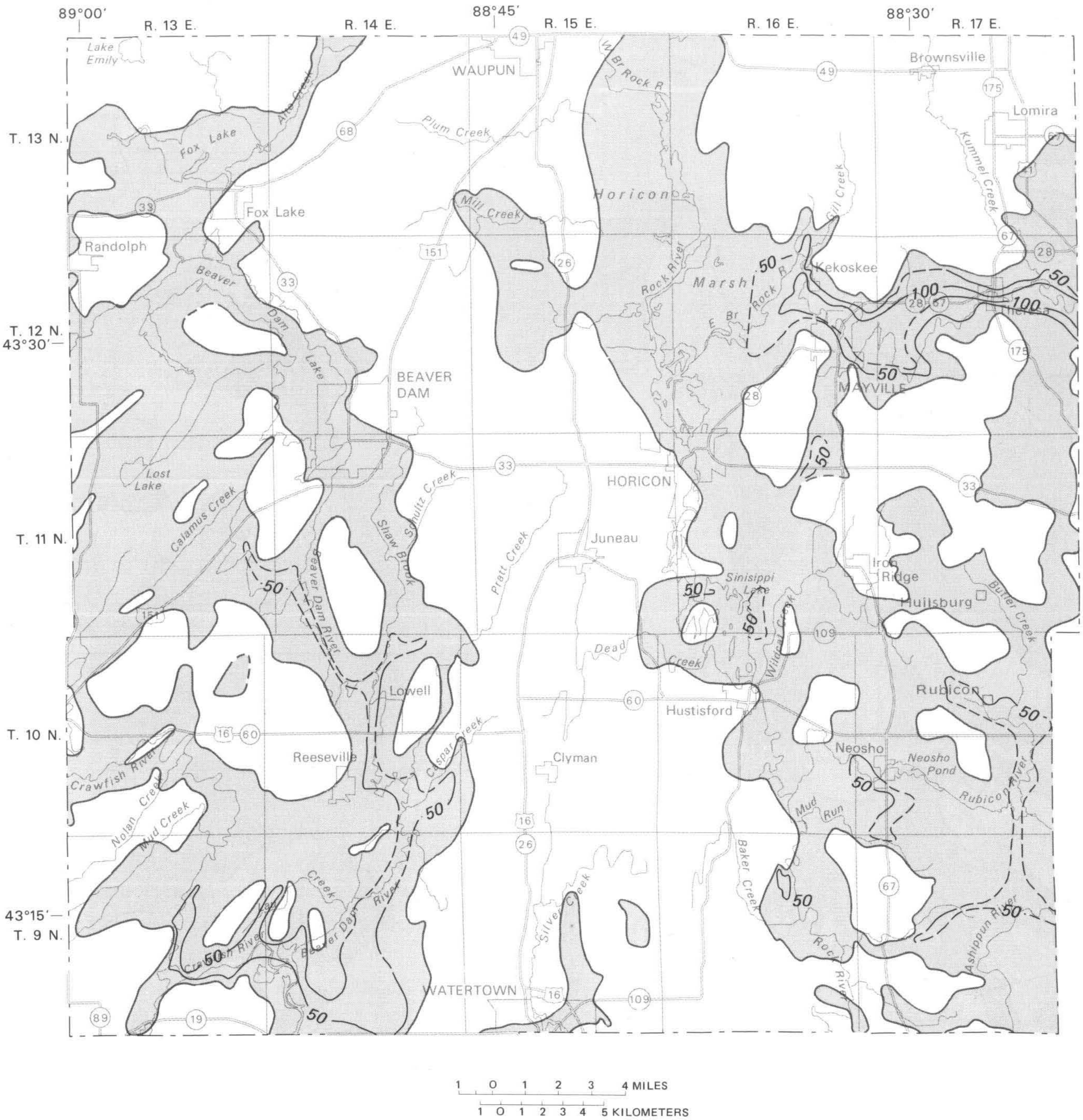
——50——

Line of equal thickness of saturated unconsolidated deposits

Dashed where approximate. Contour interval 50 feet.

Area of saturated unconsolidated deposits

Figure 7. Saturated thickness of unconsolidated deposits.



EXPLANATION

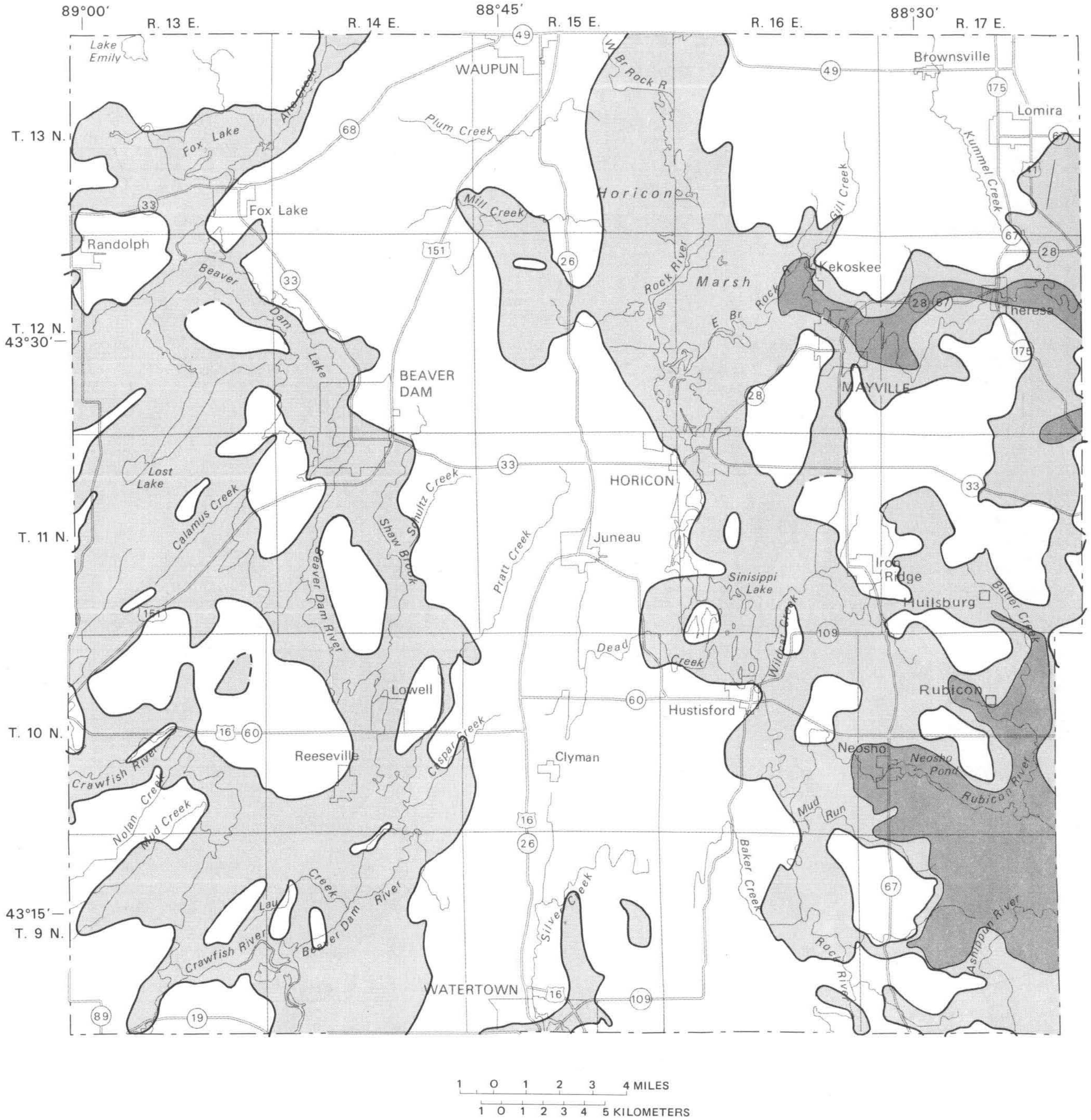
——— 50 ———

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

Dashed where approximate.
Contour interval 50 feet.

