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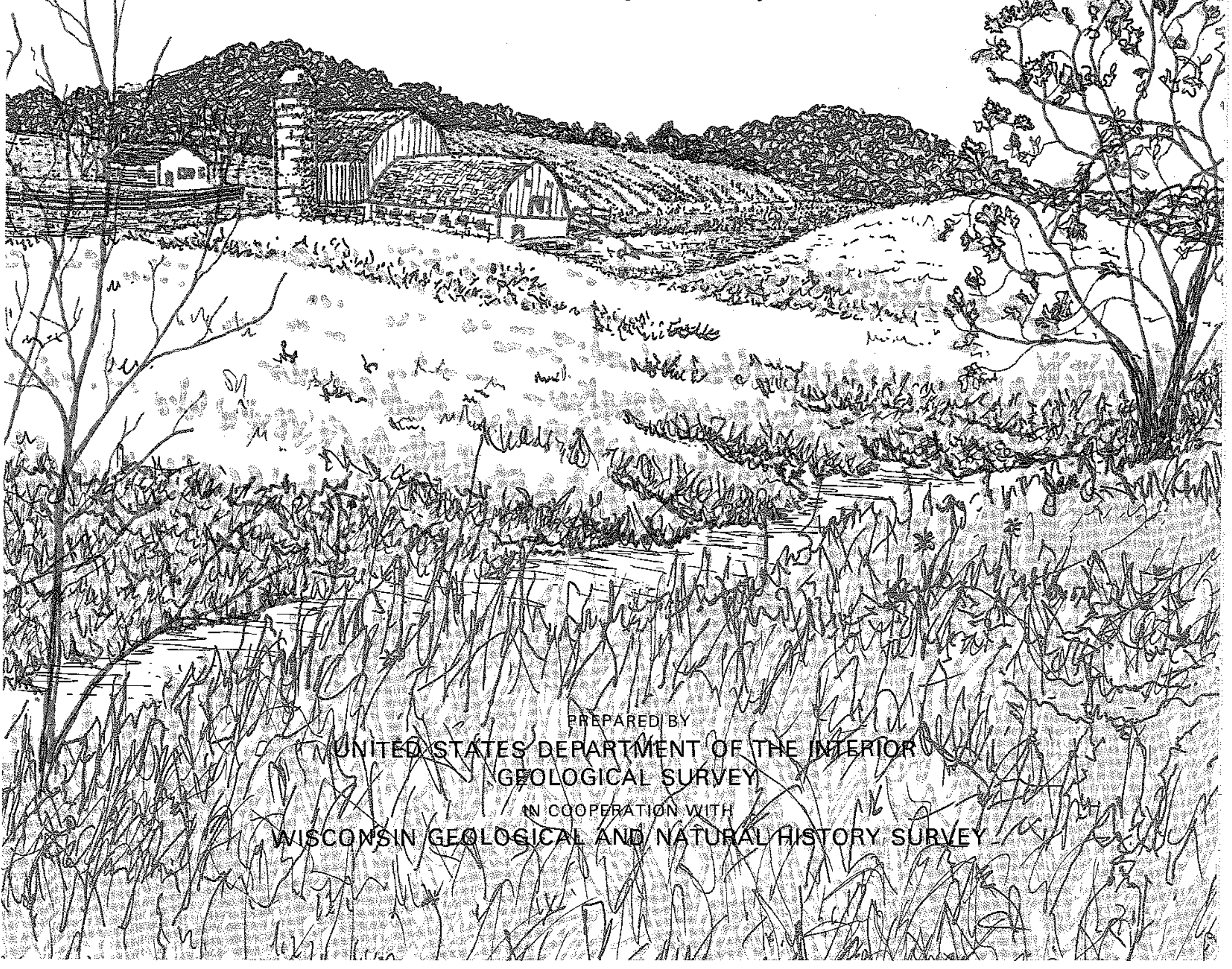
Ground-Water Resources and Geology of St. Croix County, Wisconsin

by
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
GEOLOGICAL AND NATURAL HISTORY SURVEY
M. E. Ostrom, Director and State Geologist
Madison, Wisconsin
July 1976

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CONVERSION FACTORS

Multiply English units	By	To obtain SI units
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
gallons per minute (gal/min)	.06309	litres per second (l/s)
million gallons per day (Mgal/d)	.04381	cubic metres per second (m^3/s)
gallons per day (gal/d)	3.785	litres per day (l/d)
feet per day (ft/d)	.3048	metres per day (m/d)

Ground-Water Resources and Geology of St. Croix County, Wisconsin

R. G. Borman

ABSTRACT

The increasing need for good-quality ground water in St. Croix 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 (0.95 litres per second) can be obtained from wells almost everywhere in the county. Yields of more than 1,000 gallons per minute (63 litres per second) are available from glacial deposits and alluvium where there is sufficient thickness of saturated sand and gravel. The sandstone aquifer underlies the entire county and is more than 1,000 feet (300 metres) thick in the southwest near River Falls. In St. Croix County the sandstone aquifer is all bedrock younger than Precambrian age and includes, in ascending order, from oldest to youngest, sandstones of Cambrian age (in ascending order, the Mount Simon, Eau Claire, Galesville, and Franconia Sandstones, and the Trempealeau Formation); and the Prairie du Chien Group, St. Peter Sandstone, and Galena-Platteville unit (Platteville and Decorah Formations and Galena Dolomite, undifferentiated), all of Ordovician age. This aquifer is capable of yielding more than 1,000 gallons per minute (63 litres per second) to wells in much of the county and is the principal source of municipal water.

The chemical quality of water from the two aquifers is similar. The water from both aquifers is hard to very hard, having a median hardness between 180 and 190 milligrams per litre. Iron and manganese are locally present in bothersome amounts (combined total exceeding 0.3 milligrams per litre). Nitrate is a minor problem in both aquifers, with median concentrations more than 10 milligrams per litre, possibly indicating some contamination of ground water by organic matter.

About 3.83 million gallons per day (0.168 cubic metres per second) of ground water was pumped in the county in 1974, of which 94 percent was from the sandstone aquifer. About 44 percent of the total water pumped was for industrial and commercial use, 42 percent for residential use, and 14 percent for irrigation, institutional, and municipal use.

INTRODUCTION

St. Croix County is in west-central Wisconsin (fig. 1). Hudson, the county seat, is on the St. Croix River in the west-central part of the county and is 40 mi (64 km) west of Menomonie and 20 mi (32 km) east of St. Paul, Minnesota. St. Croix County had a population growth of 17.8 percent from 1960 to 1970. The 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, availability, and use of ground water. It is intended for water planners and users in the future development of the water resources and of resources related to the ground-water supply.

The scope of the project included collection and analyses of ground-water samples and well-log, water-level, water-use, pumpage, and aquifer-test data to describe the hydrology and geology of the county. The geology was studied only in enough detail to understand and describe the ground-water hydrology.

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

Thanks are given to the many municipal and county officials, State agencies, drillers, and well owners who assisted this study by providing well and water

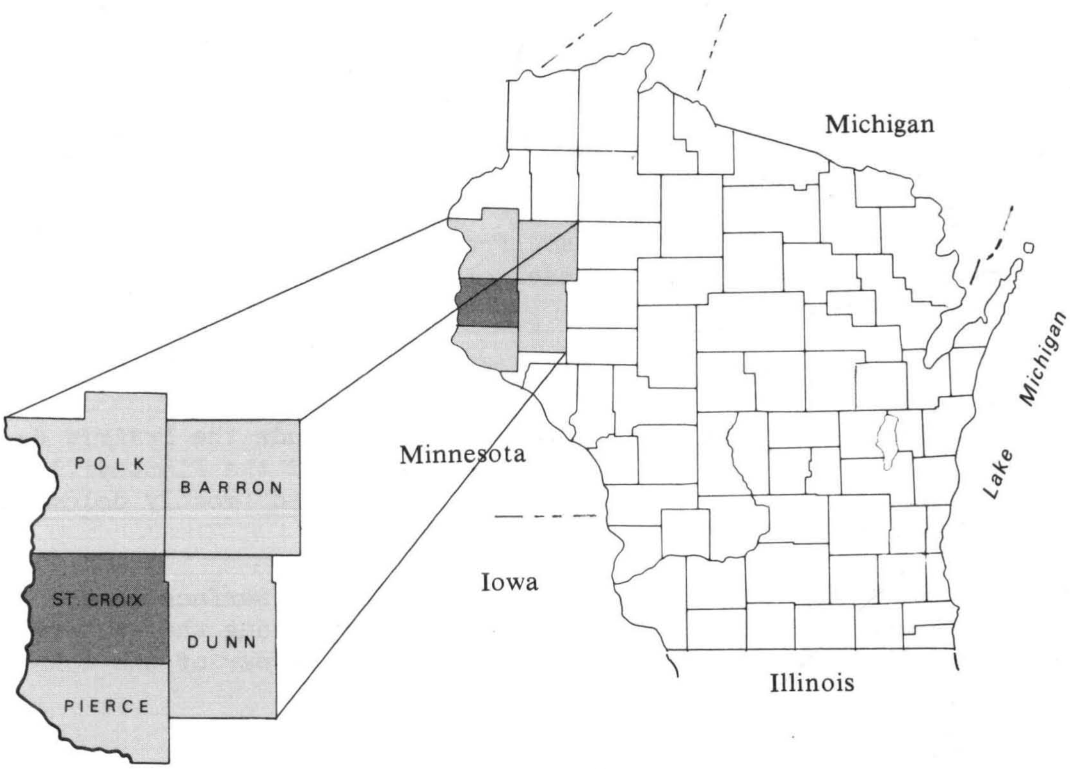


Figure 1. Location of St. Croix County in Wisconsin.

information. Thanks are given also to the many well owners who allowed access to their wells for water-level measurement or for collection of water samples. Special acknowledgment is made to the Wisconsin Department of Natural Resources for supplying well records, to the Wisconsin State Laboratory of Hygiene for chemical analyses of water samples, and to the Wisconsin Public Service Commission for pumpage records.

GEOLOGY

The rocks and soils that control the movement and storage of ground water in St. Croix County range from the basement rocks of Precambrian age to the glacial deposits, alluvium, and soils of Quaternary age. Bedrock is overlain by glacial drift throughout most of the county. The bedrock, from oldest to youngest, includes Precambrian igneous, metamorphic, and sedimentary rocks; Cambrian sandstone; and Ordovician dolomite and sandstone (table 1). Many of these units underlie only part of the county.

PRECAMBRIAN ROCKS

Igneous, metamorphic, and sedimentary rocks of Precambrian age underlie all of St. Croix County. Precambrian rocks were penetrated by three wells at Hudson, where samples from two wells were identified as red shale and a sample from the third well was identified as rhyolite. The presence of metamorphic Precambrian rocks is inferred from the common occurrence of metamorphic Precambrian rocks elsewhere in the State. The top surface of the Precambrian rocks ranges from more than 500 ft (150 m) above sea level (400 ft or 120 m below land surface) in the northwest, where they have been raised by faulting, to less than 100 ft (30 m) below sea level (900 ft or 270 m below land surface).

CAMBRIAN ROCKS

Cambrian rocks overlie the Precambrian rocks and are present under the entire county. They are primarily sandstone but include subordinate shale, siltstone, and dolomite. They consist of five formations, from bottom to top: the Mount Simon, Eau Claire, Galesville, and Franconia Sandstones, and the Trempealeau Formation. In this report these formations are not differentiated, but are called the "Cambrian sandstone".

