DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

UNIVERSITY EXTENSION—THE UNIVERSITY OF WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY

HYDROLOGIC INVESTIGATIONS
ATLAS HA-451 (SHEET 3 OF 4)

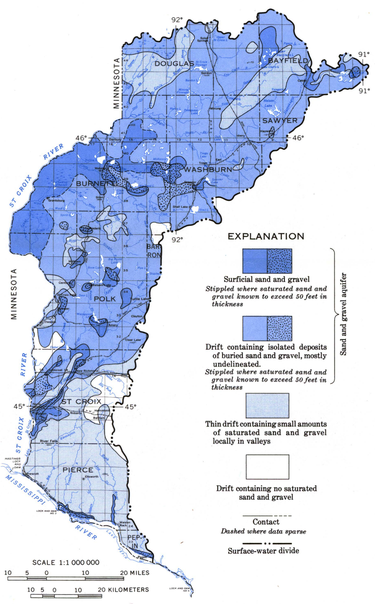
GROUND WATER

Large supplies of good quality water are obtained from the ground-water reservoir in parts of the St. Croix River basin. About 570 billion gallons of water are discharged to streams and from wells each year, which is about 5 million gallons for each person in the basin. Aquifers throughout the basin serve dual functions of providing water supply from wells and springs and of furnishing a perennial base of stream-flow and lake stage by seepage and spring discharge.

Ground water is readily available in quantities adequate to meet present and future domestic, agricultural, municipal, and industrial needs in the basin. Major areas of moderate pumpage are New Richmond, River Falls, and Hudson. In general ground-water development is small and scattered throughout the rest of the basin. Detailed ground-water studies may be needed to guide future development.

GROUND-WATER AVAILABILITY

Most ground water in the basin is obtained from the sand and gravel aquifer and the sandstone aquifer. The sand and gravel aquifer is used throughout much of the northern three-fourths of the basin and in scattered areas in the south. Where drift is thin or absent over bedrock highs, ground-water availability depends mainly on the underlying bedrock. The sandstone aquifer is used in the southern half and east-central part of the basin. Minor amounts of water are obtained locally from poorly sorted drift and from Precambrian lava flows. Lava flows and crystalline bedrock are generally impermeable and, for practical purposes, their surface is the lower limit of the ground-water reservoir. Unfortunately, most areas of thin drift in the northern half of the basin are underlain by the relatively unproductive lava flows. Areas of ground-water availability are delineated on the basis of well records, rock types, and soil types.



Aquifer	Age	Geologic unit	Columnar section	Thickness (feet)	Maximum yield reported (gpm)	Average high-capacity well yield (gpm)	Well depths (feet)
Sand and gravel	Quaternary	Surficial sand and gravel		0-365	1319	530	20-290
		Isolated deposits of buried sand and gravel in drift		0-100	500	245	20-365
Sandstone	Ordovician	Galena Dolomite, Decorah Formation, and Platteville Formation		0-115	Generally unsaturated; no known wells		
		St. Peter Sandstone		0-200	20	None	55-228
		Prairie du Chien Group		0-275	100-385 / 837-1100	Only 4 wells / 645	40-368 / 40-734
	Cambrian	Jordan Sandstone		0-800	1560	490	35-802
		St. Lawrence Formation					
		Franconia Sandstone					
		Galesville Sandstone					
		Eau Claire Sandstone					
		Mount Simon Sandstone					
	Precambrian	Sandstone, shale, and conglomerate		0-8000?	No known wells in the basin; however, it provides a few tens of gallons per minute to wells in the Lake Superior basin to the north		
		Lava flows		0-25,000?	20	None	30-140
		Crystalline igneous and metamorphic rocks		Unknown	Although not generally classed as an aquifer, a few wells may obtain small domestic supplies		

