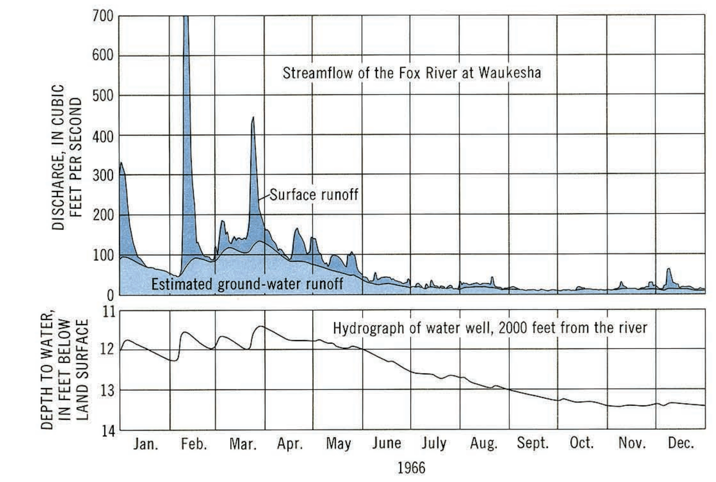
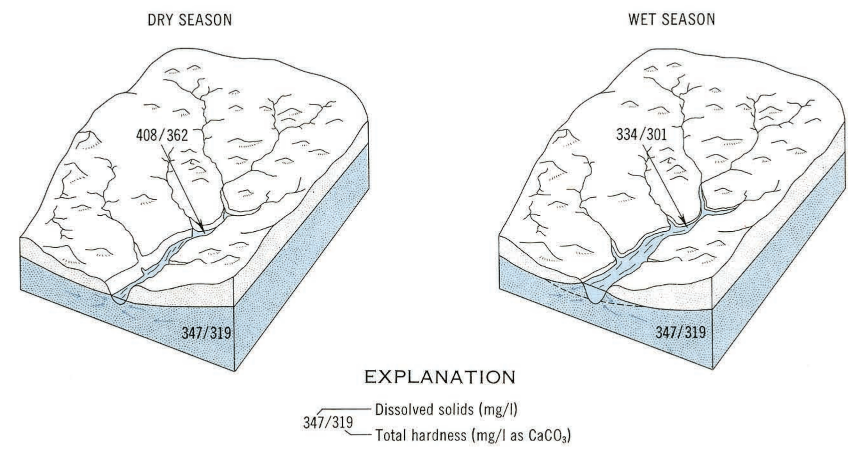
GROUND-WATER—SURFACE-WATER RELATIONSHIPS



GROUND-WATER CONTRIBUTION TO STREAMFLOW

Streamflow is a combination of surface runoff and ground-water runoff. During snowmelt and periods of prolonged, heavy precipitation surface runoff is quickly carried off by the streams. Water that is recharged to the shallow ground-water reservoir during these periods is discharged more slowly and maintains streamflow during dry periods.

These hydrographs show the close relation between streamflow in the Fox River at Waukesha and ground-water levels in a nearby well. The streamflow hydrograph has been separated into surface-runoff and ground-water contributions to the river. Although the separation line is only approximate, it can be seen that the ground-water runoff is the more uniform part, and the surface runoff the more erratic part, of the total streamflow. It is estimated that ground water contributed 55 percent of the flow of the Fox River at Waukesha in 1966.