ORDOVICIAN ROCKS

Ordovician sedimentary rocks in St. Croix County include the Prairie du Chien Group (mostly dolomite), the St. Peter Sandstone, and the Platteville and Decorah Formations and Galena Dolomite, undifferentiated (mostly dolomite and herein called the Galena-Platteville unit).

All of these rocks dip generally westward. The bottom surface of the Prairie du Chien ranges in altitude from 1,100 ft (340 m) along the eastern county line to less than 600 ft (180 m) in the southwest corner of the county.

Table 1.--Stratigraphy of St. Croix County

System	Rock unit	Predominant lithology
QUATERNARY	Holocene deposits	Unconsolidated stratified deposits ranging in size from clay to boulders and marsh deposits.
	Pleistocene deposits	Unconsolidated stratified deposits ranging in size from clay to boulders and marsh deposits.
ORDOVICIAN	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	Dolomite and some slightly shaly dolomite, light gray.
	St. Peter Sandstone	Sandstone, dolomitic in places, white to yellow-brown, fine- to medium-grained; shale.
	Prairie du Chien Group	Dolomite, gray; some sandstone and sandy dolomite.
CAMBRIAN	Trempealeau Formation	Sandstone, fine- to medium-grained; dolomite; some siltstone, light gray.
	Franconia Sandstone	Sandstone, dolomitic, very fine- to medium-grained; siltstone, dolomitic.
	Galesville Sandstone	Sandstone, light-gray, fine- to coarse-grained.
	Eau Claire Sandstone	Sandstone, dolomitic, light-gray, fine- to medium-grained; shale and siltstone.
	Mount Simon Sandstone	Sandstone, light-gray, fine- to coarse-grained; some interbedded siltstone.
PRE-CAMBRIAN	Precambrian rocks, undifferentiated	Crystalline and sedimentary rocks.

BEDROCK SURFACE

The bedrock geologic map (fig. 2) shows the rock that would be exposed if the unconsolidated material above it were stripped away. Actually the bedrock in the county is covered by glacial drift except for a few small outcrops. The bedrock geologic map is based on these outcrops and numerous drill records.

The Prairie du Chien Group is the uppermost bedrock in about one-half of the county. The Cambrian sandstone is the uppermost bedrock in about one-fifth of the county, mainly in the west where it has been uplifted by faulting and the overlying rock units have been eroded away. The St. Peter Sandstone is the uppermost unit in about one-fifth of the county, and the Galena-Platteville unit caps some hills in the southwest quarter.

The shape of the bedrock surface (fig. 3) is a result of erosion during preglacial and glacial time. The resulting bedrock surface then was buried beneath glacial drift. Some parts of the county that were covered by thin drift have been modified by postglacial erosion.

The altitude of the bedrock surface ranges from more than 1,200 ft (370 m) in several places in the east to less than 500 ft (150 m) at Hudson and north of Hudson, where preglacial valleys trend northeastward from the St. Croix River valley.

QUATERNARY DEPOSITS

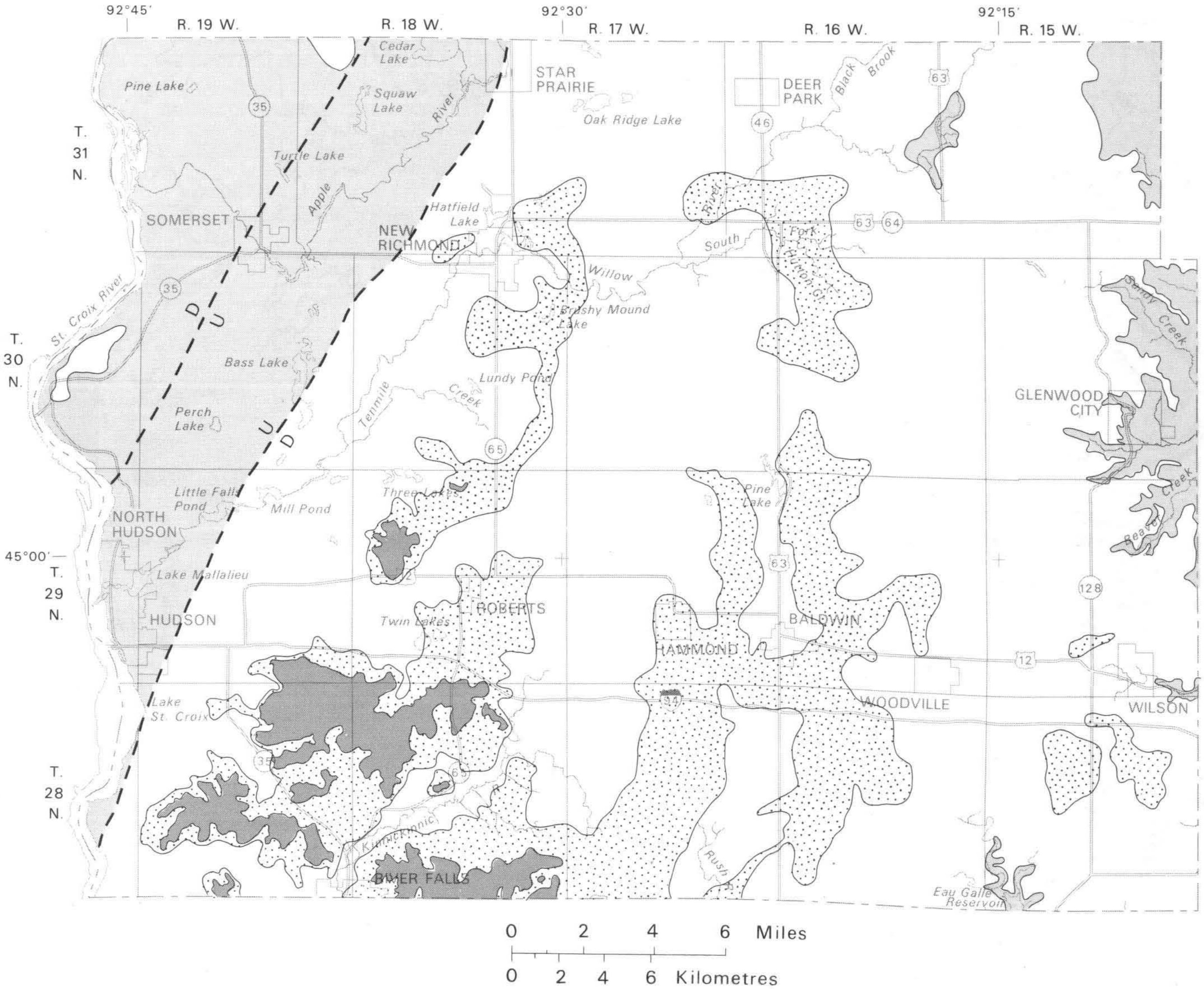
The unconsolidated Quaternary deposits overlying bedrock in St. Croix County are largely glacial sediments, but they also include some alluvium and marsh deposits. Landforms produced by glacial deposition include end moraine, ground moraine, and outwash plains (fig. 4).

End moraines are formed by deposition at the margin of a glacier during a standstill of the glacial front, when the rate of melting equals the rate of glacier advance. They may form either at the point of maximum ice advance or during recession of the glacier. They consist of unsorted glacial material ranging in size from clay to boulders. A typical end moraine is a ridge with a rolling to hummocky surface; kettles or pits are common and may contain lakes or marshes. A broad area of end moraine (fig. 4) in the northwest quarter of St. Croix County was formed by the Superior lobe during Wisconsin Glaciation.

Ground moraine is deposited under glacial ice as a blanket of unsorted rock debris ranging in size from clay to boulders. The ground moraine (fig. 4) that covers much of St. Croix County was deposited by early-Wisconsin or pre-Wisconsin age glaciers. Ground moraine in the county is a gently undulating plain with moderate relief and no definite alinement of the undulation.

An outwash plain is stratified gravel, sand, silt, and clay deposited by water from the melting glacier. Pits or kettles commonly develop in the plain from the melting of buried blocks of ice. In St. Croix County pitted outwash plains of sand and gravel were deposited in front of the Superior lobe ice front.

The combined thickness of unconsolidated glacial drift, alluvium, and marsh deposits ranges from zero where bedrock crops out, mainly on hillsides and road



EXPLANATION

ORDOVICIAN

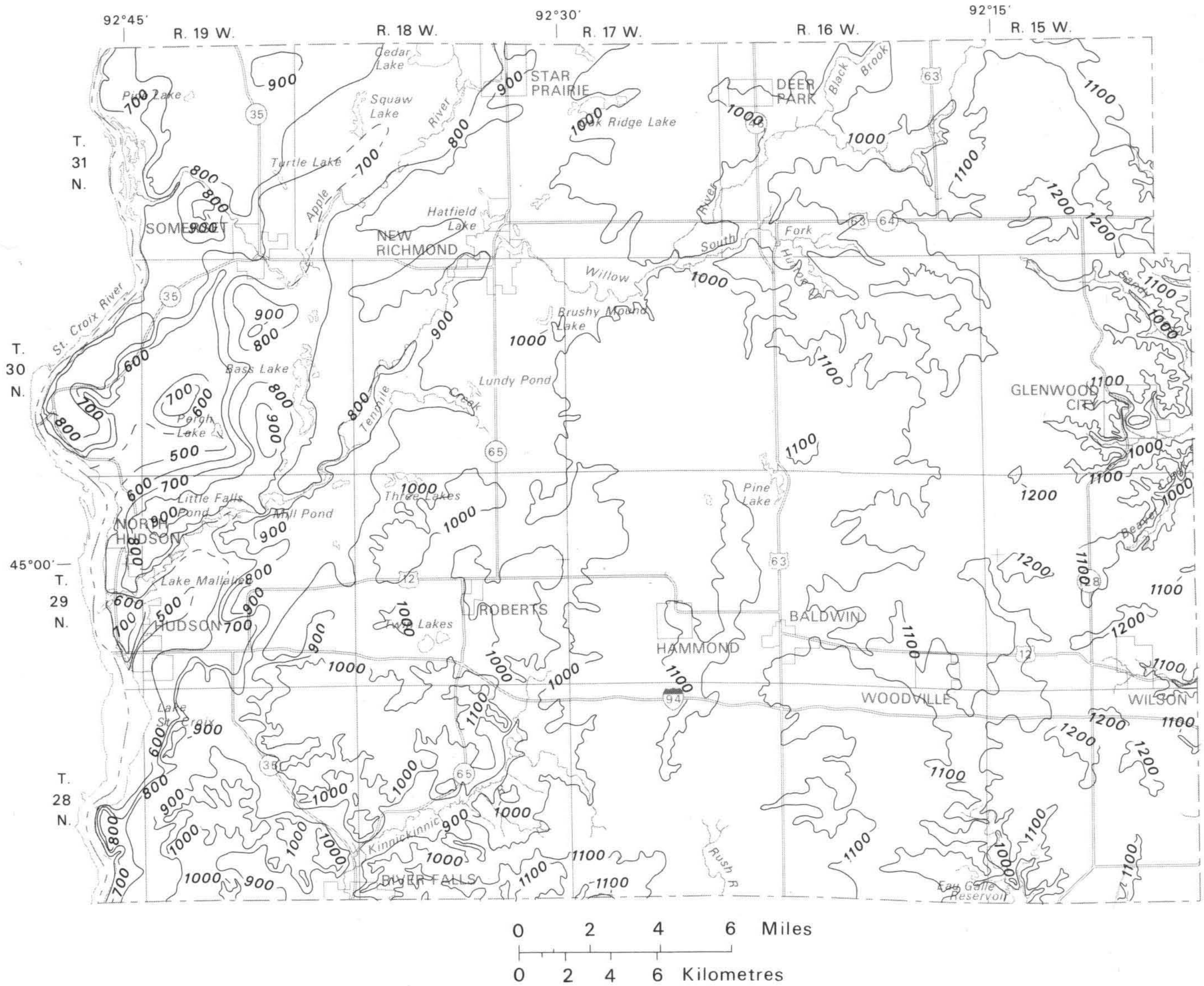
- Galena, Decorah, and Platteville Formations, undifferentiated — *Mostly dolomite*
- St. Peter Sandstone — *Mostly sandstone*
- Prairie du Chien Group — *Mostly dolomite*

CAMBRIAN

- Trempealeau Formation and Franconia, Galesville, Eau Claire, and Mount Simon Sandstones, undifferentiated — *Mostly sandstone; some shale, siltstone, and dolomite*

- - - - - Inferred fault — U, *upthrown side;* D, *downthrown side*

Figure 2. Bedrock geology.