Area of sand-and-gravel aquifer

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



EXPLANATION

Probable well yields, in gallons per minute

Less than 100

100 - 500

Boundary of the sand-and-gravel aquifer

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

of the wells are in the eastern third of the county. All these wells terminated in very coarse sand, sand and gravel, or gravel. Probable yields in the western part of the county are supported by yields of similar materials in eastern Columbia County (Harr and others, 1978, p. 14).

Wells finished in 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.

Silurian-Dolomite Aquifer

The Silurian-dolomite aquifer is present only in the northeastern part of the county and in a small area in the southeastern corner. It is an important source of water because it occurs in some areas where the sand-and-gravel aquifer is absent.

Water in the Silurian dolomite is generally under water-table conditions although it may be confined locally. The water table is below the top of the dolomite in most of the aquifer (pl. 1 and fig. 10). In some areas along the western edge of the Silurian-dolomite aquifer, the water table is below the base of the aquifer.

The saturated thickness of the Silurian dolomite aquifer ranges from 0 to more than 100 ft in the northeastern corner of the county and several areas along the Washington County line (fig. 10).

The hydraulic conductivity of the Silurian dolomite aquifer ranges from 0.6 to 194 ft/d, with a median value of 23 ft/d. The upper part of the aquifer generally has a higher hydraulic conductivity than the remainder, owing to greater fracturing and solution along interconnecting joints and fractures. The differences in hydraulic conductivity are a result of vertical differences in conductivity and lithologic differences within the stratigraphic section.

Probable well yields from the Silurian dolomite aquifer (fig. 11) are based on 6-in. diameter wells open to the full saturated thickness in which drawdown is limited to 40 percent of the total head. The total head (height of the water table above the base of the aquifer) increases from west to east as thickness of the aquifer increases, and is approximately equal to the saturated thickness (fig. 10).

Because of the great differences of the hydraulic conductivity in the aquifer, probable yields may differ significantly from those shown in figure 11. Higher yields will probably be available from the upper parts of the aquifer, where there are large numbers of fractures, and where the aquifer is overlain by saturated drift. Of the wells studied, all yielded less than 100 gal/min. Yields of at least 100 gal/min are probably obtainable in extreme northeastern Dodge County.

Maquoketa Shale

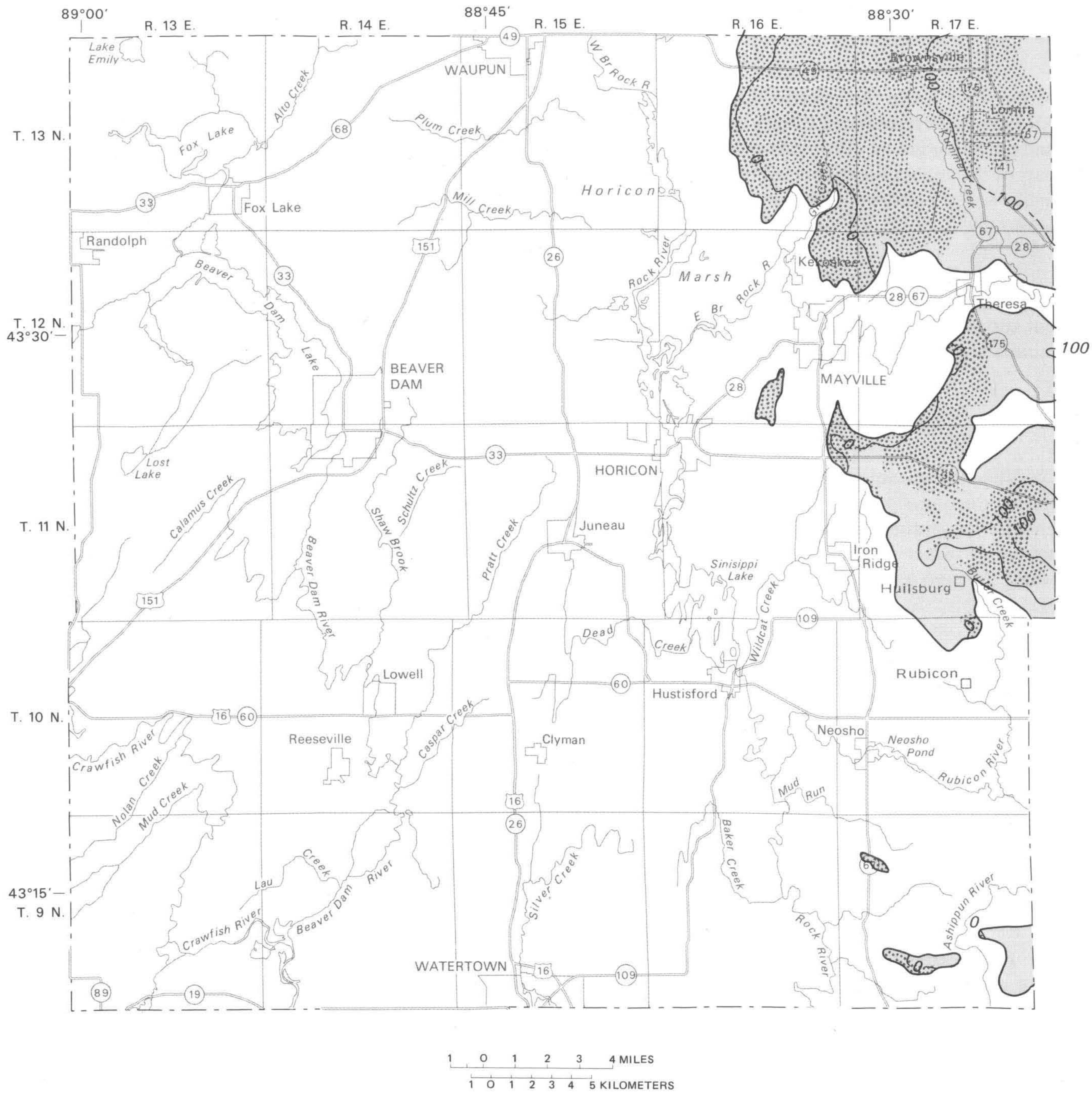
The Maquoketa Shale separates the Silurian-dolomite aquifer from the Galena-Platteville aquifer. Although it has a very low permeability, some leakage takes place downward through it as recharge to the Galena-Platteville and sandstone aquifers. A few wells in the county are finished in the Maquoketa Shale and obtain limited quantities of water from it.

Galena-Platteville Aquifer

The Galena-Platteville aquifer underlies the eastern three-fourths of Dodge County. It is the uppermost bedrock unit beneath about one-half of the county. In areas where the sand-and-gravel aquifer is thin or absent, it furnishes water for most domestic supplies.

The saturated thickness of the Galena-Platteville aquifer ranges from 0 to to more than 300 ft (fig. 12) and is more than 100 ft throughout about 85 percent of its areal extent. Water in the aquifer is under water-table conditions except in the eastern part of the county where it is confined beneath the Maquoketa Shale. The Galena-Platteville aquifer is completely saturated where it underlies the Maquoketa Shale, but west of the shale the surficial unconsolidated deposits are unsaturated in many areas and the water table is below the top of the Galena-Platteville aquifer.