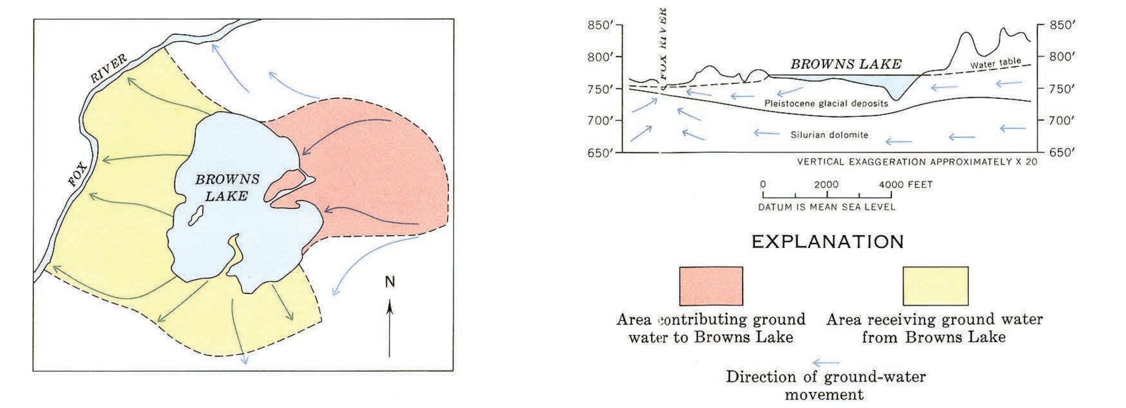


SEASONAL VARIATIONS IN WATER QUALITY

Chemical quality of surface water varies with the season and differs from the quality of ground water. Average dissolved solids and hardness from analyses of 319 ground-water samples and 34 surface-water samples were compared to determine differences due to the source and the season. An example of the seasonal variations in water quality are shown in the illustration to the left.

Ground-water quality is nearly constant and is not changed rapidly by infiltrating precipitation.

Surface-water quality changes seasonally and very rapidly during storms. During wet seasons the water in streams is less mineralized because it is mostly overland runoff that has had only brief contact with soils and rocks. None of the samples analyzed were taken during extreme high flow (bankfull or flood stage). If they had been, the average concentrations might have been lower. During dry seasons normally highly mineralized ground-water discharge in streams may become more highly mineralized than the local ground water because waste water is added to the streams.



GROUND-WATER MOVEMENT AT BROWNS LAKE, RACINE COUNTY

In humid areas underlain by permeable rocks, such as the Rock-Fox basin, lakes and marshes are extensions of the water table and are areas of ground-water discharge. Ground water discharged to the lakes commonly flows out of the lake through a stream. However, many lakes in the Rock-Fox River basin have no surface outlets, and discharge into aquifers. As an example of ground-water flow through a lake, Browns Lake in Racine County receives ground water mainly from the east and loses it by ground-water seepage to the Fox River on the west. The natural gradient is toward the river, which is about 17 feet below the lake level.

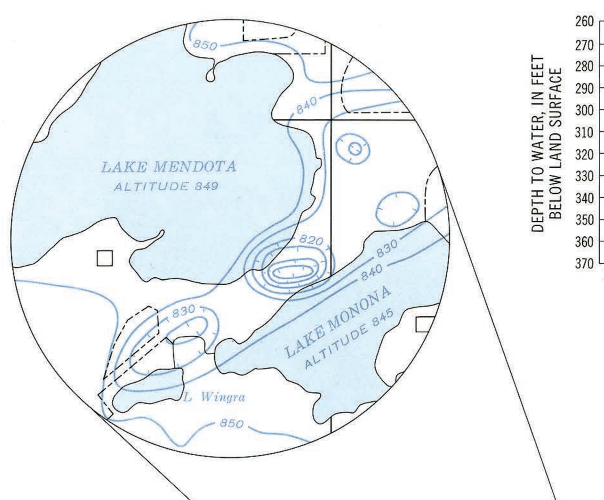
This type of detailed knowledge on water movement is useful for planning land and water use in lake watersheds. Problems of ground-water contamination, excessive weed growth, and loss of fish and wildlife habitat may be lessened by considering water movement when locating wells and septic tanks.

GROUND WATER

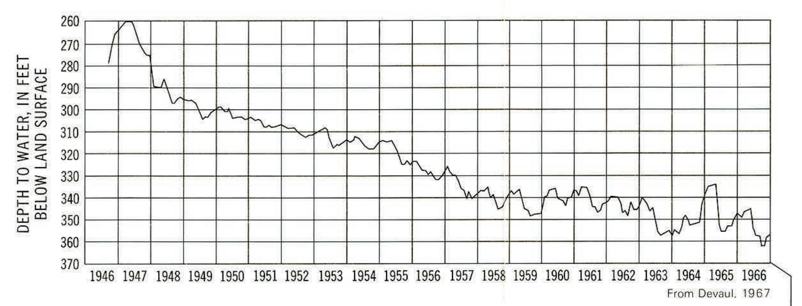
Large undeveloped supplies of good quality water are available in the Rock-Fox River basin from its underground reservoir. About 200 billion gallons of water are discharged to streams and wells each year, which is about 300,000 gallons for each person in the basin. Yet, this is less than one-half of 1 percent of the total water stored underground.