EXPLANATION

——— *1200* – – –   **Bedrock contour**

Shows altitude of bedrock surface. Dashed where approximately located. Contour interval 100 feet (30 metres). Datum is mean sea level.

Figure 3. Bedrock topography.

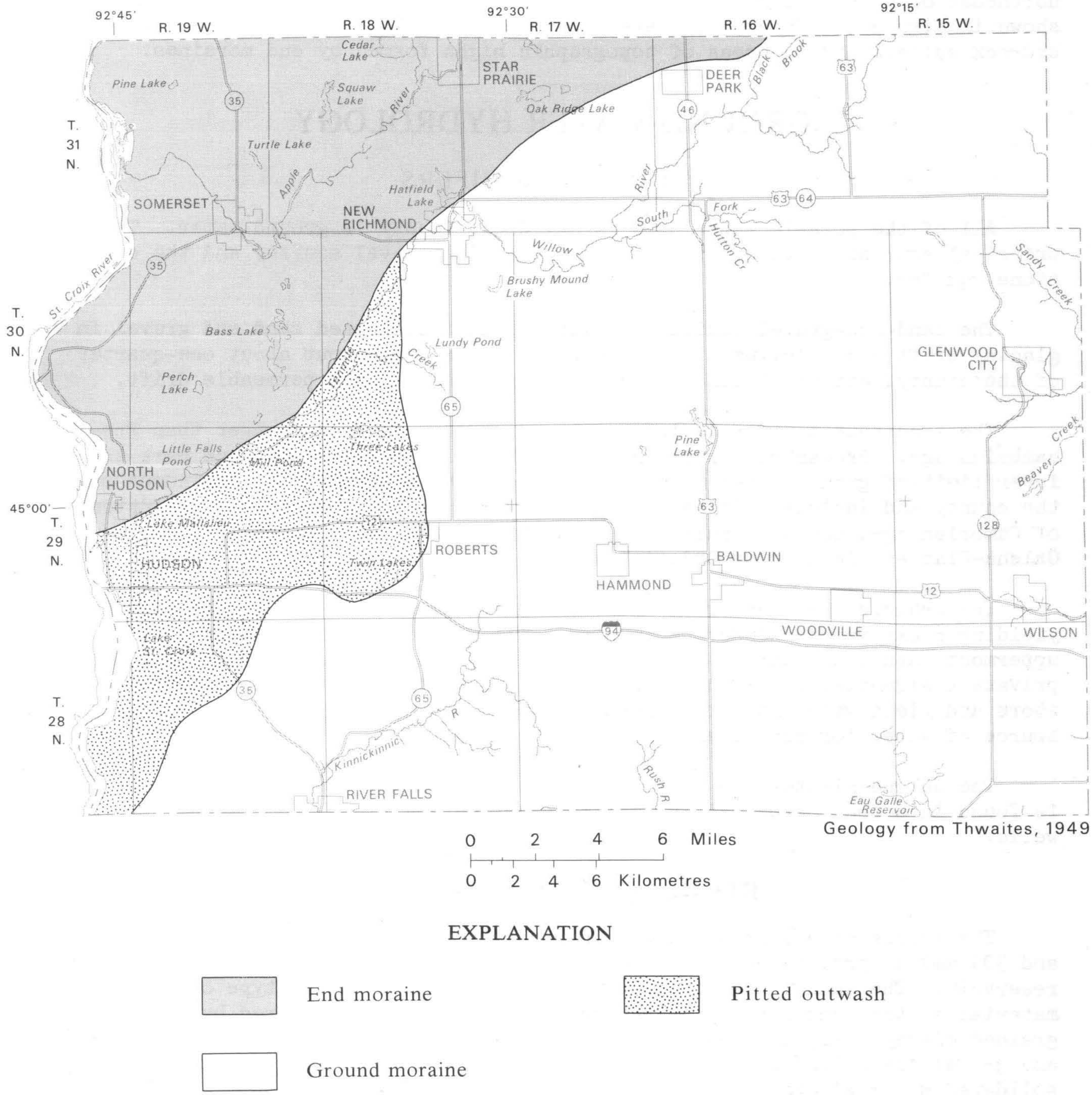


Figure 4. Glacial geology.

cuts along the eastern and southern parts of the county and in the valleys of the Apple and Willow Rivers, to more than 450 ft (140 m) about 6 mi (10 km) northeast of Hudson (fig. 5). The areas of zero thickness are too small to be shown in figure 5. Thicknesses are greatest where glacial materials fill bedrock valleys and in areas of topographic highs formed by end moraines.

GROUND-WATER HYDROLOGY

PRINCIPAL AQUIFERS

All of the potable water used in St. Croix County is ground water. The principal sources of this supply are the sand-and-gravel aquifer and the sandstone aquifer.

The sand-and-gravel aquifer consists of unconsolidated sand and gravel in glacial drift and alluvium. These deposits occur throughout about one-quarter of the county, either at land surface or buried under less permeable drift.

The sandstone aquifer includes all sedimentary bedrock younger than Precambrian age. Precambrian rocks generally have low permeability and mark the lower limit of ground-water movement. The sandstone aquifer is continuous over the county and includes, in ascending order from oldest to youngest, sandstones of Cambrian age, and the Prairie du Chien Group, St. Peter Sandstone, and Galena-Platteville unit of Ordovician age.

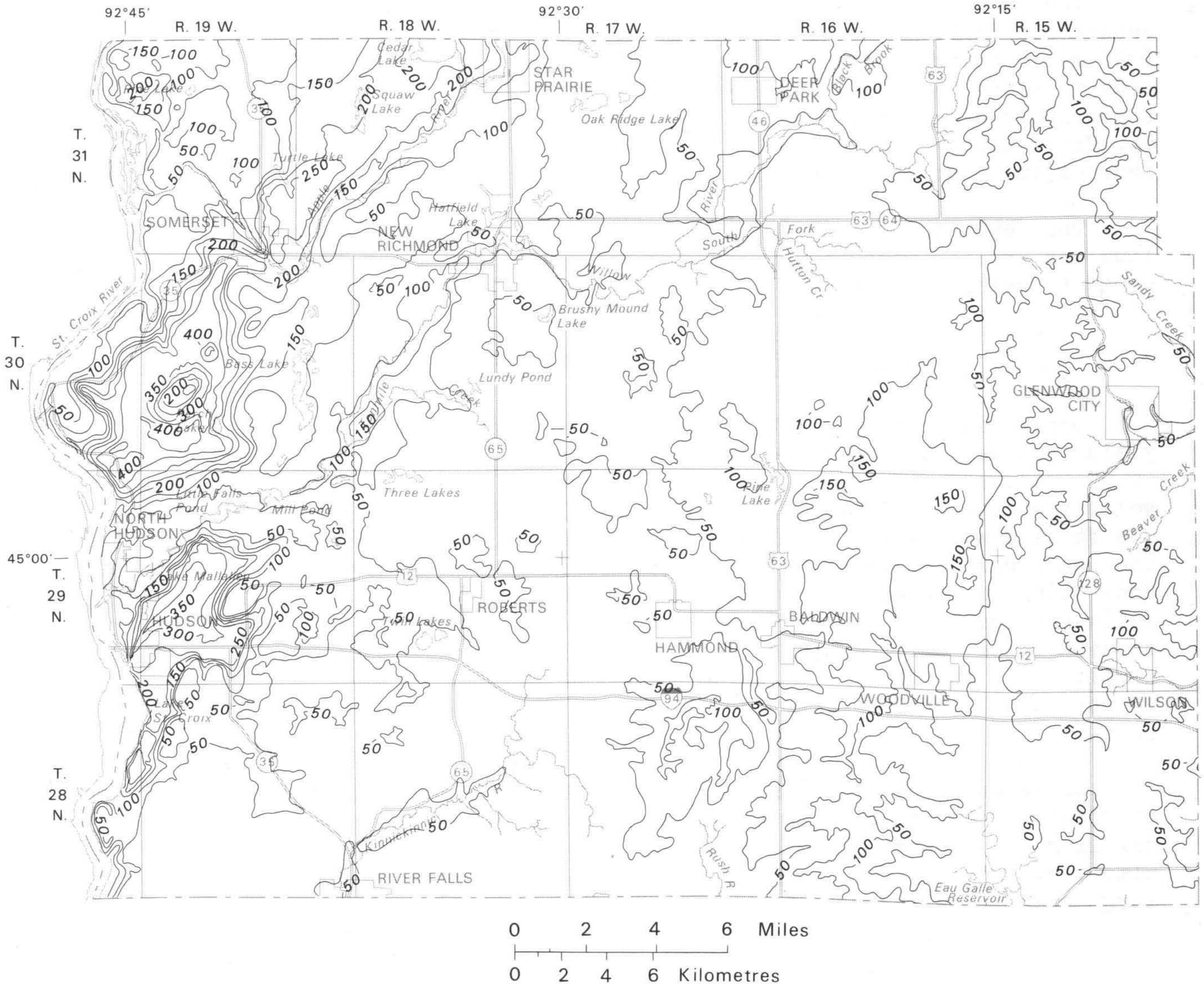
The Prairie du Chien Group and the Cambrian sandstone are the major water-yielding rocks in the sandstone aquifer. The Prairie du Chien Group is the uppermost saturated bedrock in much of the county and is used extensively for private residential water supplies. The ability of the Cambrian sandstone to store and yield water and its generally great thickness make it the principal source of water for municipal supplies.

The Galena-Platteville unit is mostly unsaturated; the St. Peter Sandstone is found in a small area and is partly saturated and yields some water to wells.

RECHARGE AND MOVEMENT

The source of all ground water is precipitation. Between 1 and 10 in (30 and 300 mm) of precipitation per year infiltrates and recharges the ground-water reservoir. The amount that infiltrates depends mainly on the type of rock material at the land surface. Recharge is least in areas covered by fine-grained clayey till, is greater in silty sandy till, and is greatest where sand and gravel are at the surface. Recharge also can be high where thin unconsolidated material overlies dolomite with fractures and solution channels.