The range of well yields from the from the Galena-Platteville aquifer depends on fracturing of the dolomite, but the degree of fracturing is unknown. Therefore, estimated well yields must be generalized.



EXPLANATION

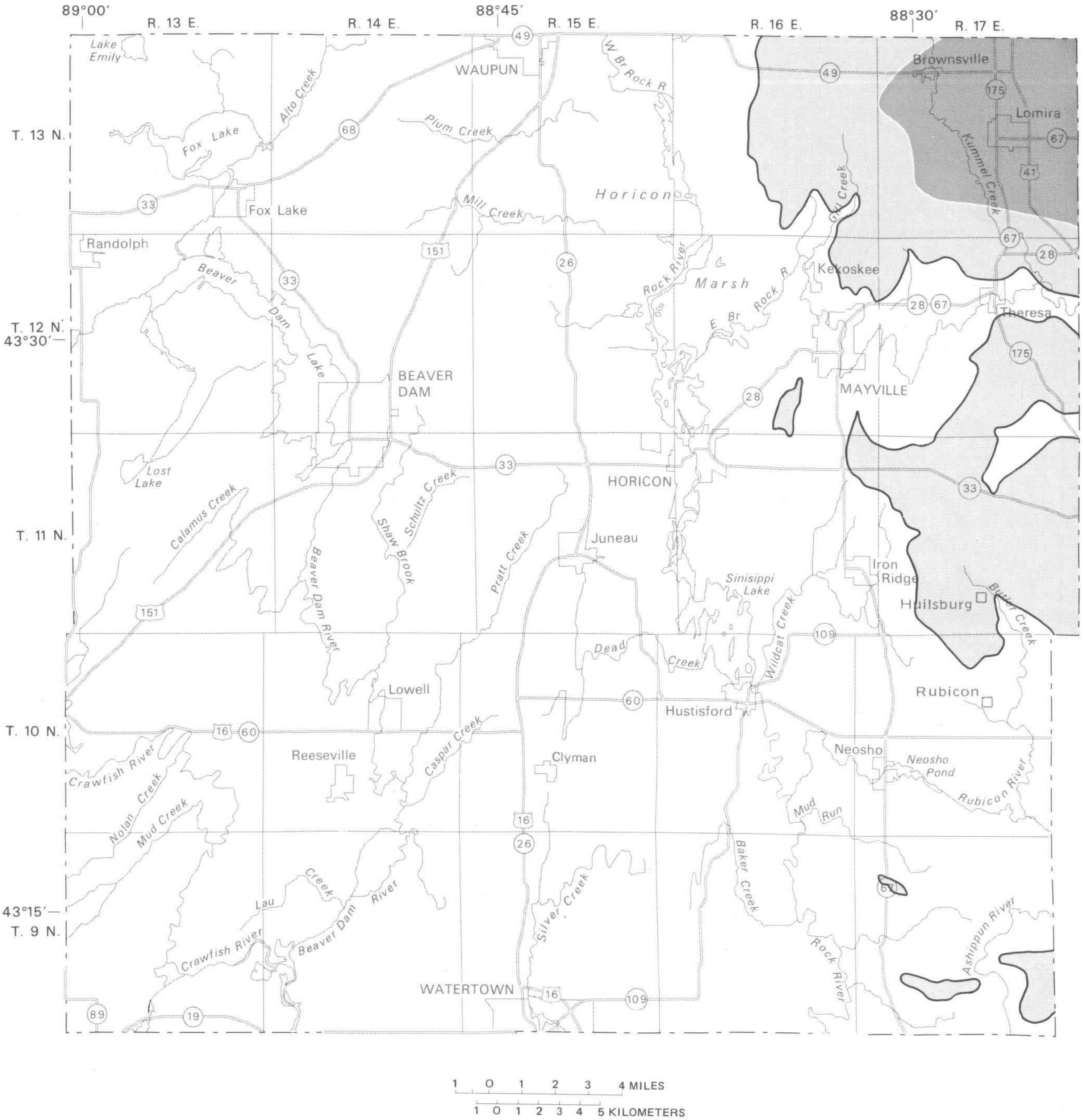
——100——

Line of equal saturated thickness of the Silurian-dolomite aquifer
Contour interval 100 feet.

Area where the water table is below the top of the Silurian-dolomite aquifer.

Area of the Silurian-dolomite aquifer

Figure 10. Saturated thickness of the Silurian-dolomite aquifer.



EXPLANATION

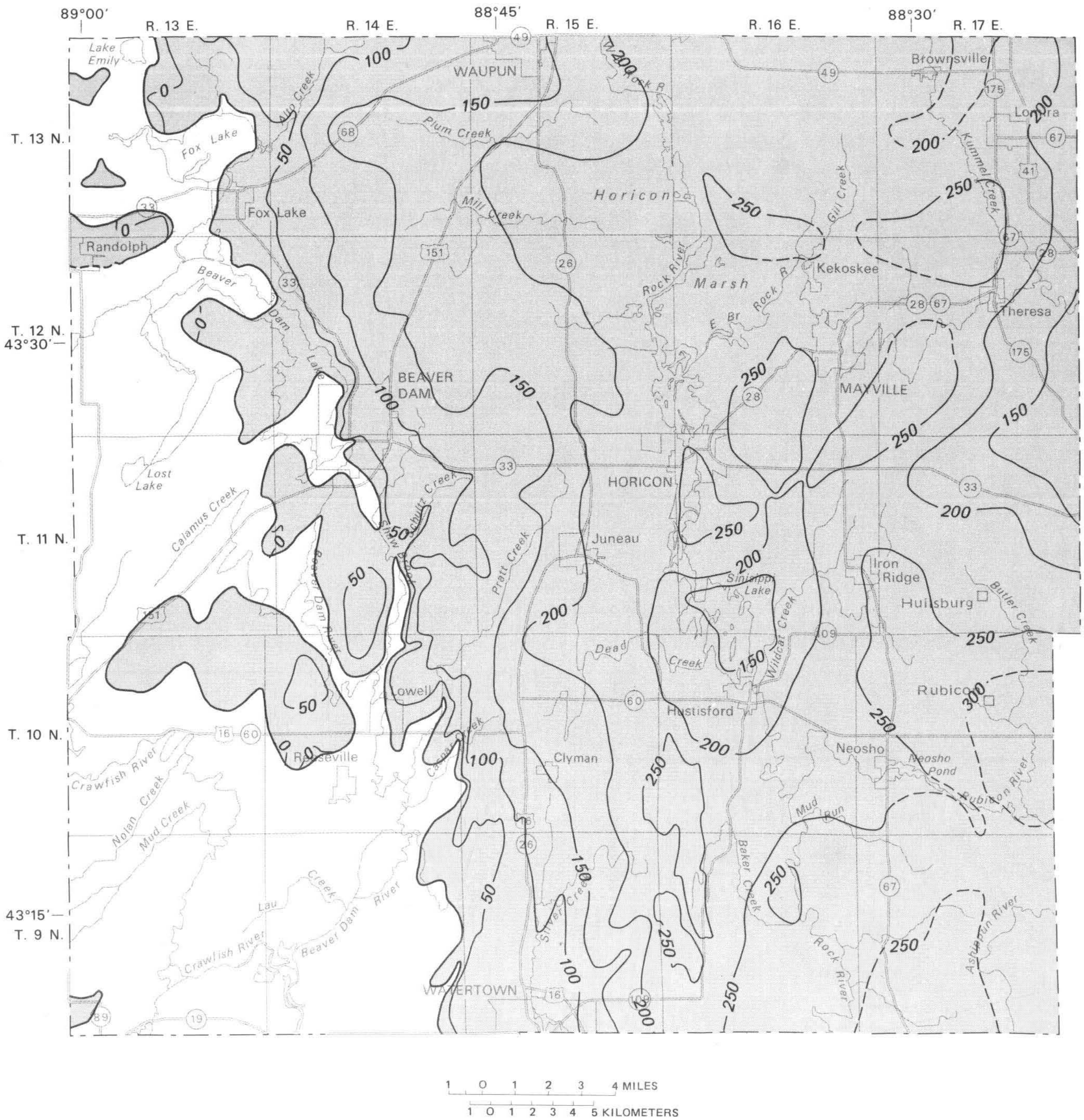
Probable well yields, in gallons per minute

Less than 100

Greater than 100

Boundary of the Silurian-dolomite aquifer

Figure 11. Probable well yields from the Silurian-dolomite aquifer.