Aquifers throughout the basin serve the dual function of providing water supply via wells and springs and of furnishing a perennial base of streamflow by seepage and spring discharge. The amount of water that can be continuously pumped, disregarding economic factors, from a well or group of wells depends upon the aquifer thickness and areal extent, the rate that water seeps from the surface or from other aquifers to recharge the aquifer, the ease with which water moves through the aquifer and the amount of storage.

Ground water will continue to meet domestic, agricultural, municipal, and industrial needs in the basin because only a small part of the total potential is being utilized. Present areas of heavy pumpage are relatively few, and the density of settlement within the basin is thin as a whole. But, because ground-water availability varies locally, detailed studies are needed to guide resource development, especially in present and anticipated pumpage centers.

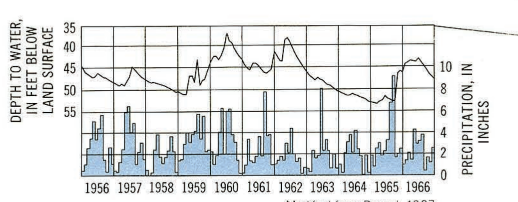


City wells in Madison have developed small drawdown cones. This detailed enlargement of a segment of the potentiometric map for 1968 shows two drawdown cones extended to where they intercept ground-water that previously moved to the lakes and probably induce recharge from the lakes.



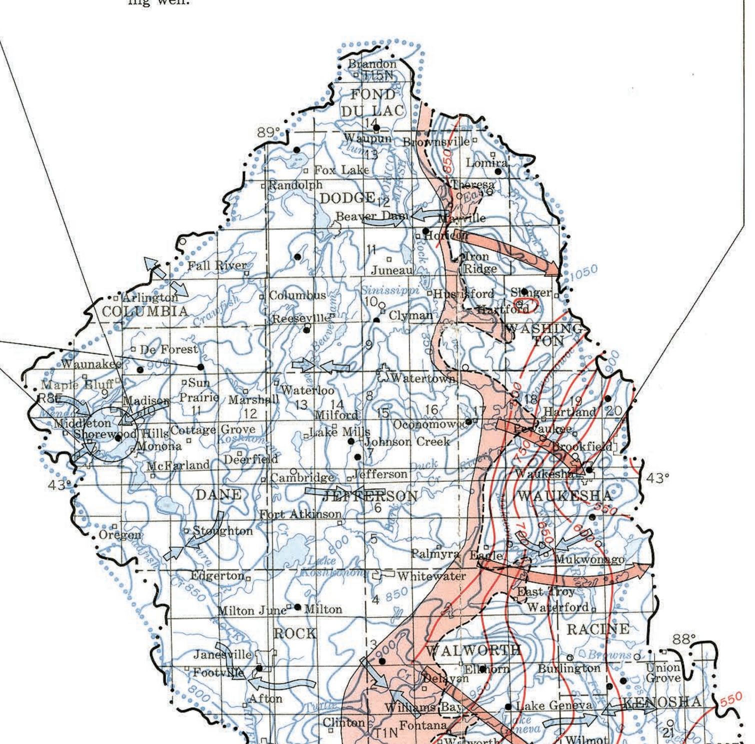
The potentiometric surface in the artesian system is declining regionally because of continued pumpage from the greater Milwaukee area and increased pumpage from the Chicago area.

The above hydrograph of a well in Waukesha shows regional and local effects of pumping. Minor fluctuations imposed on the gradual water-level decline of about 3 feet per year are due to heavier summer pumpage by Waukesha city wells. The water-level rise in 1964-65 was caused by the temporary shutdown of a nearby pumping well.



The potentiometric surface is always changing. This hydrograph shows how the water level in a well not affected by pumping responds to precipitation. Recharge from local precipitation during the spring and summer is followed by a rise in the water level in the well. During the late summer evapotranspiration utilizes most of the precipitation, and only extended periods of rainfall recharge the aquifer. In most years the ground is frozen during the winter months, preventing recharge, and the water level in the well falls.

No long-term changes in water levels are shown by this hydrograph, and water levels are nearly the same in 1966 as they were 10 years earlier.



