Geology and Ground-Water Resources of Rock County Wisconsin

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-X

Prepared in cooperation with the Wisconsin Geological and Natural History Survey

Geology and Ground-Water Resources of Rock County Wisconsin

By E. F. LeROUX

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-X

Prepared in cooperation with the Wisconsin Geological and Natural History Survey

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402

CONTENTS

ILLUSTRATIONS

[Plates 1-5 are in pocket]

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGY AND GROUND-WATER RESOURCES OF ROCK COUNTY, WISCONSIN

By E. F. Le Roux

ABSTRACT

Rock County is in south-central Wisconsin adjacent to the Illinois State line. The county has an area of about 723 square miles and had a population of about 113,000 in 1957; it is one of the leading agricultural and industrial counties in the State. The total annual precipitation averages about 32 inches, and the mean annual temperature is about 48° F.

Land-surface altitudes are generally between 800 and and 900 feet, but range from 731 feet, where the Rock River flows into Illinois, to above 1,080 feet, at several places in the northwestern part of the county. The northern part of Rock County consists of the hills and kettles of a terminal moraine which slopes southward to a flat, undissected outwash plain. The southeastern part of the county is an area of gentle slopes, whereas the southwestern part consists of steep-sided valleys and ridges.

Rock County is within the drainage basin of the Rock River, which flows southward through the center of the county. The western and southwestern parts of the county are drained by the Sugar River and Coon Creek, both of which flow into the Pecatonica River in Illinois and thence into the Rock River. The southeastern part of the county is drained by Turtle Creek, which also flows into Illinois before joining the Rock River. Nearly all the lakes and ponds are in the northern one-third of the county, the area of most recent glaciation.

The aquifers in Rock County are of sedimentary origin and include deeply buried sandstones, shales, and dolomites of the Upper Cambrian series. This series overlies crystalline rocks of Precambrian age and supplies water to all the cities and villages in the county. The St. Peter sandstone of Ordovician age underlies all Rock County except where the formation has been removed by erosion in the Rock and Sugar River valleys, and perhaps in Coon Creek valley. The St. Peter sandstone is the principal source of water for domestic, stock, and small industrial wells in the western half of the county. This sandstone also yields some water to uncased wells that tap the deeper rocks of the Upper Cambrian series. East of the Rock River the Platteville, Decorah, and Galena formations undifferentiated, or Platteville-Galena unit, is the principal source of water for domestic and stock wells. Unconsolidated deposits of glacial origin cover most of Rock County and supply water to many small wells. In the outwash deposits along the Rock River, wells of extremely high capacity have been developed for industrial and municipal use.

The most significant feature of the bedrock surface in Rock County is the ancestral Rock River valley, which has been filled with glacial outwash to a depth of at least 396 feet below the present land surface. East of the buried valley the bedrock has a flat, relatively undissected surface. West of the valley the bedrock surface is rugged and greatly dissected.

Ground water in Rock County occurs under both water-table and artesian conditions; however, because of the interconnection and close relation of all ground water in the county, the entire system is considered to be a single ground-water body whose surface may be represented by one piezometric map. Recharge occurs locally throughout the county. Nearly all recharge is derived directly from precipitation that percolates downward to become a part of the ground-water body. Natural movement of water in the consolidated water-bearing units is generally toward the buried Rock and Sugar River valleys. Movement of water in the sandstones of Cambrian age was calculated to be about 44 million gallons a day toward the Rock River.

Discharge from wells in Rock County in 1957 was about 23 million gallons a day. Nearly 90 percent of this water was drawn from the area along the Rock River. Drilled wells, most of which were drilled by the cable-tool method, range in diameter from 3 to 26 inches, and in depth from 46 to 1,225 feet. Driven wells in alluvium and glacial drift are usually 1¼ to 2½ inches in diameter.

Water levels in wells fluctuate according to a rather definite annual pattern; they are generally highest in the spring, lower through the summer, and lowest in the fall and winter. Short-term fluctuations result from atmospheric-pressure changes, pumping of wells, and individual rains. Long-term trends in water level are the result of long-term trends in the precipitation or pumping patterns.

Five aquifer tests were made to determine the transmissibility of the major aquifers. The transmissibility of the sandstones of Cambrian age is about 34,000 gallons per day per foot; that of the Rock River valley fill is about 1 million gallons per day per foot.

Ground water in Rock County is generally a hard, calcium magnesium bicarbonate type that is slightly alkaline. Iron is not usually a serious problem, but concentrations as high as 5.4 parts per million have been reported. Measured temperatures of water discharging from wells ranged from 48.8° F to 53.4° F.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The people of Wisconsin are becoming increasingly aware of the importance of ground water to an expanding agricultural and industrial economy. MacKichan (1957) reports that 42 percent of the water furnished by public water-supply systems in Wisconsin and 80 percent of the rural supplies are from ground-water sources. Rock County is one of the leading agricultural and industrial counties in the State. Its location with respect to markets should encourage expansion in both fields, and a knowledge of the ground-water resources of the county will be of value in determining the direction and amount of expansion.