EXPLANATION

——200——

Line of equal saturated thickness of the Galena-Platteville aquifer.
Dashed where approximate.
Contour interval 50 feet.

Area of the Galena-Platteville aquifer

Figure 12. Saturated thickness of the Galena-Platteville aquifer.

Specific capacities of 233 wells were used to estimate potential yield of the aquifer. Attainable yields were estimated by extrapolating specific capacities that would result under the following conditions: full penetration of the aquifer, uniform vertical permeability, and limiting drawdown to 40 percent of the total head. Total head is shown is figure 13.

The Galena-Platteville aquifer can probably yield as much as 500 gal/min to wells in the central part of Dodge County (fig. 14). Well yields of as much as 100 gal/min from this aquifer have been reported by well drillers. Most wells, however, are used for domestic supply and are pumped at less than 20 gal/min. Individual wells may produce more or less than indicated on figure 14.

The eastern limit of the 100 to 500 gal/min zone is based on the western limit of the Maquoketa Shale. No records were found of wells drilled through the shale and finished in the Galena-Platteville aquifer. However, well drillers report that where overlain by the shale, the Galena-Platteville dolomite is dense, unfractured, and does not yield water.

Sandstone Aquifer

The sandstone aquifer, of Ordovician and Cambrian age, underlies all of Dodge County except where rocks of Precambrian age crop out. The sandstone aquifer, underlies the Galena-Platteville aquifer in most of the county, is the the principal source of water for municipal and industrial supply and, in the western part of the county where the aquifer is close to the land surface, is the sole source of water for domestic supply.

The saturated thickness of the sandstone aquifer ranges from 0, in the southwestern part of the county around Precambrian rock outcrops, to more than 800 ft in the south-central and northeastern parts of the county (fig. 15).

The probable yields of wells from the sandstone aquifer were based on the saturated thickness, on lithologic and specific-capacity data, and on the following assumptions: The wells are fully penetrating, are screened in all parts of the aquifer, have an effective radius of 0.5 ft, have a negligible loss, and have drawdowns that do not exceed 40 percent of the total head (fig. 16). The total head of water above the base of the aquifer exceeds 1,000 ft in northeastern and south-central Dodge County. Probable yields from the sandstone aquifer are shown in figure 17. The well yields in the county are likely to occur where the saturated thickness and total head (figs. 15 and 16) are the greatest.

Wells in some areas produce more than 1,000 gal/min from the sandstone aquifer alone. Domestic and high-capacity wells obtain water from the Galena-Platteville and the sandstone aquifers in areas where the Galena-Platteville unit is thin. In the eastern one-third of the county where the Maquoketa Shale is present, are unknown but are unlikely to be greater than 1,000 gal/min.

Precambrian Rocks

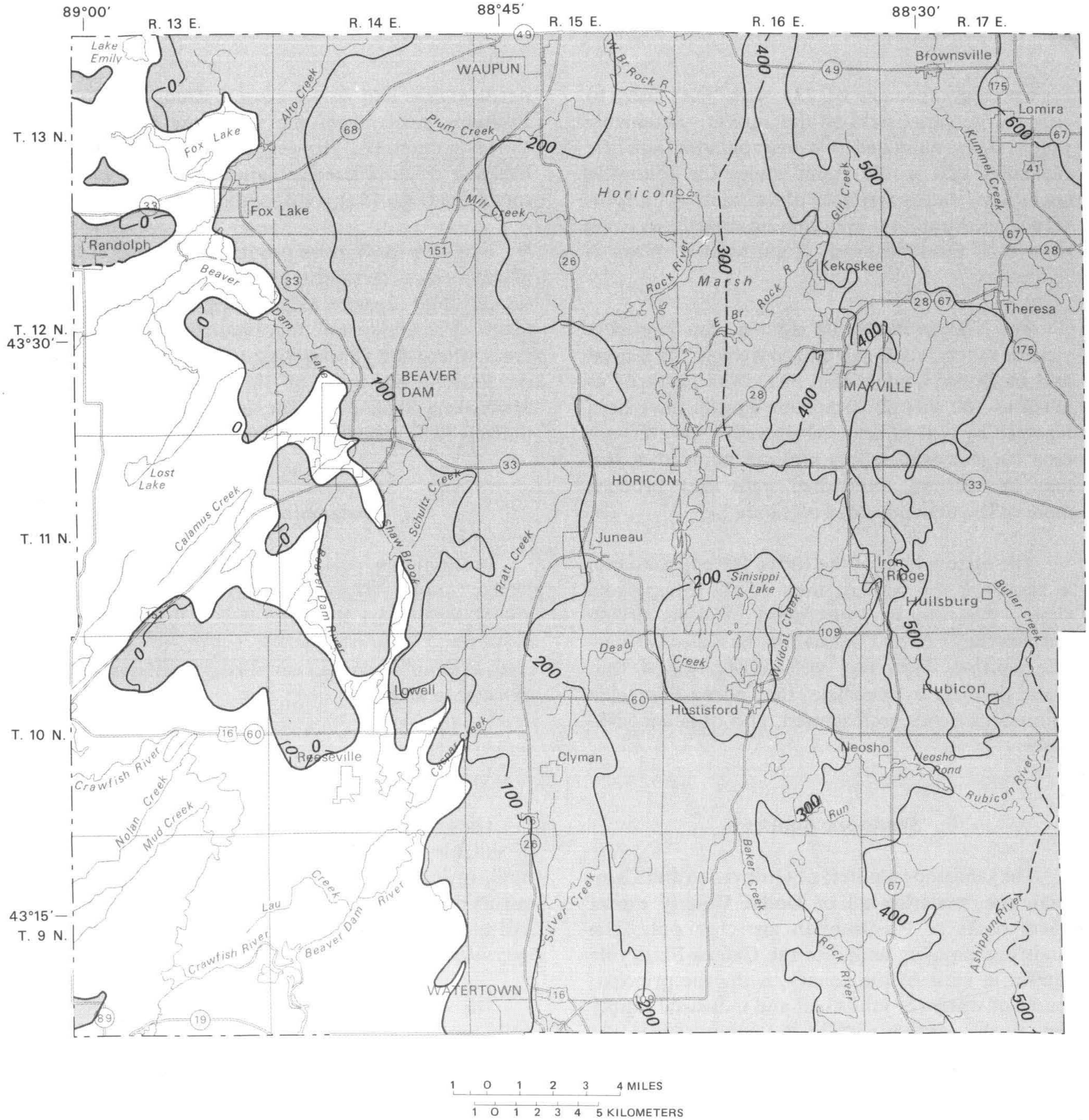
Precambrian crystalline rocks underlie all of Dodge County. These rocks have low permeability and typically mark the lower limit of ground-water movement. However, where fractured or weathered, Precambrian rocks can supply small quantities of water to wells.