AVAILABILITY FROM GLACIAL DRIFT

SAND AND GRAVEL AQUIFER

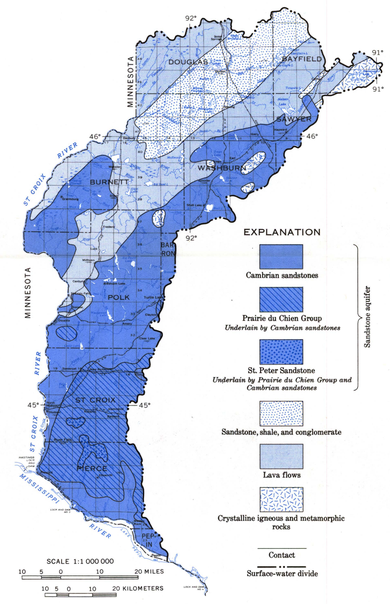
Surficial deposits.—Most deposits of surficial sand and gravel are mainly in extensive outwash plains and ice-contact features in the central part of the basin. Some outwash fills preglacial bedrock valleys as, for example, east of Hudson and in the Mississippi valley (see block diagram, sheet 1).

These deposits are highly permeable and yield large quantities of water to wells. Most high-capacity wells[1] in surficial sand and gravel are between 40 and 170 feet deep. The range of specific capacities of these wells is generally from 10 to 70 gpm (gallons per minute) per foot of drawdown, and the median is 21. The specific capacity of 25 percent of them is 40 or more. Present withdrawal from these sand and gravel deposits is insignificant compared to their potential for use in the basin. The best potential is in areas where saturated sand and gravel is more than 50 feet thick.

[1] The Wisconsin "high-capacity" well law requires a permit from the Wisconsin Department of Natural Resources before installation of a well with a capacity of 70 gpm or more (Wisconsin Natural Resources Committee of State Agencies, 1967, p. 16).

Isolated buried deposits.—Buried sand and gravel deposits are beneath or within most of the ground and end moraine in the basin. These buried deposits are thickest in preglacial bedrock valleys and are similar to the outwash deposits in the Mississippi valley. Size and continuity of most buried aquifers are unknown. The known areas of best potential from buried deposits are those shown on the map with more than 50 feet of saturated sand and gravel.

The yields of buried sand and gravel deposits are small to moderate. Yields of 5 to 15 gpm, adequate for domestic supplies, are obtained from wells finished in lenses of sand and gravel, often less than 5 feet thick, at depths ranging from 20 to 365 feet. Several high-capacity wells are finished in buried sand and gravel at depths of 70 to 340 feet. Most have specific capacities ranging from 2 to 5 gpm per foot of drawdown.



AVAILABILITY FROM BEDROCK

SANDSTONE AQUIFER

In the St. Croix basin the sandstone aquifer, important in the southern and eastern parts of the basin, consists of the saturated parts of the Ordovician formations and Cambrian sandstones. The latter comprise the bulk of the aquifer. The map shows that the Prairie du Chien Group also forms a substantial part of the aquifer, but the St. Peter Sandstone is only a minor part. The Galena-Platteville unit commonly is not saturated. Throughout its area the sandstone aquifer provides reliable supplies for municipal, industrial, public, domestic, stock, and irrigation uses.