Compiled from well records and reports of Newport, 1962, LeRoux, 1963, Cline, 1965, and Green and Hutchinson, 1965

EXPLANATION

Active observation well

Discontinued observation well

Ground-water divide

Surface-water divide

WATER-TABLE SYSTEM

950 Water-table contour
Shows altitude to which water will rise in wells in aquifers not confined by the Maquoketa Shale. Contour interval 50 feet. Datum is mean sea level

Direction of ground-water movement

ARTESIAN SYSTEM

700 Artesian contour
Shows altitude to which water will rise in wells in the sandstone aquifer where it is confined by the Maquoketa Shale. Contour interval 50 feet. Datum is mean sea level

Direction of ground-water movement

West limit of Maquoketa Shale

Recharge area for artesian system

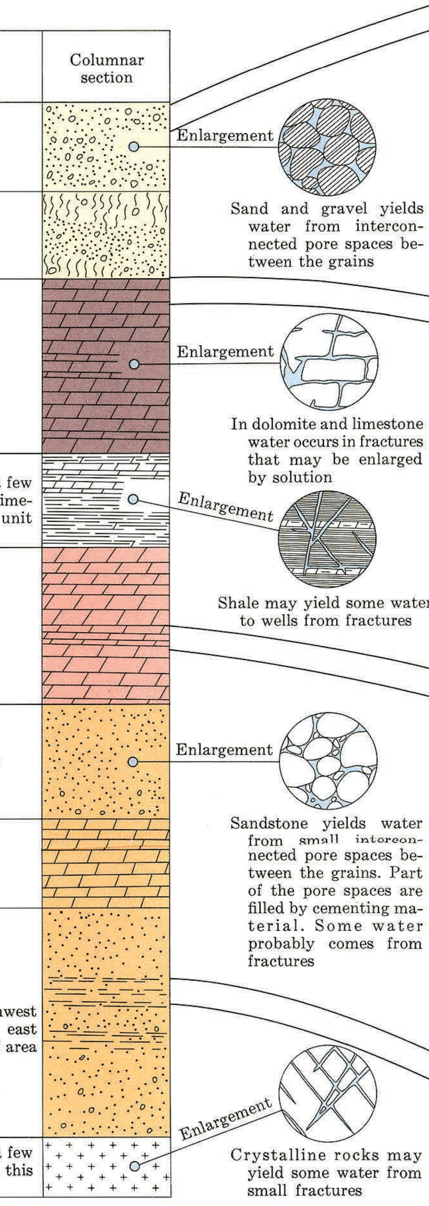
POTENTIOMETRIC SURFACE AND OBSERVATION WELL NETWORK

Ground water in the basin moves within two principal systems, the "water-table" and the "artesian" systems. The "water-table" system is present in all parts of the basin, and its surface is described by the water-table contours. As the arrows show, ground water moves away from high points on the potentiometric surface and discharges into lakes, streams, wetlands, and areas of pumpage. Flow paths are short. Ground-water divides follow surface-water divides only generally, and some ground water flows into or out of the surface-water basin near its borders. This "water-table" system is not truly a single hydrologic system. Within it there are numerous areas of local confinement, and nearby wells may have very different water levels. The composite "water-table" system described here is a generalization.

The "artesian" system includes those parts of aquifers confined beneath the Maquoketa Shale. Most recharge to this system is from the area just west of the western limit of the shale. Flow paths are long, and discharge is at wells located mainly in the areas of Milwaukee and Chicago.

The information on this sheet was compiled using data from observation wells located on the map, records from over 1,000 other wells, and reports of Cline (1965), Foley and others (1953), Green and Hutchinson (1965), Hutchinson (in press), Le Roux (1963), and Newport (1962).

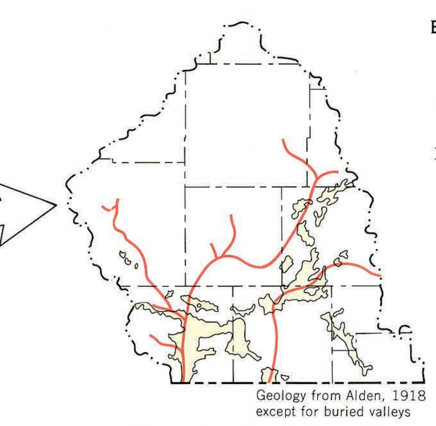
Aquifer	Geologic unit	Thickness (feet)	Maximum yield available (gpm)	Well depth (feet)	Columnar section
Sand and gravel	Surface sand and gravel (mostly outwash)	0 to 300	500-5,000	Up to 300	
	Buried sand and gravel	0 to 100	10 to 500	Average 120	
Niagara	Niagara Dolomite	0 to 450	0 to 1,500	Average 150	
(Not an aquifer)	Maquoketa Shale	0 to 225	Although not generally classed as an aquifer, a few wells obtain small quantities of water from limestone and dolomite in the upper part of this unit		
Platteville-Galena	Galena Dolomite, Decorah and Platteville Formations	0 to 400	10 to 100	Average 130	
Sandstone	St. Peter Sandstone	0 to 350	100-250	Commonly less than 200	
	Prairie du Chien Group	0 to 200	10 to 50	Average 125	
	Trempealeau Formation				
	Franconia Sandstone				
	Galesville Sandstone	0 to 3,000?	500 to 2,000	100 to 1,000 in northwest to over 2,000 in east and south parts of area	
	Eau Claire Sandstone				
	Mount Simon Sandstone				
(Not an aquifer)	Crystalline rocks	Unknown	Although not generally classed as an aquifer, a few wells obtain small quantities of water from this unit		