GROUND-WATER QUALITY

The ground water in Dodge County generally is of suitable chemical quality for domestic, agricultural, or industrial use. The similarity of chemical quality of the ground water from each aquifer indicates the similarity of chemical composition of the rocks with which the water is in contact.

The chemical analyses of ground water from wells tapping the sand-and-gravel, Silurian dolomite, Galena-Platteville, sandstone, the combined Galena-Platteville and sand-and-gravel aquifers, the Maquoketa Shale, and the Precambrian rocks are summarized in table 2. The chemical characteristics of water from the Precambrian rocks is not discussed below because of insufficient data.

Calcium and bicarbonate are the principal ions in solution. The median concentration of calcium ranged from 67 mg/L (milligrams per liter) in ground water from the sandstone aquifer to 78 mg/L in ground water from the Galena-Platteville aquifer. The median concentration of bicarbonate ranged from 340 mg/L in ground water from the combined Galena-Platteville and sandstone aquifer to 392 mg/L in ground water from the sand-and-gravel aquifer.



EXPLANATION

——— 600 ———

Line of equal total head in the Galena-Platteville aquifer.
Shows head above the base of the Galena-Platteville aquifer in 1979. Interval 100 feet.

[shaded box]

Area of the Galena-Platteville aquifer

Figure 13. Total head in the Galena-Platteville aquifer.

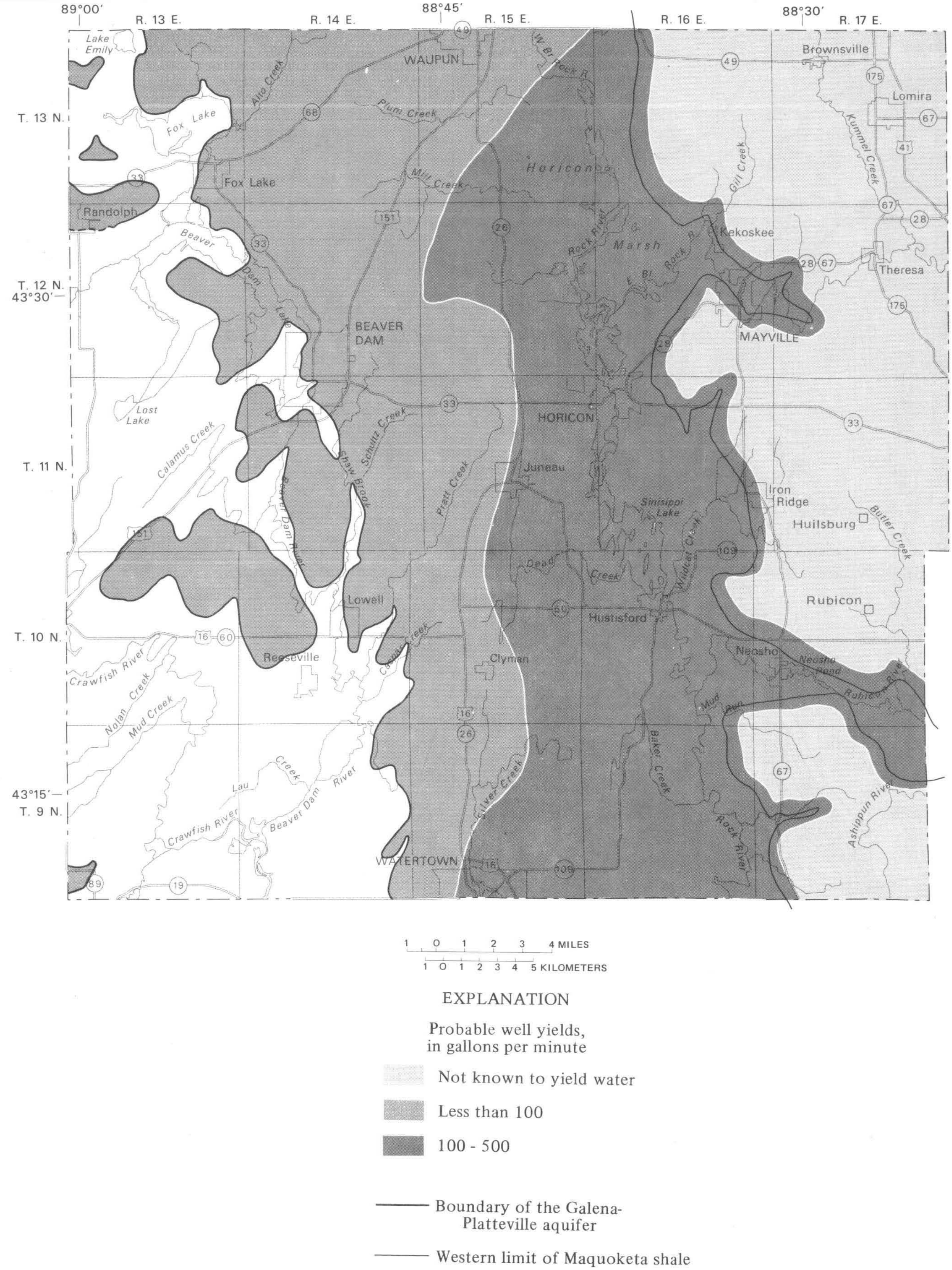
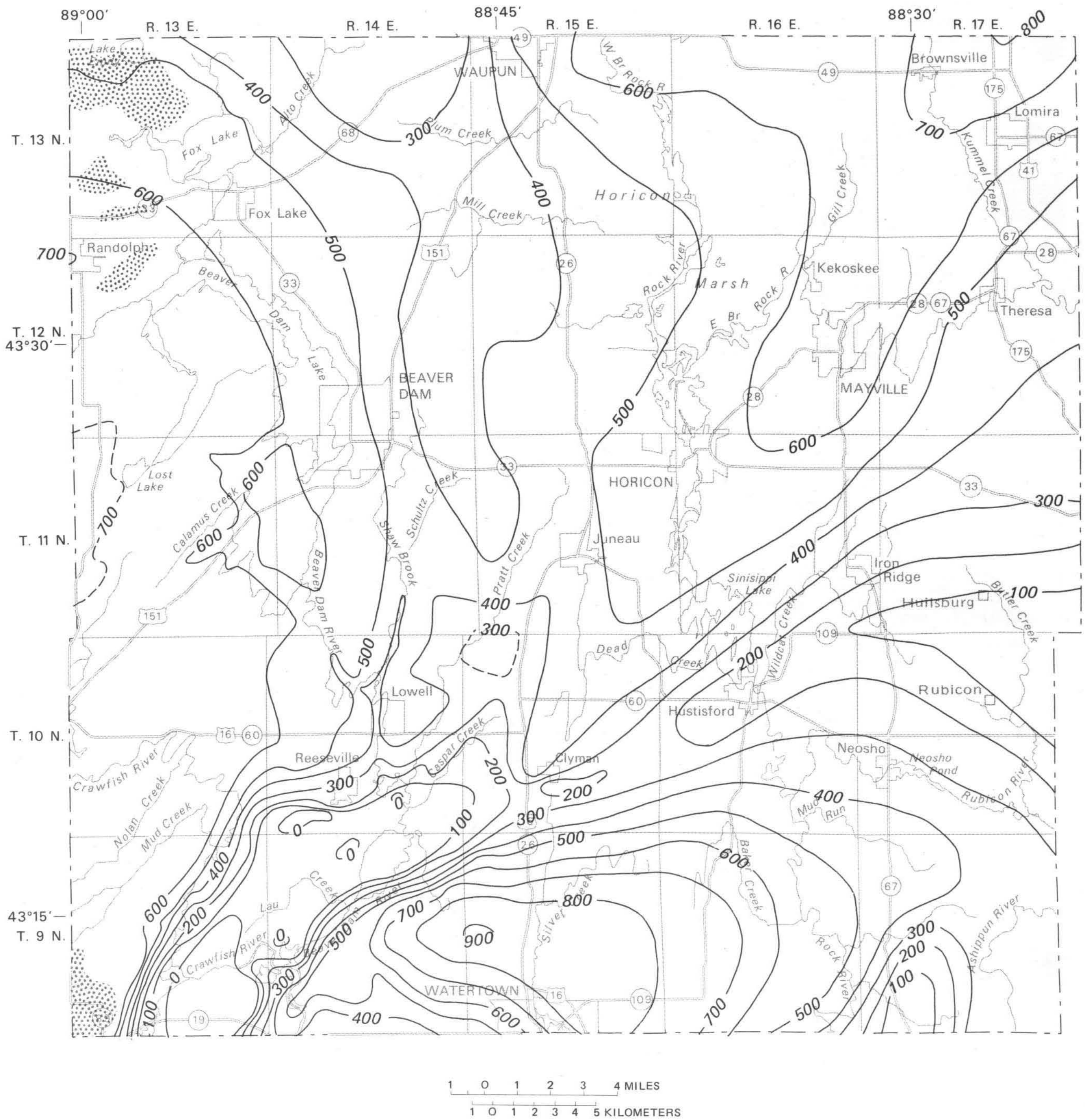