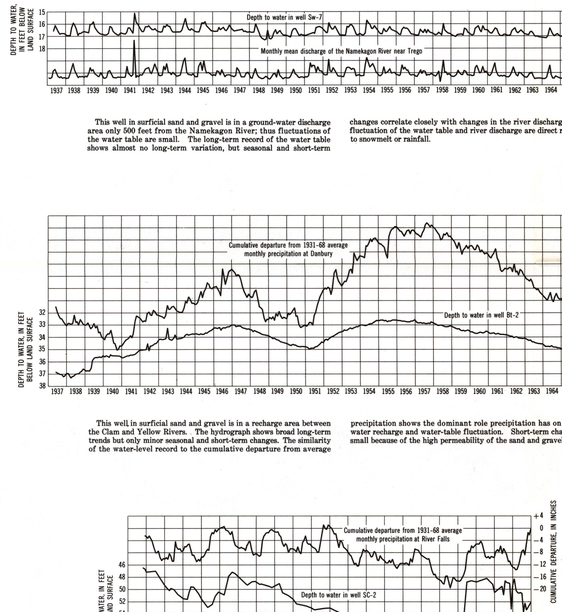
Cambrian sandstones.—These rocks are the most widespread part of the aquifer and, therefore, are the most commonly used. They produce large to very large yields, as much as 1,500 gpm, in the southern one-third of the basin. The yields diminish as the sandstone thins to the north. The most productive unit is the Jordan Sandstone. The Eau Claire Sandstone and the St. Lawrence Formation are relatively unproductive.

Because consolidated sandstone is less permeable than unconsolidated sand and gravel, high-capacity wells must penetrate a greater saturated thickness of sandstone than sand and gravel to obtain comparable yields. Depths of high-capacity wells in sandstone range from 196 to 802 feet; however, the median depth is 358 feet. The specific capacities of these wells range generally from 5 to 35 gpm per foot of drawdown, and the median is 15. The specific capacities of 25 percent of them are 27 or more.

Prairie du Chien Group.—Rocks of this group, mostly dolomite, furnish water to several domestic and stock wells in the southern one-fourth of the basin. Only four high-capacity wells are known to be finished solely in this unit. Their depths range from 200 to 300 feet, and their yields range from 100 to 837 gpm.

Prairie du Chien Group and Jordan Sandstone.—This combined unit, mainly in Pierce and St. Croix Counties, is highly productive, yielding as much as 1,100 gpm to wells. The range of specific capacities of the high-capacity wells generally is from 20 to 60 gpm per foot of drawdown, and the median is 28. These wells range from 246 to 734 feet in depth, but the median depth is 365 feet.

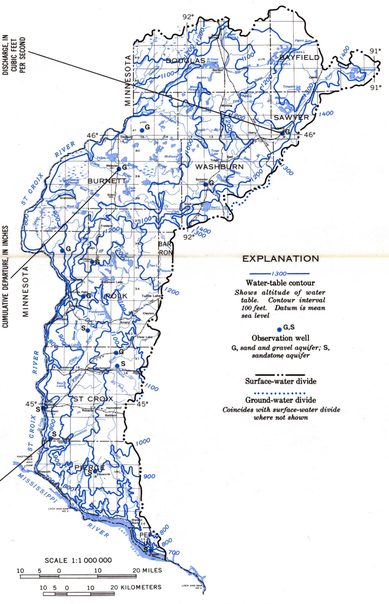
St. Peter Sandstone.—This sandstone is topographically high, commonly is unsaturated, and is limited in areal extent. It is an aquifer only locally, mainly where overlain by the Platteville Formation. Adequate yields, 10 to 20 gpm, are obtained for domestic and stock uses from wells generally between 100 and 200 feet in depth.



This well in surficial sand and gravel is in a ground-water discharge area only 500 feet from the Namekagon River; thus fluctuations of the water table are small. The long-term record of the water table shows almost no long-term variation, but seasonal and short-term changes correlate closely with changes in the river discharge. The fluctuation of the water table and river discharge are direct responses to snowmelt or rainfall.

This well in surficial sand and gravel is in a recharge area between the Clam and Yellow Rivers. The hydrograph shows broad long-term trends but only minor seasonal and short-term changes. The similarity of the water-level record to the cumulative departure from average precipitation shows the dominant role precipitation has on ground-water recharge and water-table fluctuation. Short-term changes are small because of the high permeability of the sand and gravel.

Over the long term, the precipitation trend is the major control of the water table at this well in the sandstone aquifer (Prairie du Chien Group). Some delay in response to increases or decreases in precipitation is evident and is probably the time required for recharge to percolate to the water table.