GROUND-WATER AVAILABILITY

Ground water is available nearly everywhere within the basin, usually at depths of less than 150 feet. The water yielding rocks, or aquifers, are grouped into four major aquifers for convenience of discussion. The sandstone aquifer is the major aquifer for large supply uses and underlies the entire basin. The sand and gravel aquifer yields large supplies of water in the Rock River valley and other local areas. The Niagara and Platteville-Galena aquifers are of limited local importance.

The physical properties of the geologic units control ground-water movement. Well yields from permeable sand and gravel are generally high where saturated thicknesses are over 50 feet. However, the distribution and permeability of sand and gravel deposits change greatly within short distances, and well yields may be difficult to predict. The Prairie du Chien Group, the Platteville-Galena unit, and the Niagara Dolomite are composed mainly of dense, crystalline dolomitic rock that yields water from fractures and solution channels rather than from intergranular pore spaces, as in sandstone or sand and gravel. Because the distribution of fractures and channels is much less uniform than the distribution of intergranular pore spaces, well yields from dolomitic rocks are even less predictable.



Geology from Alden, 1918 except for buried valleys

SAND AND GRAVEL AQUIFER

EXPLANATION

Area underlain by surficial outwash

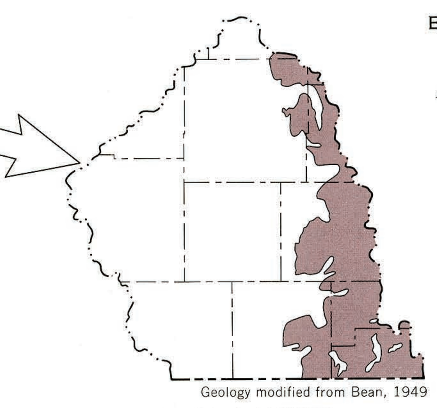
Location of buried valley

Sand and gravel in the basin constitute a major source of water. Sand and gravel may occur either at the surface in well-drained hills and in flat valley deposits, or they may be buried beneath less permeable deposits.

Large deposits of surficial outwash sand and gravel are shown at the left. Because of their high permeability, these deposits are easily and rapidly recharged. Buried sand and gravel deposits occur throughout the basin, but their extent is too poorly known to map in detail. Productive sand and gravel aquifers commonly are in buried bedrock valleys, and the aquifers may or may not be buried beneath less permeable deposits. Traces of deep bedrock valleys are shown.

Several thousand gallons of water per minute have been obtained from drilled wells in outwash sand and gravel where the aquifer is thick and underlies a perennial stream, such as along the Rock River in Rock County. In areas not containing thick outwash, small yields of water have been developed from local deposits of sand and gravel.

Because they are surficial, glacial deposits are recharged from the surface; natural discharge is to lakes and streams.



Geology modified from Bean, 1949

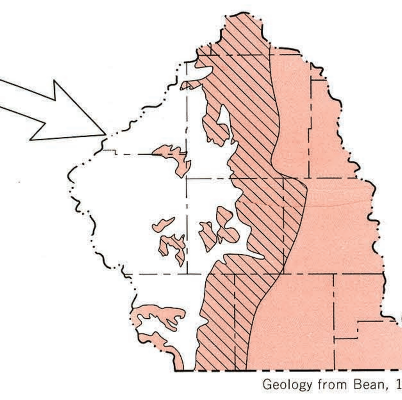
NIAGARA AQUIFER

EXPLANATION

Area underlain by aquifer

The Niagara aquifer, which underlies about 25 percent of the basin, provides water supplies in the rapidly developing eastern part of the basin to meet domestic, commercial, light industrial, and some municipal and agricultural water needs. Nearly all wells will produce at least 10 gpm (gallons per minute), the amount usually considered necessary for a single household.