Most ground water moves through the unconsolidated material and bedrock units and then discharges to surface-water bodies. The general direction of ground-water movement within the glacial drift or the shallow bedrock at any locality can be determined from the water-table contours (pl. 1). Ground water moves in the direction of decreasing head, approximately at right angles to the contours.



EXPLANATION

——— *150* ——— Line of equal thickness of unconsolidated materials
Interval 50 feet (15 metres)

Figure 5. Thickness of unconsolidated materials.

WATER TABLE

The water-table map (pl. 1) shows the altitude of the top of the zone of saturation in St. Croix County. The altitude ranges from more than 1,100 ft (340 m) in several places in the eastern quarter of the county to about 675 ft (206 m) along the St. Croix River. The water table is generally higher under topographic highs, and lower under topographic lows, such as the low along the St. Croix River. The water table is below the glacial drift and within the bedrock in about half the county.

The depth to water below land surface is generally less under topographic lows and greater under topographic highs. Figure 6 shows the areas where the depth to water is less than 10 ft (3 m) for at least part of the year.

GROUND-WATER AVAILABILITY

Ground water is available throughout the county, but individual well yields and well depths differ widely. Small yields of ground water, 15 gal/min (0.95 l/s), are obtained by drillers everywhere in the county. Most domestic wells are between 100 and 200 ft (30 and 61 m) deep, with some as deep as 350 ft (110 m). Wells usually are completed in the sand-and-gravel aquifer or the shallowest saturated bedrock. As determined by a representative sample consisting of 180 well-construction reports, about 28 percent of the domestic wells are completed in the sand-and-gravel aquifer and 72 percent in the sandstone aquifer. Of the wells finished in the sandstone aquifer, 52 percent are completed in the Prairie du Chien Group, 27 percent in the Cambrian sandstone, 14 percent in the St. Peter Sandstone, and 7 percent are open to more than one unit.

Large supplies of ground water for industries and municipalities are more difficult to obtain because wells for these supplies require more complex drilling and construction techniques. The sandstone aquifer has been used almost exclusively for large water supplies because it is capable of yielding large quantities throughout the county.

THE SAND-AND-GRAVEL AQUIFER

The sand-and-gravel aquifer is the permeable part of the unconsolidated materials. It includes materials described in well records as sand, gravel, or a mixture of sand and gravel. The saturated sand-and-gravel aquifer is present in less than one-fourth of the county, mostly in an area from Star Prairie to Hudson, where it fills bedrock valleys. The aquifer may extend down from the surface or be buried below relatively impermeable materials. Few high-capacity wells (capable of yielding at least 70 gal/min or 4 l/s) have been developed in the sand-and-gravel aquifer. The highest yield reported is 1,300 gal/min (82 l/s).

Water in the sand-and-gravel aquifer is generally under water-table conditions. Water levels of wells in the aquifer are represented by the water-table map (pl. 1).

The saturated thickness of unconsolidated deposits ranges from zero in about half the county to more than 350 ft (110 m) in a bedrock valley north

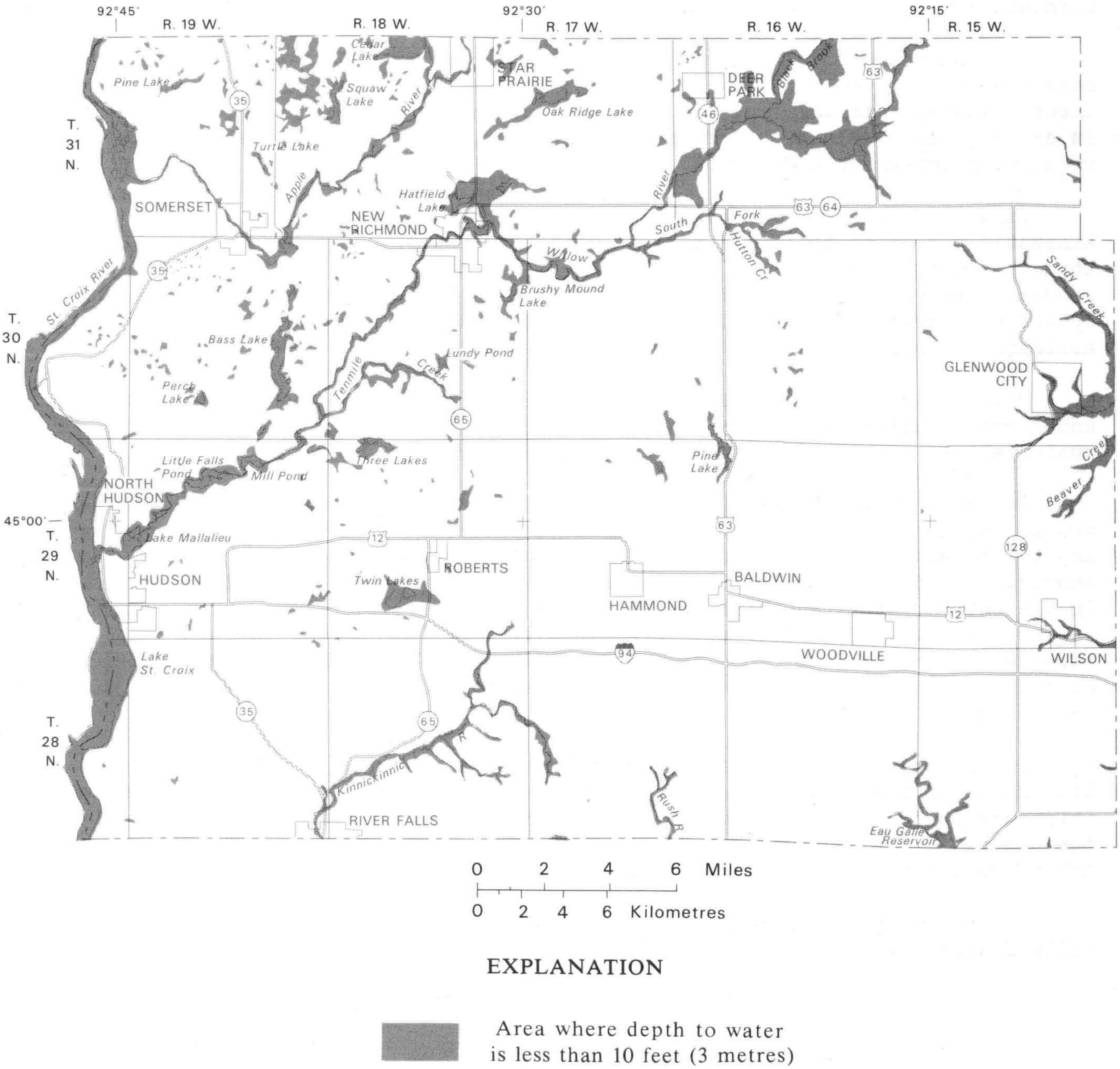


Figure 6. Areas where the depth to water is less than 10 feet(3 metres)

of Hudson (fig. 7). This thickness includes all unconsolidated materials between the bedrock surface and the water table, regardless of grain size, sorting, or permeability.

The saturated thickness of the sand-and-gravel aquifer ranges from zero to more than 150 ft (46 m) (fig. 8). This thickness includes all saturated permeable unconsolidated material from the land surface to the bedrock surface, whether it is exposed, is overlain by impermeable deposits, or occurs in beds separated by relatively impermeable deposits.

Values of hydraulic conductivity (the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow) for the sand-and-gravel aquifer in St. Croix County were estimated from lithologic and specific-capacity data for about 120 wells finished in the aquifer. These estimates ranged from about 7 ft/d (2 m/d) to about 670 ft/d (200 m/d).

Well yields sufficient for domestic use are obtainable wherever the sand-and-gravel aquifer is present. Higher yields sufficient for industrial or municipal use are possible in parts of the county.

Figure 9 shows the well yields obtainable from the sand-and-gravel aquifer and is based on the hydraulic conductivity, saturated thickness of the aquifer, and total head (height of the water above the bottom of the aquifer). It should be used with caution because wells may have to penetrate and be screened in the entire saturated thickness of sand and gravel (which may not be economically feasible). Effective well diameters of 2 ft (0.6 m) may be required, especially for yields of more than 500 gal/min (32 l/s). Recharge may limit the ability of a well or well field to provide sustained yields of more than 500 gal/min (32 l/s).

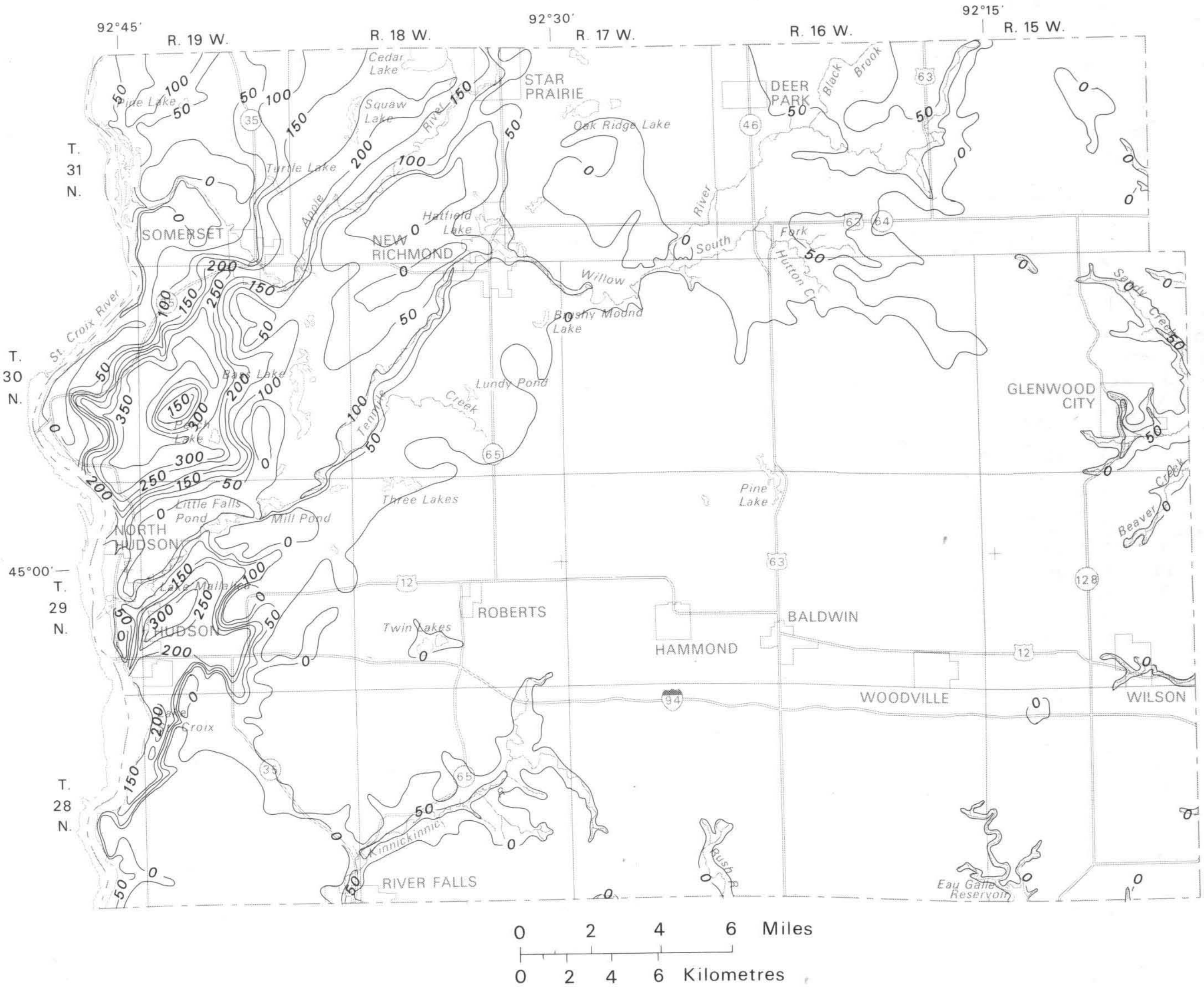
In preparing figure 9, drawdowns caused by pumping wells were limited to two-thirds of the total head. (The total head is taken as equal to the saturated thickness of unconsolidated materials, assuming there is some sand and gravel at the bottom of the unconsolidated materials, figure 7.) This is a reasonable but arbitrary limitation of drawdown that is useful for planning.