A study of the geology and ground-water resources of Rock County was begun in 1955 by the U.S. Geological Survey in cooperation with the Wisconsin Geological and Natural History Survey, University of Wisconsin, as part of a statewide cooperative program of ground-water studies begun in 1946.

The investigation, planned cooperatively with George F. Hanson, State Geologist, was under the immediate supervision of W. J. Drescher district engineer, and his successor C. L. R. Holt, Jr., district geologist. The purpose of the project was to determine (1) the location of available ground-water supplies for farms, municipalities, and industries; (2) the geologic and hydrologic characteristics of the aquifers; and (3) the chemical quality of the water.

A study was made of the geologic history, physiography, structure, and stratigraphy of the area, and a geologic map was prepared. Mapping was done on U.S. Geological Survey topographic maps at a scale of 1: 62,500 (1 inch on the map equals about 1 mile on the ground). Of 470 wells located in the field, drillers' logs were available for 385, and logs compiled by geologists from examination of samples were available for 33. In addition to the wells visited in the field, the location of 152 other wells for which drillers' logs were available was established to aid in geologic and hydrologic interpretation. Depth-to-water measurements were made in about 230 wells for use in construction of a piezometric map (fig. 15). Thirty-six wells (fig. 6) were designated as observation wells to be measured periodically during the investigation. Aquifer tests were made in Beloit, Evansville, Janesville, and Orfordville to determine the hydraulic properties of the aquifers. Three samples of well water were collected for analysis to supplement 41 chemical analyses obtained from various sources.

ACKNOWLEDGMENTS

Appreciation is expressed to the many well drillers, well owners, industry representatives, and municipal officials, who cooperated in the collection of basic records. The aquifer tests were greatly facilitated by the cooperation of Joseph Lustig, city engineer, and E. C. Burhans of the Janesville Water Department; R. R. Curtius, operations superintendent, Wisconsin Power & Light Co., Beloit; H. A. Taite, utilities superintendent, Evansville; and Joseph Nelson, water superintendent, Orfordville. Special thanks are due John A. Strand, consulting engineer, for his cooperation in planning and making the tests at Evansville and Orfordville.

G. F. Hanson, State Geologist, is acknowledged for his review of this report and for supplying geologists' logs prepared by the State Geological and Natural History Survey. O. J. Muegge, State sanitary engineer, provided well records and chemical analyses from the

files of the State Board of Health. The Wisconsin State Laboratory of Hygiene made chemical analyses of water from Rock County. Municipal pumpage data were supplied by the Wisconsin Public Service Commission.

PREVIOUS REPORTS

Little detailed work pertaining directly to ground water had been done previously in the report area. Chamberlin (1877, 1883) discussed the history of the geologic units in Rock County and described their character, thickness, and distribution. A report by Weidman and Schultz (1915) contains data on municipal ground-water supplies, the quality of the water, and the occurrence of springs and flowing wells. A report by Alden (1918) describes the glacial geology and the character and distribution of the bedrock formations. The geologic map of Wisconsin (Bean, 1949) shows the relation of the bedrock geology of Rock County to that of the rest of the State. The soils of the county are described by Whitson (1922), the physical geography by Martin (1916; reprinted in 1932), and the agriculture of the county by the Wisconsin Department of Agriculture (1953).

WELL-NUMBERING SYSTEM

The system of numbering wells in Wisconsin (fig. 1) is based on the Federal system of rectangular land subdivision. A well number consists of five parts. The prefix is derived from the county name (Ro, Rock County; Gn, Green County; Wg, Winnebago County, Ill.), and the three numbers immediately following the county designation give the location of the well by township, range, and section. The letter "W" following a range number indicates that the well is west of the Fourth principal meridian; the absence of the letter indicates that the well is east of the principal meridian. The final number is the well serial number and indicates the approximate order in which the wells of the county were first visited in the field. On maps showing well locations, only the serial number is used to identify a well.

GEOGRAPHY

LOCATION AND EXTENT OF AREA

An index map (fig. 2) shows the location of Rock County, which is immediately north of the Illinois State line, between lat 42°30′ to 42°51′ N. and long 88°47′ to 89°22′ W. The nearly rectangular county is about 30 miles long, from east to west, and 24 miles wide. The total area is about 723 square miles, of which 8.5 square miles is lakes and streams.