The aquifer is recharged mostly by downward seepage from the glacial drift, and it discharges through the drift into streams, lakes, wetlands, and wells.



Geology from Bean, 1949

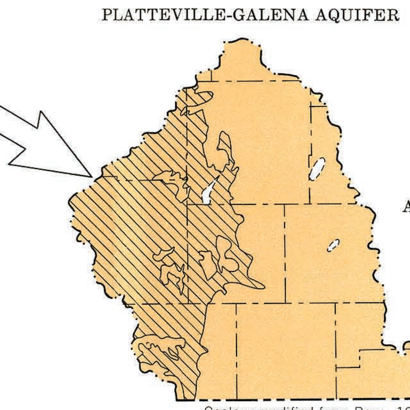
PLATTEVILLE-GALENA AQUIFER

EXPLANATION

Area underlain by aquifer

Area in which aquifer is widely used

The Platteville-Galena aquifer underlies 70 percent of the basin and is widely used for domestic and farm supplies where it is covered by thin drift, but yields little water to wells where it is deeply buried, particularly where it underlies Maquoketa Shale (see map). Because the shale reduces downward circulation of water (recharge) crevices in the Platteville-Galena aquifer have less opportunity to be enlarged by solution. Such poor circulation reduces well productivity and adversely affects water quality. West of the shale, recharge is to the aquifer through the overlying drift; discharge is through the drift to surface-water bodies or downward to the sandstone.



Geology modified from Bean, 1949

SANDSTONE AQUIFER

EXPLANATION

Area underlain by aquifer

Area in which aquifer is shallow and widely used for domestic supplies.

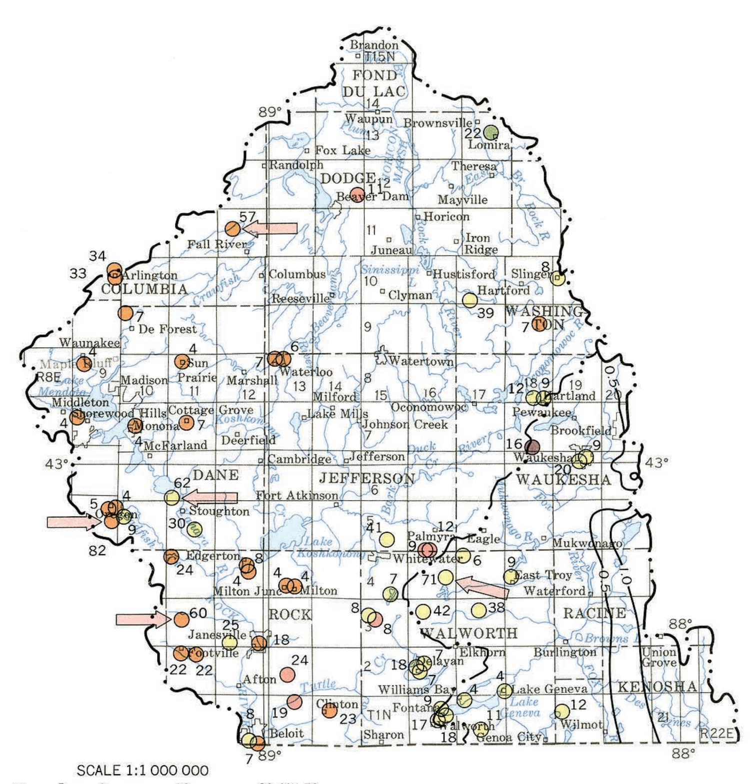
The sandstone aquifer, the most important aquifer in the basin, underlies the entire basin except in the vicinity of three small Precambrian crystalline rock ridges. This aquifer consists of several geologic units, each of which contributes some water to wells, but the Mount Simon and Galesville Sandstones of Cambrian age (see sheet 1) are commonly the most productive. Yields in most wells depend primarily on the thickness of sandstone penetrated.

Recharge to the sandstone seeps down through the drift and through the overlying bedrock units where they are present. Where the Maquoketa Shale overlies the sandstone aquifer there is little recharge, but a small quantity of water moves downward through the shale and through wells open to the Niagara and sandstone aquifers. Where the aquifer underlies the Maquoketa Shale water levels have steadily declined in wells (locally up to 8 feet per year), because recharge is small, ground-water movement is slow, and pumpage is large.