Sustained yields of more than a few gallons per minute are unlikely from wells finished in saturated, fine-grained unconsolidated deposits.

THE SANDSTONE AQUIFER

The sandstone aquifer underlies all of St. Croix County and is the principal source of water for residential, municipal, and industrial supplies. Most municipal or industrial wells pump between 200 gal/min (13 l/s) and 1,000 gal/min (63 l/s).

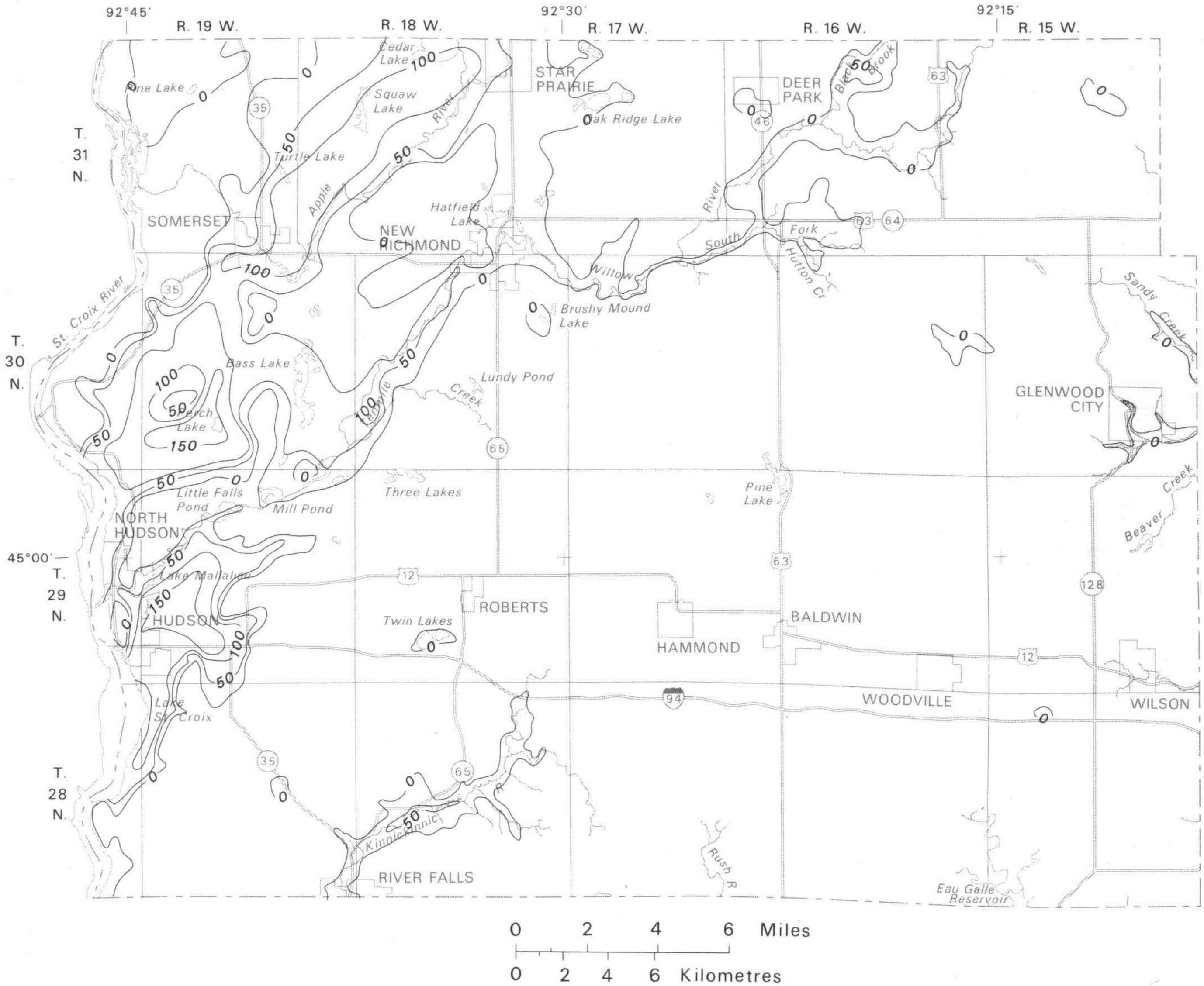
Water in the sandstone aquifer is generally under water-table conditions. Water levels of wells in the aquifer are represented by the water-table map (pl. 1). The aquifer is completely saturated in about half the county where the water table is in the overlying glacial drift.



EXPLANATION

——— 50 ——— Line of equal saturated thickness of unconsolidated materials
Interval 50 feet (15 metres)

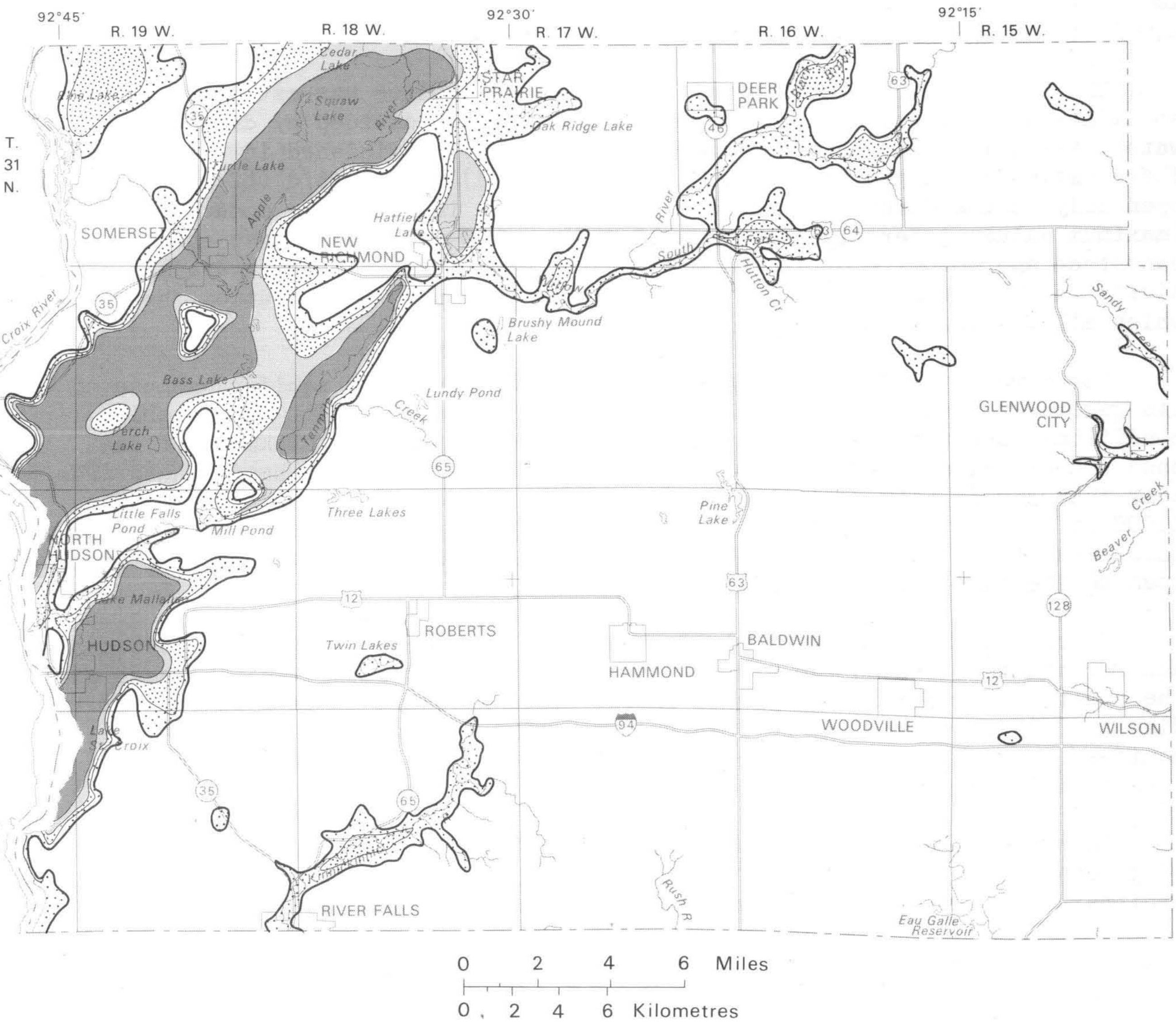
Figure 7. Saturated thickness of unconsolidated materials.



EXPLANATION

——— 50 ——— Line of equal saturated thickness of the sand-and-gravel aquifer
Interval 50 feet (15 metres)

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



EXPLANATION

Probable well yields

- Chances of more than 100 gallons per minute (6.3 litres per second) are poor
- Chances of 500-1,000 gallons per minute (32-63 litres per second) are good
- Chances of 100-500 gallons per minute (6.3-32 litres per second) are good
- Chances of more than 1,000 gallons per minute (63 litres per second) are good

——— Boundary of saturated sand-and-gravel aquifer

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

The saturated thickness of the sandstone aquifer ranges from less than 100 ft (30 m) in a bedrock valley 6 mi (10 m) northeast of Hudson to more than 1,000 ft (300 m) in places near River Falls (fig. 10).

The hydraulic conductivity of the sandstone aquifer was estimated from specific-capacity (discharge, in gallons per minute, divided by drawdown of water level, in feet) data from several hundred wells finished in the aquifer. These estimates ranged from about 1 ft/d (0.3 m/d) to 270 ft/d (82 m/d). Wells open only to the Cambrian sandstone differed less in hydraulic conductivity (maximum values generally less than 13 ft/d or 4.0 m/d) than those open to sandstone and dolomite or to dolomite only. The differences in hydraulic conductivity in the dolomite probably are caused by fractures and solution channels, which allow water to move rapidly through the rock.

Large well yields can be developed from the sandstone aquifer because of its generally great saturated thickness and total head. Under water-table conditions, the total head includes the combined saturated thickness of the sand-and-gravel aquifer and the sandstone aquifer. The total head ranges from less than 350 ft (110 m) in bedrock valleys northeast of Hudson to more than 1,000 ft (300 m) near River Falls (fig. 12). Well yields depend on the saturated thickness of the sandstone aquifer because wells finished in the aquifer are not open to the sand-and-gravel aquifer.