Figure 14. Probable well yields from the Galena-Platteville aquifer.



EXPLANATION

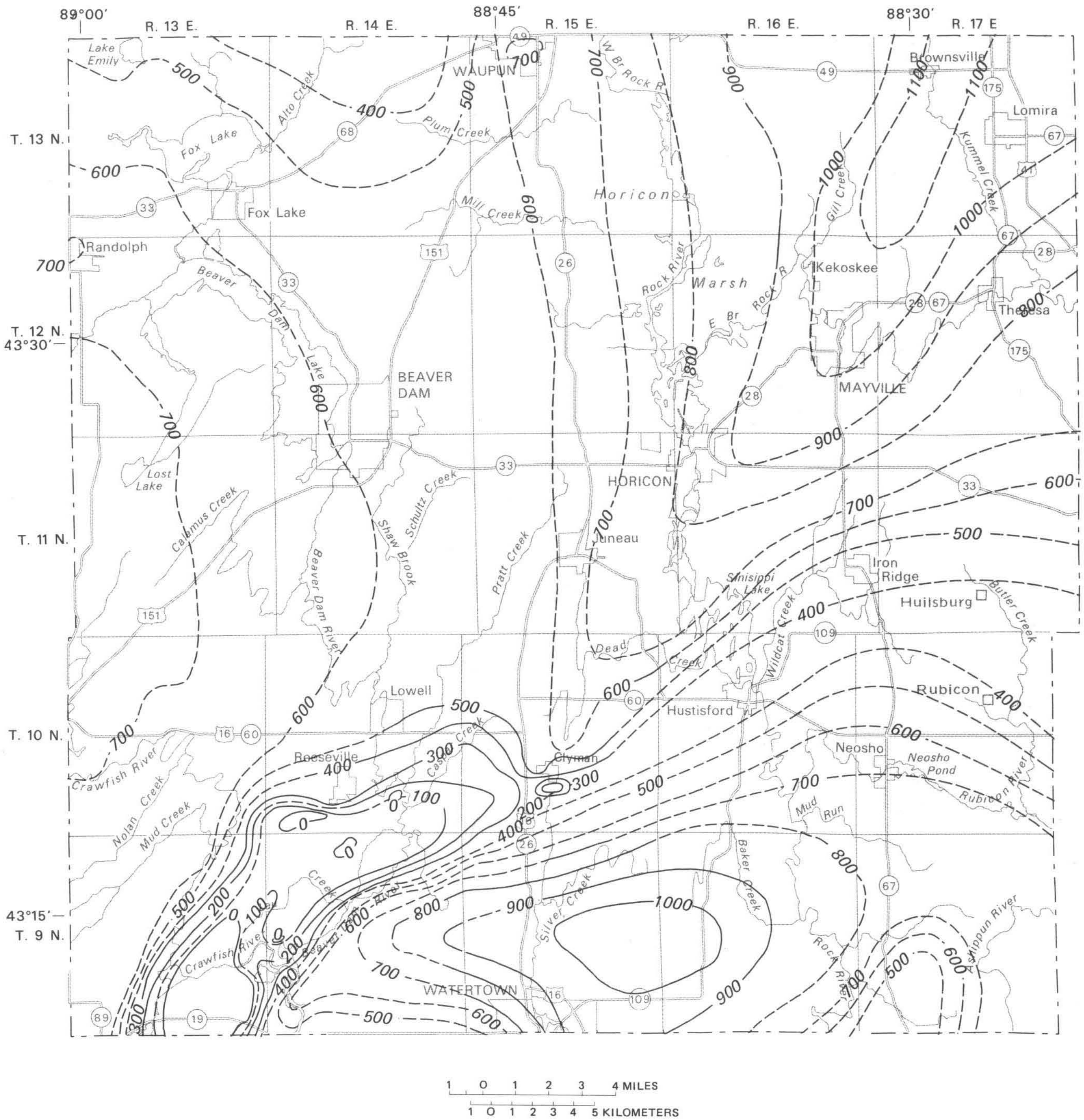
300

Line of equal saturated thickness of the sandstone aquifer

Dashed where approximate.
Contour interval 100 feet.

Area where the water table is below the top of the Sandstone aquifer.

Figure 15. Saturated thickness of the sandstone aquifer.



EXPLANATION

500

Line of equal total head in the Sandstone aquifer.
Dashed where approximate.
Contour interval 100 feet.

Western limit of Maquoketa shale

Figure 16. Total head in the sandstone aquifer.