WATER TABLE AND OBSERVATION-WELL NETWORK

Ground water underlies the entire basin and moves constantly from areas of recharge to areas of discharge (streams, lakes, wetlands, and springs). Ground water moves perpendicular to the water-table contours and conforms regionally to the direction of surface runoff. Ground water in the basin generally travels less than 4 miles to discharge areas.

The ground-water divide coincides closely with the surface-water divide except in a few areas, mainly along the eastern edge of the basin. The largest difference is in Washburn County where the ground-water divide is outside the surface-water basin. Ground water in the area between the divides moves from the Chippewa River basin into the St. Croix River basin. The surface-water basin is about 20 square miles smaller than the ground-water basin; thus a very small net gain of ground-water underflow occurs (see Hydrologic Budget, sheet 1).

The water table in the basin generally is within a few tens of feet of the land surface. It is commonly most shallow near lakes and streams and in areas of thin glacial drift over Precambrian bedrock. The water table is deepest below hills, especially in the south where topographic relief is great. Maximum water-table depths of 200 to 300 feet occur below hills in Pepin and Pierce Counties.

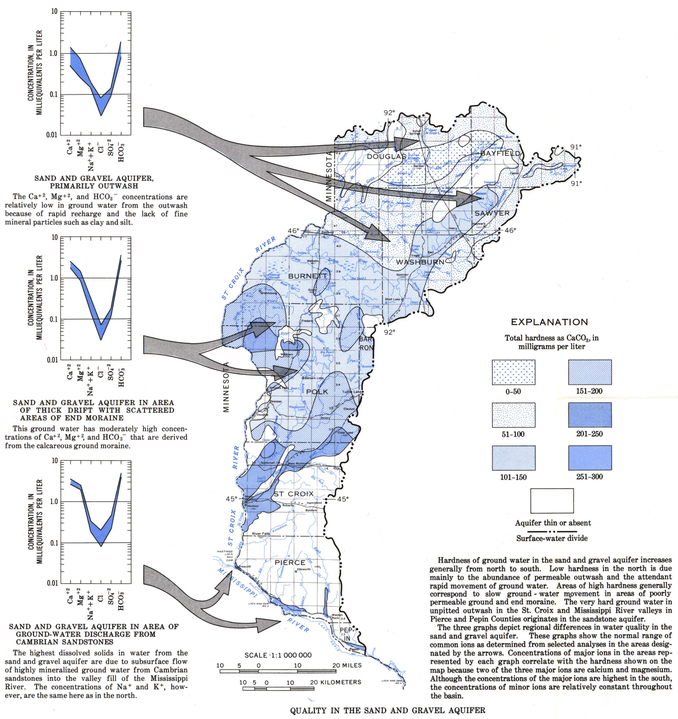
The water table fluctuates with changes in recharge and discharge. The three hydrographs for wells illustrate these fluctuations. Four or more years of water-level records are available from each of the 14 observation wells indicated on the map. Hydrographs are published for 12 of the wells (Devaul, 1967).

Artesian wells occur locally in low-lying areas in the southern part of the basin. Weidman and Schultz (1915) reported flowing artesian wells in Cambrian sandstones at Maiden Rock in the Mississippi River valley, at River Falls in the Kinnickinnic River valley, and near Osceola in the St. Croix River valley; and in valley fill at Hudson and Osceola. Artesian heads were low, and most of these wells had small flows, less than 100 gpm. The pressure has since declined because of pumpage, unchecked flow, and leaky well casings; most artesian wells now in use must be pumped.

GROUND-WATER QUALITY

Ground water in the St. Croix River basin is generally of very good quality and is usable for most purposes. Regional differences in the quality of ground water are due to the composition, solubility, and surface area of the particles of soil and rock through which the water moves, and to the length of time the water is in contact with these materials. The main chemical constituents in the water are calcium, magnesium, and bicarbonate ions that are derived primarily from dolomite and glacial drift containing fragments of dolomite.