Figure 11 shows the well yields that may be expected from the sandstone aquifer and is based on the hydraulic conductivity and saturated thickness of the aquifer. To obtain the yields shown, wells may have to be 1 ft (0.3 m) in diameter and penetrate and be open to the entire saturated thickness of the aquifer. The ability of a well or well field to provide sustained yields of more than 500 gal/min (32 l/s) may be limited by available recharge.

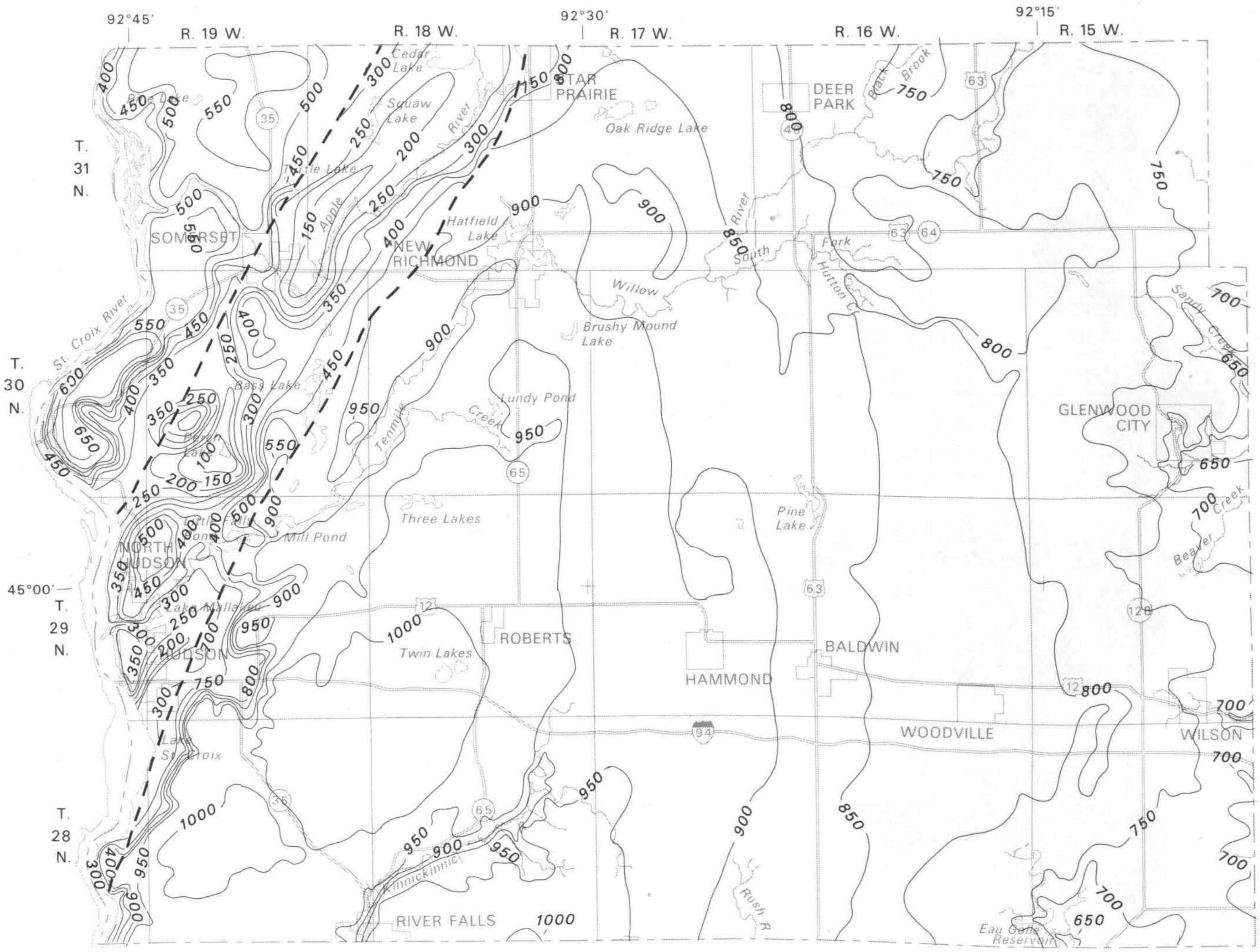
In preparing figure 11, drawdowns caused by pumping wells were limited to 40 percent of the total head of the aquifer (fig. 12). This is a reasonable but arbitrary limitation of drawdown that is useful for planning.

GROUND-WATER QUALITY

The quality of ground water in St. Croix County generally is good. However, some has chemical characteristics that make it objectionable or unsuitable for domestic or industrial uses. Some chemical constituents that determine the quality of ground water and its suitability for use are dissolved-solids, iron, manganese, and nitrate concentrations. Hardness also determines its suitability for some uses. The known range of concentration of these constituents and hardness is shown for each aquifer in figure 13.

DISSOLVED SOLIDS

Dissolved-solids concentration is a measure of the dissolved mineral constituents in water and is reported as milligrams per litre (mg/l). An upper limit of 500 mg/l for dissolved solids is recommended by the U.S. Public Health Service (1962, p. 7) because higher amounts create taste problems. These standards apply only to drinking water and water-supply systems used by carriers and others subject to Federal quarantine regulations; however, they have been accepted



0 2 4 6 Miles

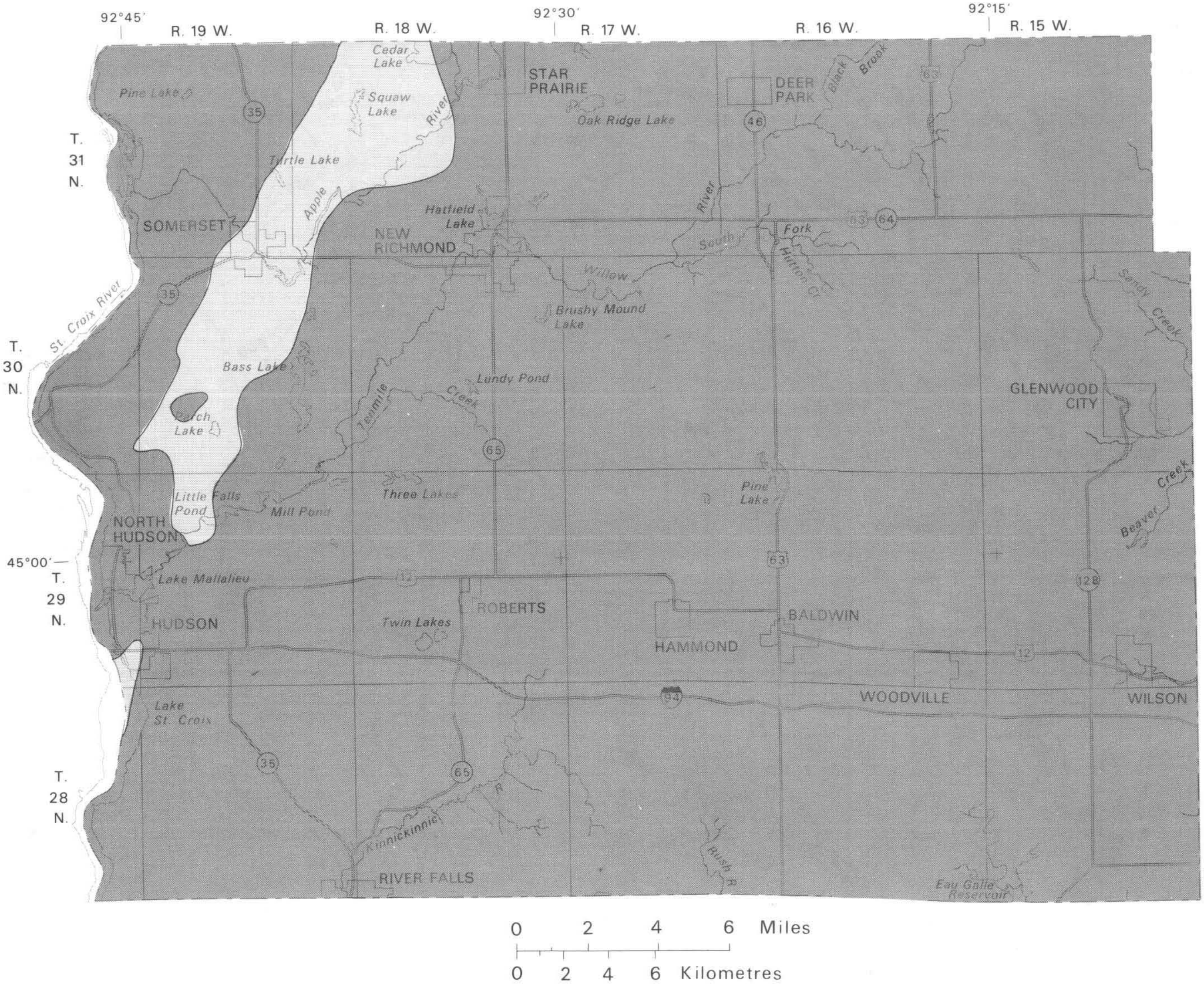
0 2 4 6 Kilometres

EXPLANATION

850 — Line of equal saturated thickness of the sandstone aquifer
Interval 50 feet(15 metres)

– – – – – – – Inferred fault

Figure 10. Saturated thickness of the sandstone aquifer.