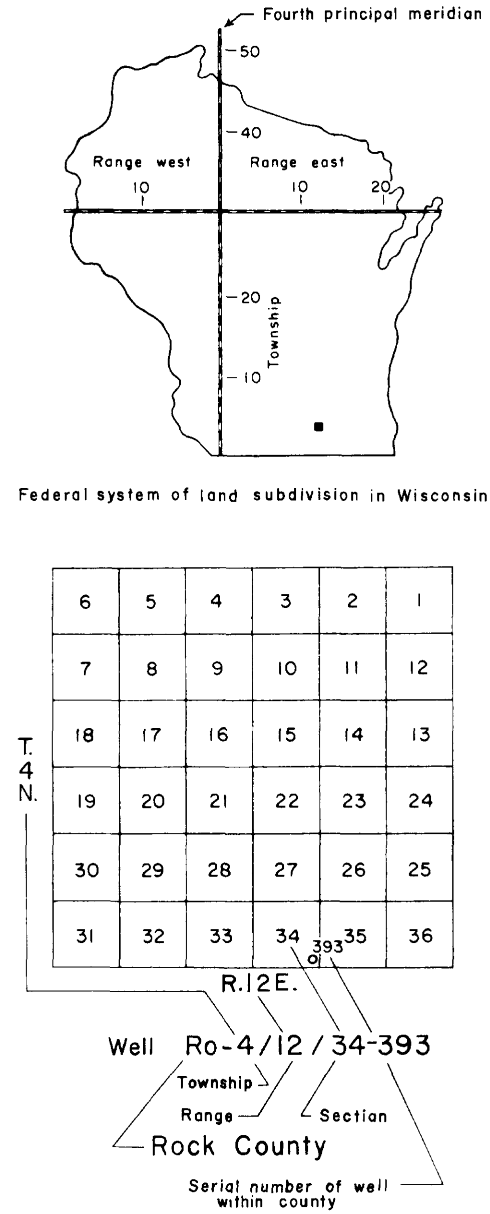


FIGURE 1.—Well-numbering system in Wisconsin.

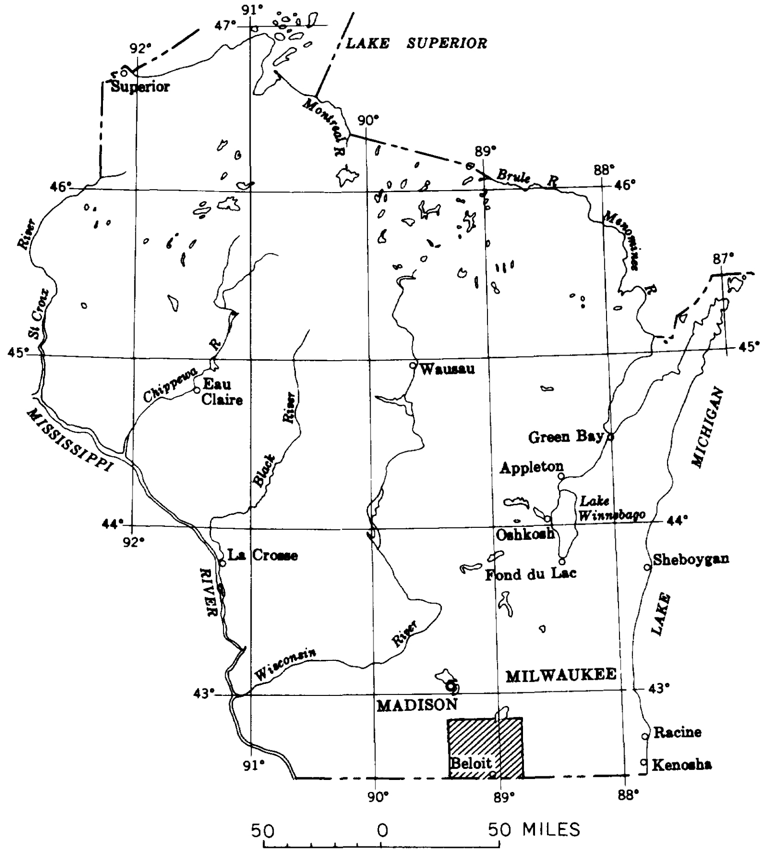


FIGURE 2.—Index map showing area of this report.

CULTURE

The population of Rock County, according to the U.S. Census of 1960, totals 113,105. A study made in 1957 by the University of Wisconsin indicates that about 16 percent of the population is classed as farm, 14 percent as rural nonfarm, and 70 percent as urban. Beloit is the largest city and has a population of about 30,000. Janesville, the county seat, has a population of about 25,000.

Nearly 95 percent of the land in the county is in farms. Among the counties in the State, Rock County ranks 2d in corn production, 5th in hog production, 14th in milk production, and 6th in total cash farm income (Wisconsin Dept. Agriculture, 1953).

In 1956, about 20 percent of the county's population was actively engaged in manufacturing (U.S. Department of Commerce, 1958), and about 13 percent worked in commerce and industry other than manufacturing. The chief manufactured products are engines, turbines, paper-making machinery, motor vehicles, railroad equipment, electrical machinery and equipment, leather goods, and writing equipment.

TOPOGRAPHY

In the absence of adequate topographic map coverage in Rock County, the altitudes of wells and other control points were determined by aneroid altimeter. U.S. Geological Survey and U.S. Coast and Geodetic Survey bench marks were used for control. The land-surface altitudes are generally between 800 and 900 feet. The highest altitudes, above 1,080 feet, are on a morainal hill in sec. 21, T. 4 N., R. 11 E. and on a bedrock ridge in sec. 16, T. 3 N., R. 10 E. The tops of many of the bedrock ridges in R. 10 E. are above 1,000 feet in altitude. The lowest altitude, 731 feet, is at the surface of the Rock River where it leaves Wisconsin and flows into Illinois.