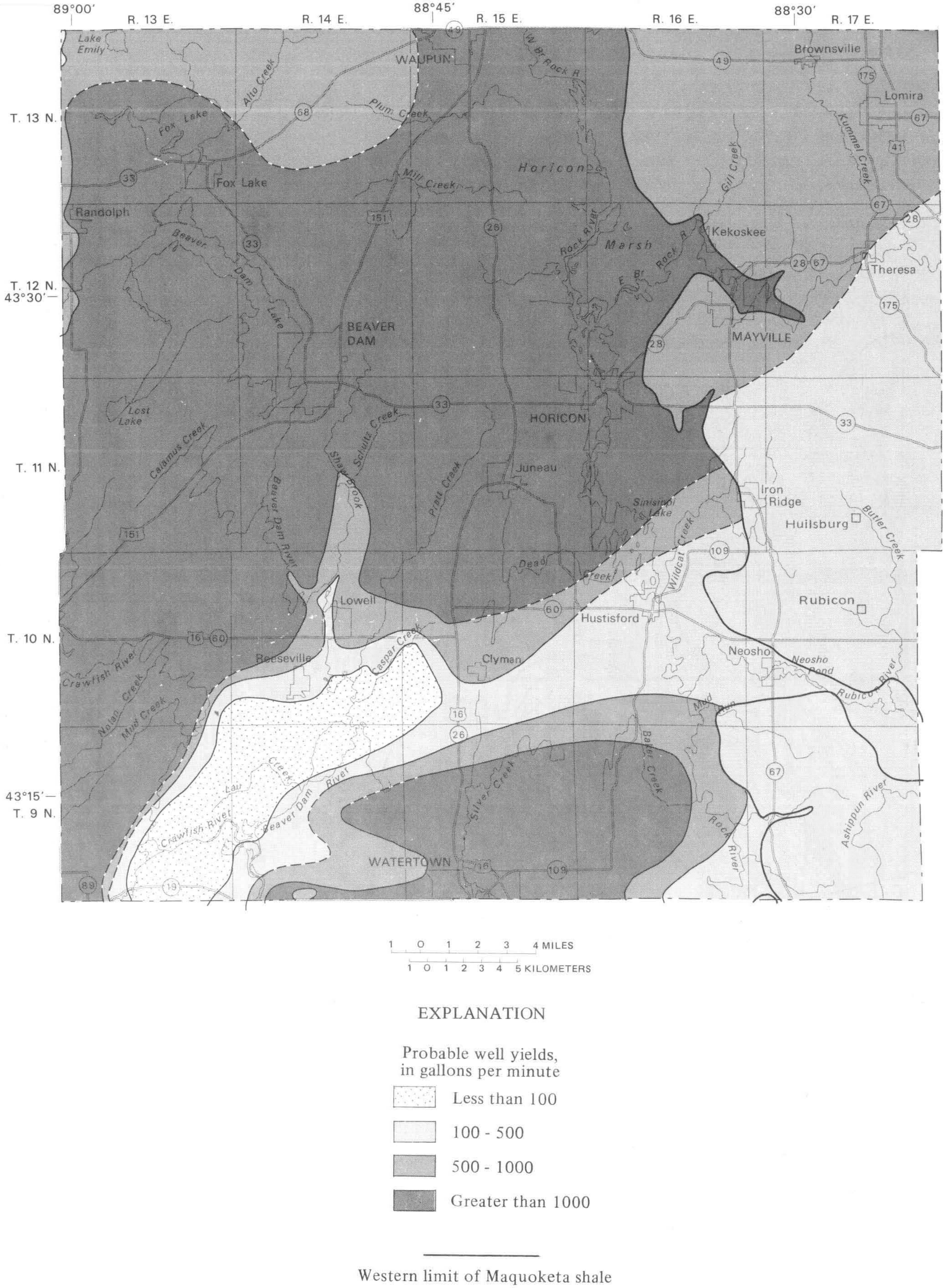


Figure 17. Probable well yields from the sandstone aquifer.

The median dissolved-solids concentration ranges from 359 mg/L in ground water from the Silurian dolomite aquifer to 425 mg/L in ground water from the Galena-Platteville aquifer.

Ground water in Dodge County is very hard; the median hardness of water ranges from 308 mg/L as calcium carbonate ($CaCO_3$) in water from the sandstone aquifer to 385 mg/L in water from the Galena-Platteville aquifer.

The median concentrations of dissolved iron in ground water from all aquifers except the Silurian dolomite exceeded the recommended limiting concentration of 300 μg/L (micrograms per liter) recommended by the National Academy of Sciences, National Academy of Engineering, (1973) for drinking water and were greater than desirable for water used for high-pressure boiler feed, some food processing, and leather finishing.

GROUND-WATER PUMPAGE AND USE

About 13 Mgal/d of ground water was pumped in Dodge County during 1979. This water was used for residential, industrial, commercial, institutional, irrigation, and municipal purposes.

Pumpage

More than one-half of the water pumped was from wells open to the Galena-Platteville and sandstone aquifers. The following table shows the percentage of water pumped from each aquifer Dodge County. These percentages are based on aquifers tapped by public-supply wells and on a sampling of 440 private residential wells drilled between 1968 and 1970.

Aquifer	Pumpage, in percentage from each aquifer		
	Public supply	Private residential	Total
Sand and gravel	-	9	6
Silurian dolomite	3	3	3
Galena-Platteville	4	44	28
Combined Galena-Platteville and sandstone	93	35	57
Maquoketa Shale	-	6	4
Precambrian rocks	-	3	2
Total	100	100	100

Six municipalities, three corporations, and one institution pumped about 70 percent of the ground water during 1979. The average daily pumpages were:

User	Pumpage (Mgal/d)
City of Beaver Dam	2.0
City of Horicon	.6
City of Juneau	.3
City of Mayville	.8
City of Watertown	3.0
City of Waupun	1.0
California Canners and Growers	.3
Green Giant Company	.4
Kraft Foods, Inc.	.4
Wisconsin State Prison, Waupun	.4
TOTAL	9.2

Use

The amount of ground water used for residential, industrial, commercial, irrigation, stock watering, and other purposes in Dodge County during 1979 is shown below (Lawrence and Ellefson, 1982).

Use	Quantity Used (Mgal/d)	Quantity Used (percent)
Residential	3.34	25
Industrial	4.44	34
Commercial	1.24	9
Irrigation	.09	1
Stock watering	2.60	20
Other	1.49	11
	---	---
TOTAL	13.20	100

Residential use includes water used for urban and rural domestic purposes. Industrial use refers to water used in plants that manufacture products and may be incorporated in the product, or used for cooling, sanitation, and irrigation of plant grounds. Commercial use includes water used by businesses, such as service stations, restaurants, and motels, that do not manufacture a product.

Other use includes water used by recreational camps, schools, hospitals, and prisons. Water used for flushing water lines, firefighting, municipal buildings, or water lost in distribution systems.

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

[Chemical analyses in milligrams per liter except iron and manganese, which are in micrograms per liter]

	Number of analyses	Maximum	Minimum	Mean	Median
Sand-and-gravel aquifer					
Specific conductance, µmho/cm at 25°C	19	1,070	520	680	680
pH (units)	21	8.0	7.2	7.5	7.5
Temperature, °C	19	14.0	9.5	11.4	11.5
Hardness, as $CaCO_3$	22	610	290	369	355
Noncarbonate hardness, as $CaCO_3$	22	260	0	47.0	31
Calcium (Ca)	21	100	55	73.9	76
Magnesium (Mg)	21	87	33	45.8	44
Sodium (Na)	19	24	2.3	5.8	4.0
Potassium (K)	18	2.0	.5	1.1	1.1
Bicarbonate (HCO_3)	22	450	326	394	392
Sulfate (SO_4)	22	94	.4	30.0	36
Chloride (Cl)	22	87	1.7	12.3	5.2
Fluoride (F)	21	.7	.0	.13	.1
Silica (SiO_2)	18	42	7.8	17.9	18
Dissolved solids, residue on evaporation at 180°C	22	654	298	396	379
Dissolved solids, residue on evaporation at 105°C	3	360	336	345	340
Nitrate nitrogen (N)	20	8.8	.0	1.3	.07
Organic carbon, total (C)	16	9.6	.8	5.3	4.5
Iron (Fe)	22	8,500	10	1,940	335
Manganese (Mn)	22	350	0	62	40