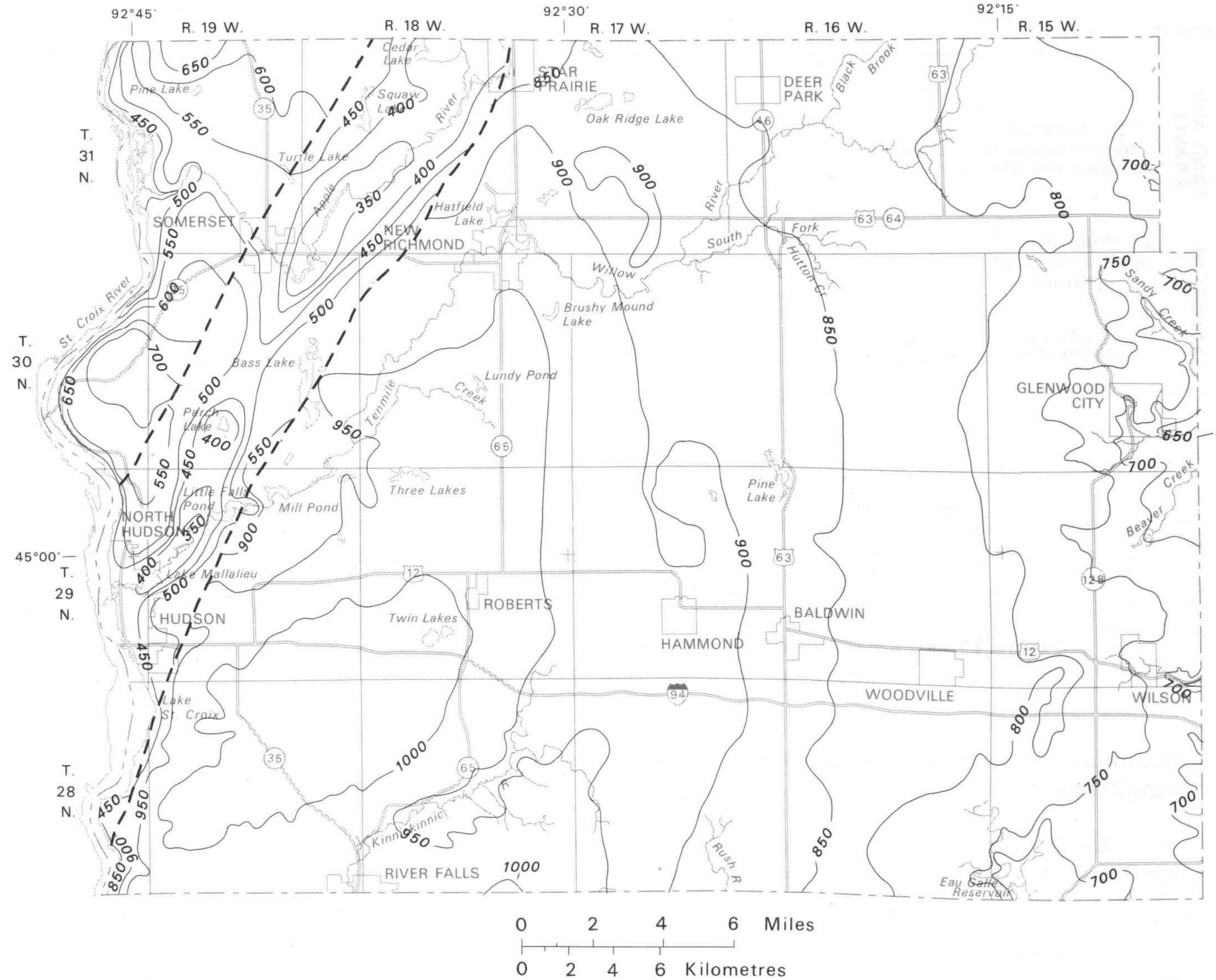


EXPLANATION

Probable well yields

Light pattern	Chances of 500-1,000 gallons per minute (32-63 litres per second) are good
Dark pattern	Chances of more than 1,000 gallons per minute (63 litres per second) are good

Figure 11. Probable well yields from the sandstone aquifer.



EXPLANATION

450 — Line of equal total head
Shows total head above the base of the sandstone aquifer in 1974
Interval 50 feet (15 metres)

- - - - Inferred fault

Figure 12. Total head for the sandstone aquifer.

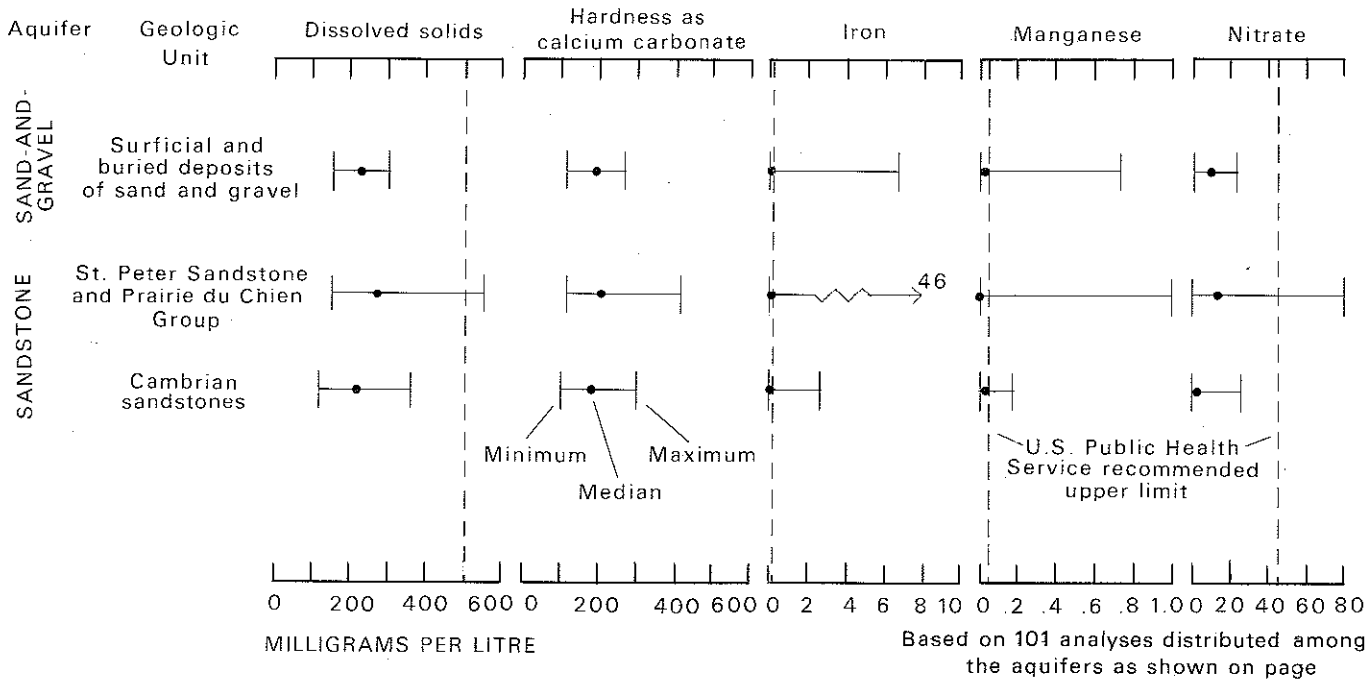


Figure 13. Comparison of concentrations of selected chemical constituents and hardness in water from principal aquifers.

voluntarily by the American Water Works Association as criteria for public-water supplies.

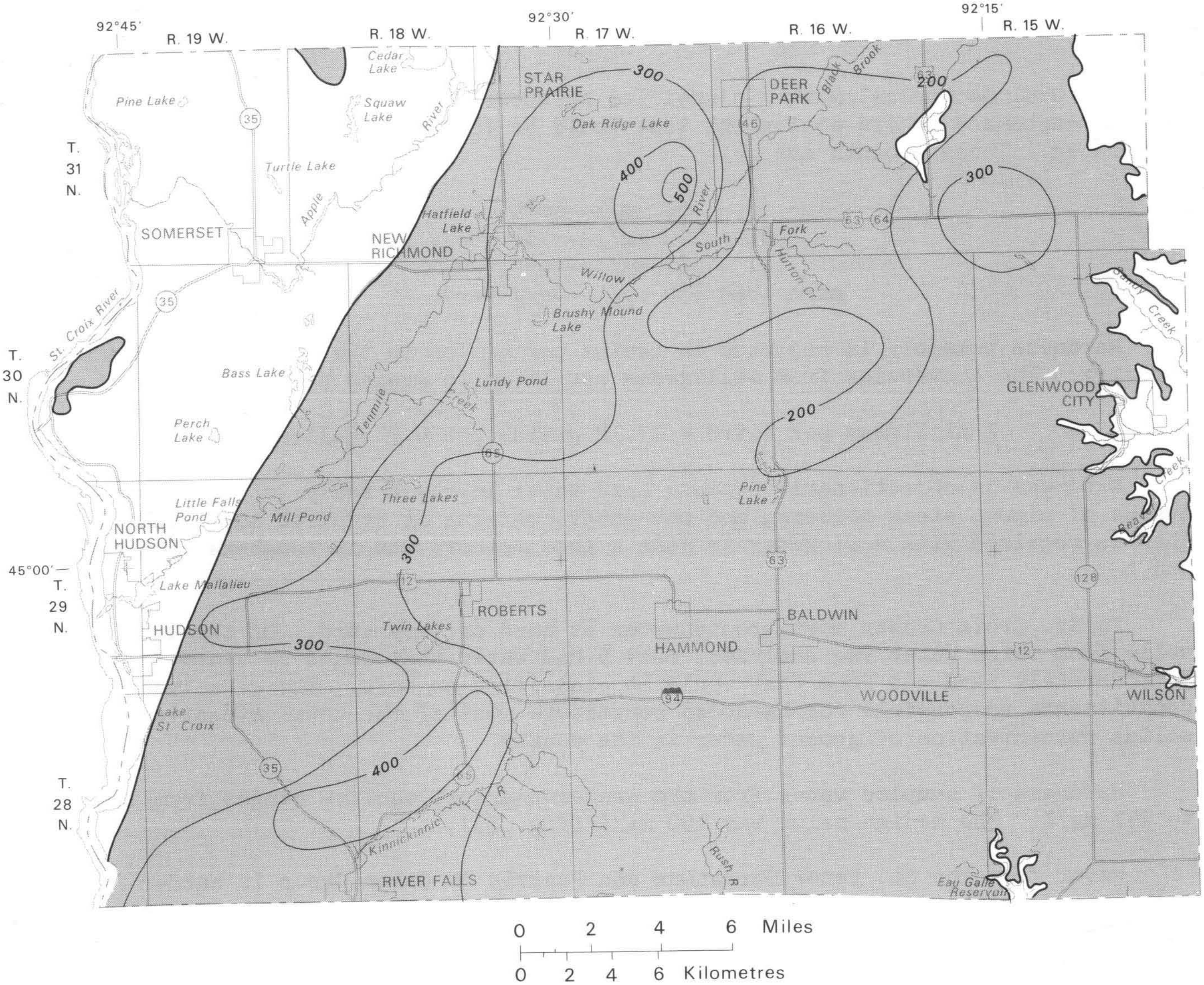
In St. Croix County, the dissolved-solids concentrations for water from the sand-and-gravel and sandstone aquifers are generally less than the recommended limit.

Chemical analyses of water from the sand-and-gravel aquifer indicate that the dissolved-solids concentrations range from 152 to 300 mg/l. The median concentration is 228 mg/l (fig. 13).

Dissolved-solids concentrations in the sandstone aquifer in St. Croix County are greater in water from the St. Peter Sandstone and the Prairie du Chien Group than in water from the Cambrian sandstone (fig. 13). The dissolved-solids concentrations in the St. Peter Sandstone and Prairie du Chien Group range from 152 to 550 mg/l and are between 200 and 300 mg/l in about 75 percent of the area where the Prairie du Chien Group is present (fig. 14). Dissolved-solids concentrations in the Cambrian sandstone range from 118 to 356 mg/l. The median concentration from water in the St. Peter Sandstone and Prairie du Chien Group is 270 mg/l and for the Cambrian sandstone is 214 mg/l.

HARDNESS

Hardness is that property of water that neutralizes soap; it is caused almost entirely by compounds of calcium and magnesium. Calcium and magnesium



EXPLANATION

—— 200 —— Line of equal dissolved-solids concentrations
Interval 100 milligrams per litre

Area underlain by Prairie du Chien Group
Includes St. Peter Sandstone, where present

Figure 14. Dissolved-solids concentrations in water from the St. Peter Sandstone and the Prairie du Chien Group.

commonly are present in rocks and soils, but the highest dissolved concentrations usually are in water that has been in contact with limestone, dolomite, and gypsum. Dolomite is abundant in both the bedrock and glacial drift of St. Croix County.

The U.S. Geological Survey classifies hardness in terms of the amount of calcium carbonate or its equivalent that would be formed if the water were evaporated. These amounts are:

0 - 60 mg/l--soft,
61 - 120 mg/l--moderately hard,
121 - 180 mg/l--hard, and
more than 180 mg/l--very hard.

Hardness commonly is reported in grains per gallon in the water-softening industry. The conversion from milligrams per litre to grains per gallon is:

1 milligram per litre = 17.12 grains per U.S. gallon.