On the basis of surface features, the county can be divided into four physiographic areas (fig. 3). One area comprises the hills and kettles in the northern part of the county. There, the landforms are due almost entirely to glacial deposition, although in some places the bedrock is near the surface and may influence the general topography. South of this area a belt of flat outwash and alluvium extends from

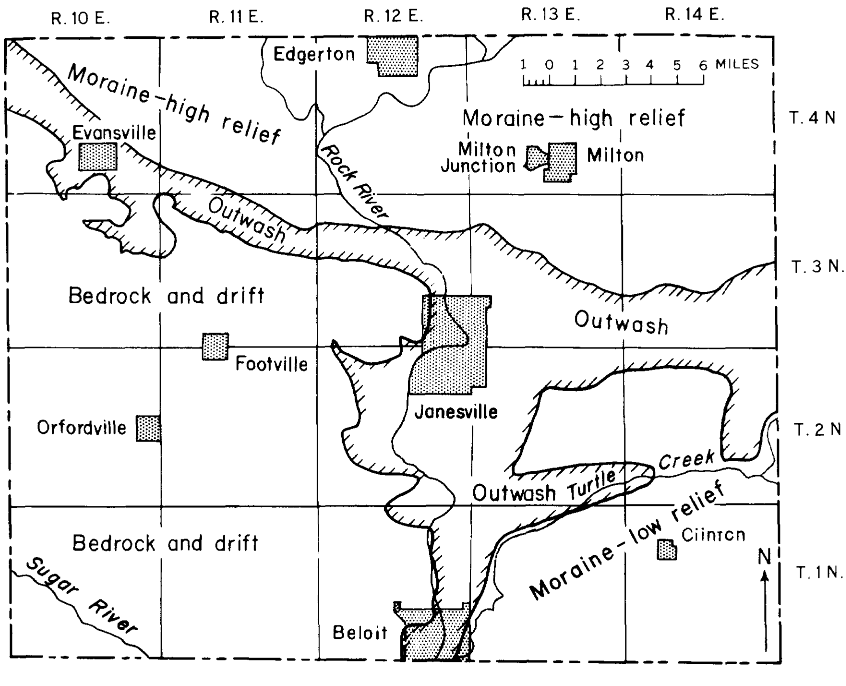


FIGURE 3.—Map showing physiographic areas in Rock County, Wis.

east to west across the county and southward along the Rock River. The third area, in the southeastern part of the county, is an area of gentle slopes and low relief, the result of both glacial deposition and bedrock control. Here, bedrock crops out in some places but is covered by glacial drift more than 100 feet thick in others. The fourth area is in the southwestern part of the county where the glacial cover is very thin or lacking and the topography is due almost entirely to differential erosion of the bedrock. The terrain in this fourth area is characterized by valleys underlain by sandstone and ridges underlain by dolomite; it is similar to that of the unglaciated part of southwestern Wisconsin.

SURFACE WATER

Rock County is in the Rock River drainage basin. The river enters the county from the southwestern end of Lake Koshkonong, about 3 miles east of Edgerton, and flows southward through Janesville and Beloit (pl. 1). In Rock County the river is 34 miles long and has a gradient of 1.4 feet per mile. About 4 miles southwest of Edgerton the Rock River is joined from the west by the Yahara River which, together with its tributary Badfish Creek, drains much of the rolling morainal land in the northwestern part of the county. North of Janesville the Rock River is joined from the west by Marsh Creek. The U.S. Geological Survey stream-gaging station on Rock River at Afton, about 4 miles south of Janesville, has been in operation since 1914 (Wells and others, 1958). The drainage area above this station is about 3,300 sq mi, and the average discharge is 1,735 cfs (cubic feet per second); the maximum discharge of record is 13,000 cfs; the minimum discharge, 36 cfs. Another eastward-flowing stream, Bass Creek, joins the Rock River immediately south of the gaging station.

The western and southwestern parts of the county are drained by the Sugar River and Coon Creek. Coon Creek flows southward into Illinois, where it joins the Pecatonica River, which in turn joins the Rock River at Rockton. The Sugar River flows into the Pecatonica River at a point about 6 miles upstream from Coon Creek. The U.S. Geological Survey stream-gaging station on the Sugar River near Brodhead, Green County, has recorded (Wells and others, 1958) a maximum discharge of 14,800 cfs, on September 13, 1915, and a minimum discharge of 44 cfs, on September 5, 1948. Since it was installed in 1914, the station has recorded an average discharge of 338 cfs. The drainage area above the gage is about 527 sq mi. The gradient of the slow-moving, meandering Sugar River is about 2.2 feet per mile in Rock County.

Turtle Creek drains the southeastern part of the county. Throughout much of its length, the creek flows on bedrock and, like the Rock and Sugar Rivers, is an effluent stream that receives water from the ground-water body. However, beyond the point where it leaves the area of bedrock outcrop and flows west over the Rock River valley fill (pl. 1), Turtle Creek is an influent stream, losing water to the ground-water body (pl. 5). The average discharge recorded by the U.S. Geological Survey stream-gaging station at Turtle Creek near Clinton for the 18-year period of operation is 102 cfs (Wells and others, 1958). The maximum discharge of record was 6,560 cfs on February 24, 1949, and the minimum discharge was 10 cfs on December 29, 1956. The gradient of the 15.5-mile reach of the stream in Rock County is about 5.1 feet per mile. The drainage area above the gage is about 186 sq mi.