Minor water-use problems are caused by hardness and, locally, by high concentrations of iron. About 73 percent of the ground water sampled has hardness greater than 120 mg/l, and 47 percent has hardness greater than 180 mg/l; the latter needs softening for many uses.



QUALITY IN THE SAND AND GRAVEL AQUIFER

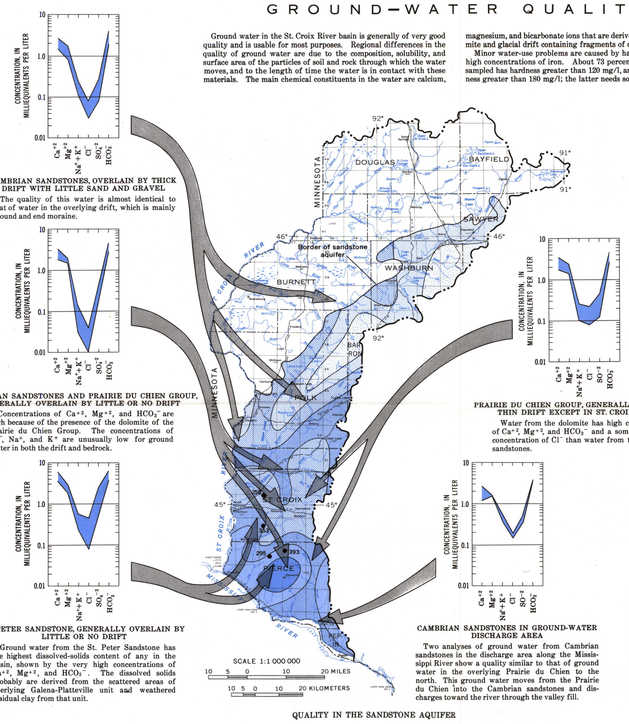
The Ca^{+2}, Mg^{+2}, and HCO_3^- concentrations are relatively low in ground water from the outwash because of rapid recharge and the lack of fine mineral particles such as clay and silt.

This ground water has moderately high concentrations of Ca^{+2}, Mg^{+2}, and HCO_3^- that are derived from the calcareous ground moraine.

The highest dissolved solids in water from the sand and gravel aquifer are due to subsurface flow of highly mineralized ground water from Cambrian sandstones into the valley fill of the Mississippi River. The concentrations of Na^+ and K^+, however, are the same here as in the north.

Hardness of ground water in the sand and gravel aquifer increases generally from north to south. Low hardness in the north is due mainly to the abundance of permeable outwash and the attendant rapid movement of ground water. Areas of high hardness generally correspond to slow ground-water movement in areas of poorly permeable ground and end moraine. The very hard ground water in unpitted outwash in the St. Croix and Mississippi River valleys in Pierce and Pepin Counties originates in the sandstone aquifer.

The three graphs depict regional differences in water quality in the sand and gravel aquifer. These graphs show the normal range of common ions as determined from selected analyses in the areas designated by the arrows. Concentrations of major ions in the areas represented by each graph correlate with the hardness shown on the map because two of the three major ions are calcium and magnesium. Although the concentrations of the major ions are highest in the south, the concentrations of minor ions are relatively constant throughout the basin.



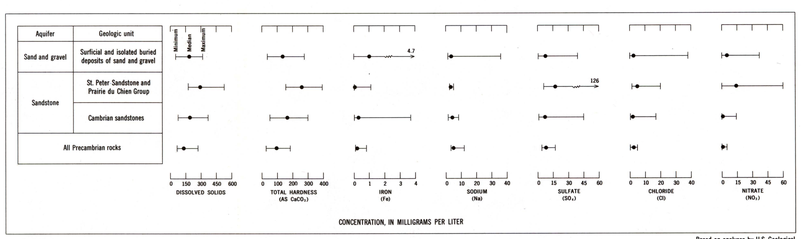
QUALITY IN THE SANDSTONE AQUIFER

Water from the dolomite has high concentrations of Ca^{+2}, Mg^{+2}, and HCO_3^- and a somewhat higher concentration of Cl^- than water from the Cambrian sandstones.