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

	Number of analyses	Maximum	Minimum	Mean	Median
		Silurian dolomite aquifer			
Specific conductance, µmho/cm at 25°C	11	2,120	485	872	615
pH (units)	11	8.0	6.9	7.3	7.3
Temperature, °C	9	11.5	9.5	10.5	10.5
Hardness, as $CaCO_3$	11	1,700	260	494	326
Noncarbonate hardness, as $CaCO_3$	11	1,400	10	191	60
Calcium (Ca)	11	530	53	120	72
Magnesium (Mg)	11	80	30	46.6	40
Sodium (Na)	11	39	1.9	12.4	9.0
Potassium (K)	11	27	.7	5.8	2.8
Bicarbonate (HCO_3)	11	500	280	364	351
Sulfate (SO_4)	11	1,400	30	175	48
Chloride (Cl)	11	86	2.6	20.5	5.2
Fluoride (F)	11	.4	1	.18	.2
Silica (SiO_2)	11	19	9.2	12.0	10
Dissolved solids, residue on evaporation at 180°C	11	2,180	282	596	359
Dissolved solids, residue on evaporation at 105°C	--	--	--	--	--
Nitrate nitrogen (N)	11	16	.0	3.0	.09
Organic carbon, total (C)	8	8.7	2.2	4.5	4.6
Iron (Fe)	8	11,000	0	1,500	45
Manganese (Mn)	8	100	10	35	20

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

	Number of analyses	Maximum	Minimum	Mean	Median
Galena-Platteville aquifer					
Specific conductance, µmho/cm at 25°C	14	1,000	520	739	720
pH (units)	14	7.9	7.1	7.4	7.3
Temperature, °C	14	14.5	9.5	11.5	11.5
Hardness, as $CaCO_3$	16	523	290	384	385
Noncarbonate hardness, as $CaCO_3$	16	170	4	74.0	76
Calcium (Ca)	12	99	64	76.0	78
Magnesium (Mg)	12	65	32	44.0	42
Sodium (Na)	11	31	2.3	9.3	6.4
Potassium (K)	11	6.0	.8	2.3	2.0
Bicarbonate (HCO_3)	16	457	330	382	378
Sulfate (SO_4)	16	119	.7	55.0	58
Chloride (Cl)	16	94	1.8	19.0	14
Fluoride (F)	12	.3	.1	.16	.1
Silica (SiO_2)	11	26	6.8	15.0	14
Dissolved solids, residue on evaporation at 180°C	15	625	305	444	425
Dissolved solids, residue on evaporation at 105°C	1	346	---	---	---
Nitrate nitrogen (N)	15	11	.0	.97	.02
Organic carbon, total (C)	10	9.3	3.0	5.4	5.4
Iron (Fe)	16	11,000	0	2,000	450
Manganese (Mn)	16	130	0	40	25

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

	Number of analyses	Maximum	Minimum	Mean	Median
		Sandstone aquifer			
Specific conductance, μmho/cm at 25°C	29	810	470	651	680
pH (units)	53	8.4	6.9	7.5	7.4
Temperature, °C	31	23.0	10.0	13.0	12.0
Hardness, as $CaCO_3$	56	450	106	316	308
Noncarbonate hardness, as $CaCO_3$	54	120	0	28.3	20
Calcium (Ca)	49	93	39	67.5	67
Magnesium (Mg)	49	59	16	36.0	37
Sodium (Na)	35	11	2.3	4.9	4.5
Potassium (K)	24	3.6	.6	1.4	1.3
Bicarbonate (HCO_3)	20	440	160	352	349
Sulfate (SO_4)	52	87	7.0	29.0	23
Chloride (Cl)	54	30	.0	6.7	5.0
Fluoride (F)	47	.5	.0	.18	.1
Silica (SiO_2)	24	38	8.0	17.9	16
Dissolved solids, residue on evaporation at 180°C	28	506	230	381	387
Dissolved solids, residue on evaporation at 105°C	25	542	250	330	312
Nitrate nitrogen (N)	28	8.4	.0	.7	.04
Organic carbon, total (C)	20	13	3.0	4.9	4.8
Iron (Fe)	56	3,200	0	680	645
Manganese (Mn)	54	580	0	78	30

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

	Number of analyses	Maximum	Minimum	Mean	Median
Galena-Platteville and sandstone aquifers					
Specific conductance, μmho/cm at 25°C	4	795	530	668	675
pH (units)	55	8.4	7.2	7.5	7.5
Temperature, °C	4	13.5	10.0	12.6	13.5
Hardness, as $CaCO_3$	55	456	216	321	318
Noncarbonate hardness, as $CaCO_3$	45	167	7	73.0	62
Calcium (Ca)	52	89	52	71.3	72
Magnesium (Mg)	52	54	21	34.4	34
Sodium (Na)	42	52	2.9	17.0	16
Potassium (K)	10	6.0	1.0	3.6	4.1
Bicarbonate (HCO_3)	45	410	176	309	340
Sulfate (SO_4)	53	105	16	46	41
Chloride (Cl)	55	140	2.0	40	15
Fluoride (F)	48	1.4	0	.43	.4
Silica (SiO_2)	4	15	8.4	11.1	10
Dissolved solids, residue on evaporation at 180°C	4	455	322	400	412
Dissolved solids, residue on evaporation at 105°C	48	572	260	398	390
Nitrate nitrogen (N)	37	.5	.0	.1	.04
Organic carbon, total (C)	---	---	---	---	---
Iron (Fe)	55	9,400	40	730	480
Manganese (Mn)	44	480	0	53	40

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

	Number of analyses	Maximum	Minimum	Mean	Median
		Maquoketa Shale			
Specific conductance, µmho/cm at 25°C	7	1,140	555	709	650
pH (units)	3	7.6	7.0	7.3	7.4
Temperature, °C	7	13.5	9.5	11.9	12.0
Hardness, as $CaCO_3$	7	520	290	364	350
Noncarbonate hardness, as $CaCO_3$	7	290	0	59	0
Calcium (Ca)	7	120	3.1	72	71
Magnesium (Mg)	7	53	1.4	33	36
Sodium (Na)	7	170	3.7	37	8.9
Potassium (K)	7	19	.7	5.6	3.9
Bicarbonate (HCO_3)	7	430	280	376	380
Sulfate (SO_4)	7	350	1.0	80	11
Chloride (Cl)	7	7.6	1.5	3.7	3.4
Fluoride (F)	7	.6	.1	.3	.2
Silica (SiO_2)	7	15	7.2	10	10
Dissolved solids, residue on evaporation at 180°C	7	747	284	428	350
Dissolved solids, residue on evaporation at 105°C	---	---	---	---	---
Nitrate nitrogen (N)	7	.03	.00	.009	.0
Organic carbon, total (C)	7	12	4.1	6.4	5.4
Iron (Fe)	7	1,500	50	420	310
Manganese (Mn)	7	140	10	50	40

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

	Number of analyses	Maximum	Minimum	Mean	Median
		Precambrian rocks			
Specific conductance, μmho/cm at 25°C	3	900	485	725	790
pH (units)	1	7.8	---	---	---
Temperature, °C	3	12.0	11.0	11.5	11.5
Hardness, as $CaCO_3$	3	505	210	395	470
Noncarbonate hardness, as $CaCO_3$	3	183	28	110	120
Calcium (Ca)	3	97	10	50	44
Magnesium (Mg)	3	55	24	40	40
Sodium (Na)	3	27	.3	13	12
Potassium (K)	2	2.2	1.9	2.1	2.1
Bicarbonate (HCO_3)	3	420	220	344	393
Sulfate (SO_4)	3	82	29	51	41
Chloride (Cl)	3	83	19	57	69
Fluoride (F)	2	.3	.2	.3	.3
Silica (SiO_2)	2	16	8.5	12	12
Dissolved solids, residue on evaporation at 180°C	3	574	254	460	552
Dissolved solids, residue on evaporation at 105°C	---	---	---	---	---
Nitrate nitrogen (N)	3	5.1	.02	1.8	.29
Organic carbon, total (C)	3	4.2	2.8	3.5	3.5
Iron (Fe)	3	820	0	280	20
Manganese (Mn)	3	550	240	400	400

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