Whitson (Whitson and others, 1922) reported that at least 16 percent of the land area of Rock County could be classed as poorly drained. By 1952, a number of drainage ditches had been dug and less than 8 percent of the total land area was marshland or swamp. About 45 percent of the poorly drained land is in the area drained by the Sugar River and Coon Creek. Other marshland and swamp areas are along Bass Creek and in the glacial moraine in the northeastern part of the county.

Nearly all the lakes and ponds are in the northern part of the county. The larger lakes, such as Gibbs Lake and Clear Lake, are exposures of the ground-water body and, therefore, are ground-water lakes (see pl. 1). Several of the smaller lakes and ponds in the area do not appear to be a part of the main ground-water body. For example, the altitude of the water level in well Ro–3/13/10–134 was 819 feet in May 1956. In contrast, a small lake about 1,000 feet northwest of this well was at an altitude between 880 and 900 feet. About 500 feet southeast of the well, a pond was at an altitude between 880 and 900 feet. The lake and pond appear to be perched—that is, underlain by impermeable strata that prohibits movement of the water downward into the main water body.

CLIMATE

Rock County has warm, humid summers and cold, snowy winters. Its temperature and precipitation are slightly above the average for the State of Wisconsin. The average annual temperature is about 48° F (fig. 4). The total yearly precipitation averages about 32 inches. The growing season, extending generally from April 25 to October 16, averages 175 days. More than 60 percent of the annual precipitation falls as rain during the growing season. At Beloit the average snowfall is about 30 inches, which is equivalent to about 8 percent of the average annual precipitation.

Weather data used in this report were obtained from the U.S. Weather Bureau observation stations at Beloit, Brodhead, Clinton, Janesville, Stoughton, Whitewater, and Williams Bay.

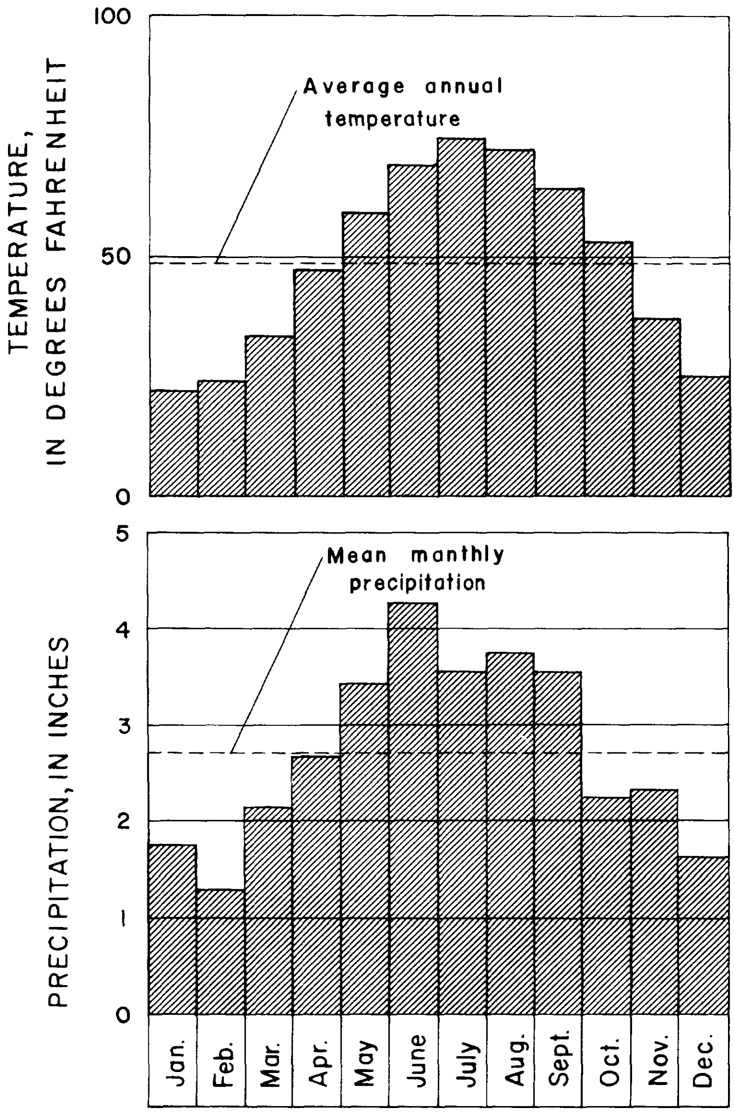


FIGURE 4.—Average monthly temperature and mean monthly precipitation, Rock County, Wis. Based on data from U.S. Weather Bureau stations at Beloit, Brodhead, Stoughton, and Williams Bay, 1931–58.