Two analyses of ground water from Cambrian sandstones in the discharge area along the Mississippi River show a quality similar to that of ground water in the overlying Prairie du Chien to the north. This ground water moves from the Prairie du Chien into the Cambrian sandstones and discharges toward the river through the valley fill.

Ground water in the sandstone aquifer is hardest in the uplands of Pierce County, where it is highly mineralized by infiltration of recharge through dolomitic rocks. Also, the long transit time required for recharge to reach the deep water table results in the solution of much mineral matter. The four available analyses of water from the St. Peter Sandstone indicate that hardness is higher in the St. Peter than in the lower parts of the sandstone aquifer. This mineralization also is derived from infiltration through overlying dolomitic rocks. Hardness is relatively low in the aquifer in the north because of the low hardness of ground water in the overlying glacial drift.

Regional differences in water quality in the sandstone aquifer are shown by the graphs of the normal range of concentrations of common ions. Differences in quality are directly related to differences in mineralogic composition of the aquifer material.



Based on analyses by U.S. Geological Survey, Wisconsin State Laboratory of Hygiene, and miscellaneous sources

QUALITY OF WATER BY AQUIFER

The overall characteristics of ground-water quality in the basin are fairly similar in all the aquifers. Dissolved-solids content and hardness are greater, successively, in Precambrian rocks, glacial sand and gravel, Cambrian sandstones, and Ordovician formations. Concentrations of minor constituents are more variable among aquifers, but high concentrations of iron in the sand and gravel aquifer are very common.

The concentration of iron or manganese (often concurrent) generally is unpredictable, and water from wells close together may have large differences in concentrations of these ions. Drinking water standards of the U.S. Public Health Service (1962) recommend maximum allowable concentrations of 0.3 mg/l of iron and 0.05 mg/l of manganese. The standards are based on levels that may produce objectionable taste and stains. The standards are equaled or exceeded by the median concentrations of these constituents in the sand and gravel aquifer and the Cambrian sandstones and by concentrations in several wells in the other units.

The known concentrations of nitrate in ground water of the basin generally are low. Concentrations more than about 10 mg/l probably are not from natural sources but may be from contamination by organic wastes. Ground water in the Ordovician dolomites may be easily contaminated because recharge to these rocks is not filtered as it moves through fractures and solution channels. Likewise, rapid recharge to surficial sand and gravel may carry contaminants. The drinking water standards recommend that nitrate content be less than 45 mg/l because of the association of nitrate with occurrence of methemoglobinemia in infants.

All analyses show low concentrations of sodium, sulfate, and chloride, the maximum concentrations being 36, 126, and 38 mg/l, respectively. This maximum sulfate concentration is in Pierce County in a well in St. Peter Sandstone, which is overlain by the Platteville Formation.

An important exception to the general quality of ground water in the basin is a very unusual occurrence of saline water (13,000 mg/l dissolved solids) from an exploratory core hole 2.5 miles southwest of St. Croix Falls, in Polk County. The hole penetrated a few feet of glacial drift, Cambrian sandstone and conglomerate to a depth of 95 feet, and Precambrian basalt to the bottom of the hole at 700 feet (Weidman and Schultz, 1915, p. 515). When it was drilled in 1901, it had an artesian head of a few feet above land surface, and it still flows about 0.1 gpm. An analysis in 1970 shows the dominant ions to be calcium (2,850 mg/l), sodium (1,640 mg/l), chloride (7,600 mg/l), and sulfate (630 mg/l).

Base from U.S. Geological Survey
1:500,000, 1968

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WATER RESOURCES OF WISCONSIN—ST. CROIX RIVER BASIN

By
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