Hardness is objectionable because hard water leaves a scaly deposit on the inside of pipes, steam boilers, and hot-water heaters; it requires more soap than is required with soft water to make a good lather; and it roughens clothes and hands.

In St. Croix County most ground water is hard or very hard. Of the 100 wells from which water was analyzed, only 5 had water that could be classified as moderately hard and none that could be classified as soft. The dissolved constituents responsible for hardness constitute most of the total dissolved-solids concentration of ground water in the county.

Hardness of sampled water from the sand-and-gravel aquifer ranged from 120 to 271 mg/l. The median value was 190 mg/l (fig. 13).

Water from the St. Peter Sandstone and Prairie du Chien Group is harder than that from the Cambrian sandstone (fig. 13). Hardness of water from the St. Peter Sandstone and Prairie du Chien Group ranges from 120 to 420 mg/l, with a median value of 210 mg/l. Hardness is less than 200 mg/l in about half the area in which the Prairie du Chien Group is present (fig. 15). Hardness of water from the Cambrian sandstone ranges from 100 to 300 mg/l, with a median value of 180 mg/l.

IRON AND MANGANESE

The concentrations of iron and manganese also affect the desirability of water for domestic and industrial uses. Iron is dissolved from many rocks and soils. On exposure to air, iron in nonacidic water oxidizes and precipitates. Very low concentrations of iron cause reddish-brown stains on white porcelain or enameled ware and fixtures and on fabrics washed in the water. Manganese resembles iron in its chemical behavior and occurrence in water. It is especially objectionable because small concentrations may cause dark-brown or black stains on fabrics and porcelain fixtures. Appreciable quantities of manganese commonly accompany objectionable quantities of iron in water. Upper limits of 0.3 mg/l for iron and 0.05 mg/l for manganese have been recommended by the U.S. Public

EXPLANATION

——— 300 ——— Line of equal hardness as calcium carbonate
Interval 100 milligrams per litre

[shaded box] Area underlain by Prairie du Chien Group
Includes St. Peter Sandstone, where present

Figure 15. Hardness, as calcium carbonate, of water from the St. Peter Sandstone and the Prairie du Chien Group.

Health Service (1962, p. 7). Iron and manganese concentrations greater than these recommended limits have been found in water from all aquifers in St. Croix County (fig. 13).

In the sand-and-gravel aquifer, iron concentration in water ranges from 0 to 6.7 mg/l, and manganese concentration ranges from 0 to 0.74 mg/l. The median concentrations for both are well below recommended limits.

Iron and manganese concentrations of water from the sandstone aquifer generally are higher in the Cambrian sandstone than in the St. Peter Sandstone and Prairie du Chien Group, but the differences in concentration are greater in the St. Peter Sandstone and Prairie du Chien Group (fig. 13). Iron concentrations range from 0 to 46 mg/l and manganese concentrations from 0 to 1.0 mg/l in the St. Peter Sandstone and the Prairie du Chien Group. The median concentration for iron is 0.01 mg/l and for manganese is 0. Concentrations range from 0 to 2.6 mg/l for iron and from 0 to 0.17 mg/l for manganese in water from the Cambrian sandstone. The median concentration for iron is 0.06 mg/l and for manganese is 0.03 mg/l.

NITRATE

Nitrate in water is considered to be a final oxidation product of nitrogen-containing matter. Nitrate concentrations of several milligrams per litre may indicate contamination by sewage or other organic matter. The effect of nitrate on industrial use of water is almost negligible. However, many studies have shown that excess nitrate in drinking water contributes or is perhaps the main cause of infant methemoglobinemia. The U.S. Public Health Service has set 45 mg/l (1962, p. 7) as the upper limit for nitrate.

In St. Croix County, nitrate is a minor problem. Of water samples from 100 wells tested for nitrate, 4 exceeded the recommended upper limit of 45 mg/l and another 42 had nitrate concentrations of more than 10 mg/l, indicating some probable degradation.

Both the sand-and-gravel and sandstone aquifers are tapped by some wells that yield water of high (greater than 10 mg/l) nitrate concentrations. The St. Peter Sandstone and Prairie du Chien Group of the sandstone aquifer are tapped by the most wells that yield water of high nitrate concentrations, with values as high as 80 mg/l. The median nitrate concentration is 14 mg/l (fig. 13). The median nitrate concentration is second highest in water from the sand-and-gravel aquifer, 10 mg/l, and is lowest in the Cambrian sandstone, 1.8 mg/l.

Water from wells in the St. Peter Sandstone and the Prairie du Chien Group may have high nitrate concentrations. The two rock units are the uppermost bedrock and are overlain by thin drift in much of the county. The Prairie du Chien Group dolomite is fractured, and many fractures have been enlarged by solution. Water moves rapidly from the land surface downward to the water table, which is within the Prairie du Chien rocks in most places. Where nitrate is available from septic-tank effluent, animal wastes, agricultural fertilizers, or other sources, local nitrate concentrations in well water may increase, especially under pumping.

OTHER CHEMICAL CHARACTERISTICS

Several other chemical constituents and properties were analyzed in addition to those described above. Table 2 summarizes these analyses by aquifer. Water from 26 wells in the sand-and-gravel aquifer and 75 wells in the sandstone aquifer was analyzed by the U.S. Geological Survey and the Wisconsin State Laboratory of Hygiene. Those from the sandstone aquifer included 45 from the St. Peter Sandstone and Prairie du Chien Group and 30 from the Cambrian sandstone.

GROUND-WATER PUMPAGE AND USE

Pumpage from the two aquifers in St. Croix County in 1974 was 3.83 Mgal/d (0.168 m^3/s). This water was used for residential, industrial, commercial, institutional, irrigation, and municipal purposes.

PUMPAGE

In 1974 pumpage from the sandstone aquifer was 3.59 Mgal/d (0.157 m^3/s), 94 percent of the county's total pumpage. Pumpage from the sand-and-gravel aquifer was 0.24 Mgal/d (0.01 m^3/s), 6 percent of the total pumpage.

USE

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

Use	Amount used (Mgal/d)	Amount used (Percent)
Residential, public supply	0.82	21
Residential, private supply	.82	21
Commercial, public and private supply	.45	12
Industrial, public and private supply	1.20	32
Irrigation, private supply	.04	1
Institutional, private supply	.03	1
Municipal	.47	12
Total	3.83	100

Residential water use includes all normal 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 defined as water used by residences on a public or private water-distribution system serving five or more homes. Water used by homes and farms with their own source of supply is considered to be private-supply residential use. Residential use by aquifer is tabulated below.

Table 2.--Summary of results of analyses of water from the sand-and-gravel and sandstone aquifers

(Chemical analysis in milligrams per litres except pH)

Aquifer	Geologic unit		Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Noncarbonate hardness as calcium carbonate	pH (standard units)
Sand-and-gravel	Surficial and buried sand and gravel	Minimum	12	28	12	1.6	0.4	131	2.0	0.0	0.0	0	7.1
		Median	20	43	19	2.6	.9	212	9.6	2.3	.1	12	7.6
		Maximum	25	61	29	3.8	1.2	304	17	6.9	.3	33	8.0
Sandstone	St. Peter Sandstone and Prairie du Chien Group	Minimum	6.4	26	11	1.4	.2	116	2.3	.9	.1	0	6.9
		Median	18	49	24	3.4	.9	230	12	5.5	.2	27	7.6
		Maximum	35	89	47	30	5.7	400	35	31	.4	94	8.4
	Cambrian sandstone	Minimum	9.4	24	9.7	1.3	.4	107	2.0	.0	.0	0	7.0
		Median	17	42	16	2.6	.9	207	10	1.8	.1	12	7.7
		Maximum	24	66	33	22	1.7	340	27	32	.3	69	8.0

Aquifer	Public supply (Mgal/d)	Private supply (Mgal/d)
Sand-and-gravel	0	0.23
Sandstone	.82	.59
Total	.82	.82

Commercial use refers to water used by businesses that do not fabricate or produce a product; filling stations, retail stores, and restaurants are examples. Commercial water use was 12 percent of the water pumped in 1974.

Industrial use refers to water used in plants that manufacture or fabricate products. Industrial water may be used for cooling, sanitation, air-conditioning, irrigating of plant grounds, and product fabrication. Industrial water use was 32 percent of the water used in St. Croix County in 1974.

Irrigation use is defined as water used for sprinkling golf courses and irrigating crops. Some public-supply water is used for sprinkling, but is included under municipal use.

Institutional use is defined as water used in the maintenance and operation of institutions such as schools, hospitals, rest homes, and prisons. Institutions may be privately or publicly owned. Private-supply institutional use is the only type tabulated. Use by institutions served by public supplies is included under municipal water use.

Municipal water use is defined as water pumped by municipalities but not sold to customers. It includes use in flushing water lines, firefighting, sprinkling, use in municipal buildings and institutions, and water lost in the distribution system. In 1974, 12 percent of the water used in the county was for municipal use.

SUMMARY

In St. Croix County potable water supplies are obtained from the sand-and-gravel and sandstone aquifers.

The sand-and-gravel aquifer consists of unconsolidated sand and gravel in glacial drift and alluvium. It is present in about 25 percent of the county, mostly in the western half. The aquifer is found beneath present-day river valleys and in buried bedrock valleys.

The chances of individual wells obtaining 1,000 gal/min (63 l/s) from the sand-and-gravel aquifer are good near Hudson, along the Willow River southwest of New Richmond, and in an area about 2 mi (3 km) wide from Cedar Lake southwest to the St. Croix River. To obtain these yields, wells may have to have an effective diameter of 2 ft (0.6 m) and be screened throughout the entire saturated thickness of sand and gravel.

Water quality in the sand-and-gravel aquifer is generally good. The water is likely to be hard or very hard and may have a high iron content. Nitrate concentrations indicate some local degradation of ground water by decaying organic matter.

The sandstone aquifer includes all sedimentary bedrock younger than Precambrian age. Precambrian rocks generally have low permeability and, for practical purposes, they represent the lower limit of ground-water movement. The sandstone aquifer is continuous over the county and includes, in ascending order from oldest to youngest, sandstones of Cambrian age and the Prairie du Chien Group, St. Peter Sandstone, and Galena-Platteville unit of Ordovician age.

In St. Croix County the Prairie du Chien Group and the Cambrian sandstone are the most important water-yielding rocks in the sandstone aquifer. The Prairie du Chien Group is the uppermost saturated bedrock in much of the county and is used extensively for private residential water supplies. The ability of the Cambrian sandstone to store and yield water and its generally great thickness make it the principal source of water for municipal supplies.

The sandstone aquifer is capable of yielding 1,000 gal/min (63 l/s) in most of the county except in an area from Cedar Lake southwest to Little Falls Pond and in part of Hudson. In these areas, the aquifer is thin because of faulting and erosion and well yields of 500 to 1,000 gal/min (32 to 63 l/s) are probable. To obtain these yields, wells may have to have an effective diameter of 1 ft (0.3 m) and be open to the entire saturated thickness of the aquifer.

Water quality in the sandstone aquifer is generally good. Water is likely to be hard (121 to 180 mg/l) or very hard (more than 180 mg/l) and may have high iron concentrations (more than 0.3 mg/l). Nitrate concentrations, particularly in water from wells finished in the St. Peter Sandstone or Prairie du Chien Group, indicate some local degradation of ground water by decaying organic matter.

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