ROCK UNITS AND THEIR WATER-BEARING PROPERTIES

An intelligent study of the ground-water resources of an area requires a knowledge of the geology. Ground water occurs almost universally in the cracks, solution openings, and pore spaces of the earth's crust in the zone of saturation. For this reason, it is not searching for ground water that is important, but rather determining the quantities of water available for use. The availability of ground water is dependent upon the size, distribution, and interconnection of pore spaces and other rock openings, upon the attitude of the rock units, and upon their relation to other rock units and to the surface of the earth.

The most widespread and productive aquifers (ground-water reservoirs) are formed by the sedimentary rocks. These rocks range in composition from unconsolidated deposits of coarse-grained sand and gravel to silt and clay, and from poorly cemented sandstone to dense limestone and impermeable shale. All these are capable of containing water, but to be important as aquifers they must transmit water to a well or spring at a rate sufficient to meet the demand. This property of a rock unit to transmit water is called its permeability and is expressed as the amount of water, in gallons per day, that will move through a 1-square-foot cross section of the aquifer under a hydraulic gradient of 1 foot per foot.

The permeability of sedimentary rocks has a wide range. Clay, although it has high porosity (ratio of intersticial volume to mass of material), has an extremely low permeability; the pore spaces between the grains are so small that nearly all the water is held in place by molecular attraction. Well-sorted sand or gravel are more permeable than poorly sorted material, because the spaces between grains are not filled with fine material that would retard the movement of water. The rocks of highest permeability are cavernous limestones and dolomites, in which the water can move unhindered through large interconnected solution openings and cracks.

In addition to the word "permeability", the terms "specific capacity" and "yield factor" will be used in the following discussion of the water-bearing properties of the geologic units. The specific capacity relates the discharge rate to the lowering of the water level in a discharging well. It is expressed as gallons per minute per foot of drawdown and is used as a rough scale for the water-yielding capacity of a well and the relative transmissibility of the water-bearing material near the well. The yield factor is used as a relative measure of the permeability of the water-bearing material penetrated by the well. It is expressed as gallons per minute per foot of drawdown (specific capacity) per foot of water-bearing material penetrated, multiplied by 100. There are definite shortcomings to using the relation of discharge to drawdown in expressing relative permeability (Wenzel, 1942); however, owing to the similarity of construction and the rather standardized methods of testing wells in Rock County, the relation is generally consistent and is a satisfactory measure of aquifer productivity.

The water-yielding rocks in Rock County include consolidated rocks, such as shale, siltstone, dolomite, and sandstone, and unconsolidated deposits of clay, silt, sand, gravel, and boulders. Of the rock units described (table 1), the unconsolidated glacial deposits—the Platteville, Decorah, and Galena formations undifferentiated (Platteville-Galena unit)—and the St. Peter sandstone are the only ones

TABLE 1.—*Lithologic and water-bearing characteristics of geologic units in Rock County, Wis.*

System	Geologic unit	Maximum thickness (ft)	Description	Water-bearing characteristics
Quaternary	Recent alluvium		Silt, sand, peat, and marl.	Not determined. Probably too thin to yield significant quantities of water to wells.
	—— Unconformity —— Pleistocene deposits	382	Till and outwash, gray to brown; consists of clay, silt, sand, gravel, and boulders.	Outwash sand and gravel in the Rock River valley yields large amounts of water. Other bodies of sand and gravel yield moderate amounts of water to properly developed wells.
Ordovician	—— Unconformity —— Platteville, Decorah, and Galena formations, undifferentiated.	288	Dolomite, light-gray to blue-gray, yellowish-gray, sandy, fractured at top, fine- to medium-grained sandstone at base; and green shale.	Yield sufficient water for domestic and stock use from fractures and solution openings. Principal source of supply for wells east of the buried Rock River valley.
	St. Peter sandstone.	185	Sandstone, yellowish-gray to white, fine- to medium-grained; white chert and chert conglomerate; and red shale.	Yields sufficient water for domestic, stock, and small industrial supplies. Principal source of ground water west of the buried Rock River valley. Usually left uncased to contribute water to wells tapping rocks of Cambrian age.
Cambrian	—— Unconformity —— Prairie du Chien group.	60	Dolomite, yellowish-brown to gray; and white and gray chert.	Not determined.
	Trempealeau formation Franconia sandstone Galesville sandstone, Eau Claire sandstone, Mount Simon sandstone } Dresbach group	960	Sandstone, white, gray, red, fine- to very coarse-grained, dolomitic; siltstone, shale; and dolomite.	Yield large amounts of water to deep wells throughout the county. Lower part usually more permeable.
Precambrian	—— Unconformity —— Crystalline rocks	?	Not penetrated by wells in Rock County.	Not determined. May yield some water from possible weathered and creviced zone.

that are exposed at the surface and that can be examined in the field. The rocks of the Prairie du Chien group, the Upper Cambrian series, and the Precambrian are not exposed in Rock County; they have been described by using data obtained from drillers' logs, geologists' sample logs, and examination of outcrops in other parts of the State.