Natural discharge occurs only west of the Maquoketa Shale—into the Rock River, its tributaries, lakes, and wetlands. In the eastern one-third of the basin discharge is entirely by pumping wells.

The sandstone is the most widely used aquifer in the basin for high capacity wells. In most areas wells in this aquifer can yield 1,000 gpm. The aquifer furnishes water to 63 municipalities and numerous industries in the basin, and it supplies numerous domestic and stock needs in the western one-third of the basin.

WATER QUALITY



EXPLANATION

57 Well
Showing nitrate content of water in milligrams per liter. Arrow indicates nitrate content in excess of 45 milligrams per liter

Aquifer supplying water to the well

Sand and gravel

Niagara

Platteville-Galena

Sandstone

Niagara, Platteville-Galena, and sandstone

1.0 Line of equal fluoride concentration
Interval 0.5 milligrams per liter

Surface-water divide

NITRATE AND FLUORIDE IN GROUND WATER

Small quantities of nitrate and fluoride generally are found in ground water throughout the basin. Higher concentrations of these constituents occur locally but are not common. The higher concentrations of nitrate may be harmful for human consumption.

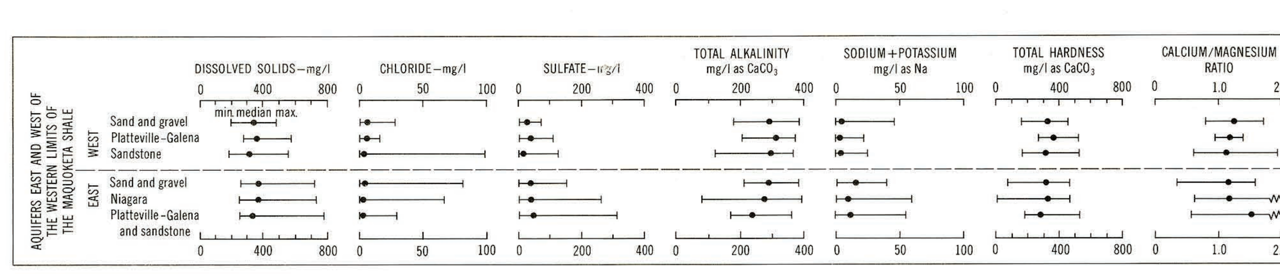
High nitrate concentrations can cause methemoglobinemia in infants (Comly, 1945), and the U.S. Public Health Service (1962) suggests an upper limit of 45 mg/l for nitrate in water to be used for drinking and culinary use on interstate carriers. This standard is usually accepted for all human consumption uses.

Nitrate is commonly derived from human and other animal wastes, fertilizer, organic decomposition, rainfall, and rocks. Water in shallow, inadequately cased, or poorly constructed wells is particularly susceptible to pollution by waste from above.

Nitrate concentrations in ground water that exceed background concentration suggest degradation of water quality in the well and possibly of part of the aquifer. As used here, background concentration is the upper limit of the modal range. Sixty-three analyses of well water exceeded the background concentration (3 mg/l in this basin) and 5 exceeded 45 mg/l (see map). The distribution of these 5 wells indicates the very local nature of ground-water pollution and its minor significance to ground-water supply.

Most fluoride concentrations in the basin are less than 0.5 mg/l, but concentrations increase to over 1.0 mg/l in the Niagara aquifer in the extreme eastern part of the basin. Although fluoride can reduce dental caries during tooth development (Dean and others, 1941 and 1942), high concentrations can mottle tooth enamel. The fluoride concentrations in the eastern area are near the optimum concentration of 1.1 mg/l and are much less than the maximum concentration of 1.5 mg/l recommended by the U.S. Public Health Service (1962) at prevailing air temperatures.

Ground water in the Rock-Fox River basin is generally of good quality and is usable for most purposes. Most problems are caused by hard water and locally by high iron concentrations. Nearly all of the ground water is very hard (181 mg/l or greater of hardness) and needs softening for many uses.