The distribution of the bedrock units in Rock County and the location of wells are shown on plate 1, which is based on the work of Alden (1918), Bean (1949), and the author and shows the geology of the area as it would appear if all the unconsolidated material were removed. Alden prepared a bedrock geologic map based on field observation and well logs. The author revisited many of the outcrops previously studied by Alden and found few points of disagreement; however, many new roadcuts have been made since 1918, and a large number of additional well logs are available. The author's modification of the previous mapping is based on these additional data.

The vertical sequence of the geologic units is shown by geologic cross sections (pl. 2). A cross section can be compared to a vertical slice through the earth's crust extending to the depth of each well, and from one well to each successive well; it shows the thickness and depth below the land surface of each rock unit and the inclination of the beds along the line of section.

PRECAMBRIAN ROCKS

Rocks of Precambrian age have not been penetrated by wells in Rock County. Although deep wells (table 3) have been drilled in the county, they have never needed to penetrate the full thickness of the sedimentary rocks to obtain an adequate supply of water.

The Precambrian complex, in areas north of Rock County, consists of igneous, metamorphic, and firmly cemented sedimentary rocks that have small or disconnected pore spaces and contain little or no recoverable water. Thwaites (1940) showed that the inferred surface of the Precambrian rocks ranges from 200 feet below sea level in the northwest corner of Rock County to 800 feet below sea level in the southeast corner.

CAMBRIAN SYSTEM

UPPER CAMBRIAN SERIES

Rocks of Late Cambrian age overlie the crystalline rocks of Precambrian age throughout Rock County. In the Rock and Sugar River valleys, and probably in the Coon Creek valley, rocks of Late Cambrian age underlie unconsolidated Quaternary deposits (pl. 1). In other areas they are overlain by Ordovician rocks of the Prairie du Chien group or the St. Peter sandstone.

690-438 O—63——2

The geologic subdivisions of the Upper Cambrian series in Rock County are, from bottom to top, the Mount Simon sandstone, the Eau Claire sandstone, the Galesville sandstone, the Franconia sandstone, and the Trempealeau formation. The Mount Simon sandstone, the Eau Claire sandstone, and the Galesville sandstone compose the Dresbach group. The Upper Cambrian series forms a single water-bearing unit.

The Mount Simon sandstone, which throughout the area overlies rocks of Precambrian age, is generally a very fine to very coarse grained sandstone that is light gray, pink, or white. Dolomitic, silty, or shaly layers are reported in some well logs. The maximum thickness of the Mount Simon sandstone penetrated by wells in Rock County is 525 feet at well Ro–1/12/35–25, at Beloit (pl. 2). However, the well does not penetrate this formation completely, and the total thickness of the unit at the well site is probably more than 850 feet. At Evansville the Mount Simon sandstone is probably about 400 feet thick.

The Eau Claire sandstone, which overlies the Mount Simon sandstone, ranges in thickness from 348 feet in well Ro–4/12/10–2, at Edgerton, to 200 feet in wells Ro–1/12/35–24 and –25, at Beloit (pl. 2). It is a fine- to coarse-grained light-gray to white and pink dolomitic sandstone. Near the top of the formation, layers of gray to green siltstone occur, and an extensive bed of gray, green, or red dolomitic shale ranges in thickness from 10 to about 99 feet. Because the shale is much less permeable than the sandstone, it undoubtedly retards the vertical movement of water in the rocks of Late Cambrian age.

The Galesville sandstone is almost entirely a fine- to coarse-grained light-gray to white sandstone. Its maximum known thickness in Rock County is at Janesville, where 150 feet was logged in well Ro–3/12/14–32 (pl. 2). At Edgerton only 25 feet of the sandstone was penetrated by well Ro–4/12/3–34.

The Franconia sandstone, which overlies the Dresbach group, is composed of very fine grained to medium-grained green, gray, and red dolomitic sandstone interbedded with reddish-brown siltstone, red shale, and red dolomite. The thickness of the Franconia sandstone is relatively constant throughout the county, ranging from 120 feet in well Ro–4/13/27–7, at Milton, to 70 feet in well Ro–2/12/2–3, at Janesville.

The Trempealeau formation, which overlies the Franconia sandstone, is the uppermost unit of the Upper Cambrian series. It is a predominantly sandy and silty gray, brown, and yellowish-gray dolomite, but it also includes shale, siltstone, and fine- to medium-grained sandstone. The formation ranges in thickness from 28 feet in well Ro–1/13/19–27, at Beloit, to 90 feet in well Ro–4/12/3–34, at

Edgerton. At Footville, the village supply well (Ro–2/11/5–28) penetrated 96 feet of the Trempealeau. At Janesville (Ro–2/12/1–30), (pl. 2), the formation is not present, having been deposited and later eroded completely by the ancestral Rock River, which cut deeply into the bedrock formations.

The upper surface of the Trempealeau formation slopes generally toward the southeast (pl. 2 and fig. 5). The altitude of this surface northwest of Evansville is about 700 feet, and southeast of Clinton it is about 450 feet. The slope of the surface in the northwestern part of the county is about 3.6 feet per mile, but in the southeastern part the gradient steepens to about 9.4 feet per mile.