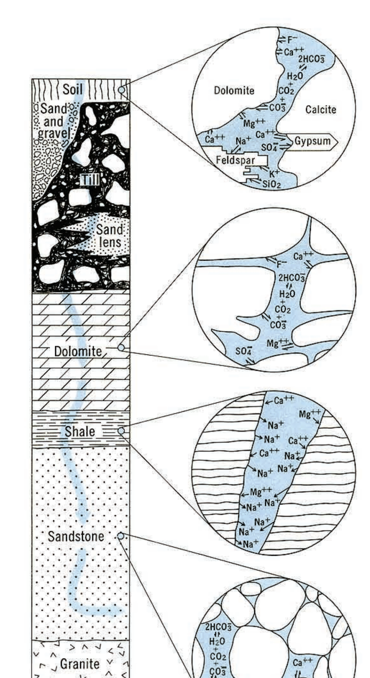
WATER QUALITY BY AQUIFER

Major chemical constituents, characteristics, and properties of water in aquifers within the Rock-Fox River basin are shown in this diagram. The median quality of ground water varies only slightly between aquifers. However, there is a wide range of local variations in quality within individual aquifers (see chart above). For example, the range of median total dissolved solids of all aquifers is less than 100 mg/l, but within the sandstone aquifer the range is nearly 400 mg/l.

A division is made between aquifers east and west of the western limit of the Maquoketa Shale because nearly all wells east of this limit that penetrate the Platteville-Galena aquifer are also open to the underlying sandstone aquifer.

Several points on the chart should be emphasized: All of the water tested has a median dissolved solids content between 300 and 400 mg/l, which is due largely to carbonate hardness. (A hardness of 300 mg/l is equal to about 18 grains of hardness.) Water in the glacial drift is slightly more mineralized east of the western limit of the shale, mostly because of an increase in sodium. Water in the sandstone aquifer changes in quality as it flows eastward beneath the shale. Mineralization increases as the distance from the recharge area increases, and sulfate and sodium progressively increase as carbonate, bicarbonate, and hardness decrease (see chart).

Iron is a problem in the water of many wells in the basin, but it is not a health hazard. The U.S. Public Health Service's suggested maximum limit for drinking water is 0.3 mg/l; above this concentration iron causes brown precipitates and stains. The areal occurrence of iron is unpredictable, and concentrations greater than 0.3 mg/l may be found almost anywhere in the basin. Iron concentrations also often vary with depth, but they cannot be correlated with depth.



In the ground-water flow system the concentration and variety of mineral matter are constantly changing as the water slowly moves through different types of rock, dissolving minerals from them. Precipitation, very low in mineral content, enters the soil zone and begins dissolving dolomite and other minerals. The calcium, magnesium, and bicarbonate contents of the water are derived from dolomite, and small quantities of silica, sulfate, sodium, potassium, and iron are dissolved from other minerals.

Percolating ground water continuously dissolves minerals from the glacial drift. The mineral content of ground water in shallow sand and gravel deposits is generally low because of the short time the water is in contact with minerals. High iron concentrations are most prevalent in poorly drained areas. High concentrations of nitrate, derived from sources of pollution, may occur locally in wells tapping shallow sands and gravels. Ground water in deposits of sand overlain by poorly permeable till is more highly mineralized but is generally protected from pollution.

As water moves through dolomite aquifers, especially through the Platteville-Galena unit, it becomes harder and more mineralized. Water in dolomite aquifers may be polluted locally where open solution channels and fractures are near the surface.

Shale beds retard the movement of ground water and locally may soften water by the process of ion exchange in which calcium and magnesium in the water are replaced by sodium.

Water in the sandstone aquifer moves very slowly, dissolving dolomite and locally acquiring small quantities of iron and other minerals. The water is very hard; however, it has slightly less total hardness than water in dolomite aquifers.

THE MINERALIZATION OF GROUND WATER

NUTRIENTS IN GROUND WATER

Nutrient concentrations (primarily nitrogen and phosphorus) in ground water have become of increasing interest in recent years. Because the ground-water reservoir sustains the surface water at low flow, nutrients in the ground water would contribute to problems of algal growth in lakes and streams. Analyses from wells in the Rock-Fox basin show the maximum, median, and minimum nitrate concentrations to be 82, 2.1, and less than 0.1 mg/l, respectively. Maximum, median, and minimum total phosphorus values as PO_4 are 0.58, 0.11, and 0.07 mg/l, respectively.

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

WATER RESOURCES OF WISCONSIN—ROCK-FOX RIVER BASIN

By

R. D. Cotter, R. D. Hutchinson, E. L. Skinner, and D. A. Wentz

1969