All the cities and villages in Rock County obtain water from wells tapping rocks of Late Cambrian age. Although this unit is characterized by poor water-yielding properties, its great saturated thickness (fig. 6) permits the construction of high-capacity wells (table 2). A map (fig. 6) showing the probable thickness of the unit in Rock County is based on information from well logs, and from the work of Thwaites (1940) on the buried Precambrian rocks in Wisconsin. The thickness of the Late Cambrian rocks is about 920 feet at Brooklyn, in Green County; it increases toward the southeast and is about 1,320 feet at Clinton and Beloit.

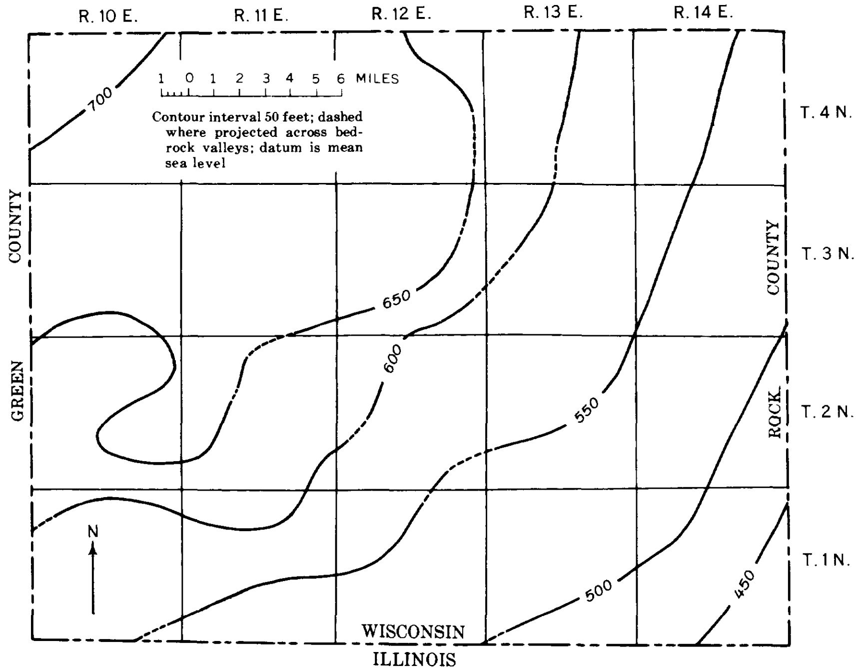


FIGURE 5.—Map showing contours of the Cambrian-Ordovician contact, Rock County, Wis.

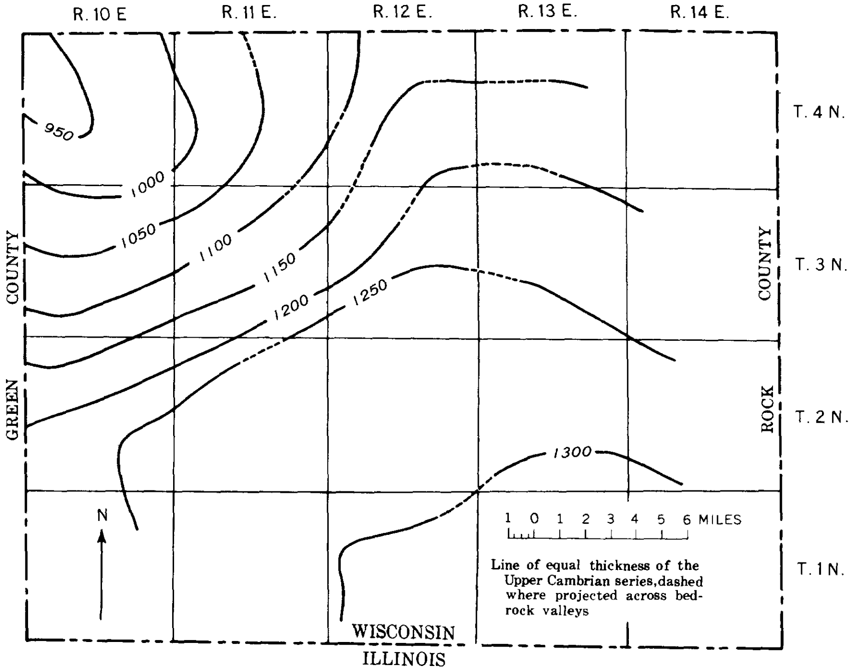


FIGURE 6.—Generalized map showing thickness of the Upper Cambrian series, Rock County, Wis.

Table 2 summarizes the available data on specific capacity and yield factors of wells in Rock County. It shows that wells penetrating deeply into the rocks of Late Cambrian age have rather high specific capacity, but because of the greater thickness penetrated, very low yield factor. Wells penetrating only a short distance into this unit have very low specific capacity, but relatively high yield factor.

TABLE 2.—*Specific capacity and yield factor of wells in Rock County, Wis.*

Geologic source	Specific capacity [1]				Yield factor [2]				Average thickness of aquifer penetrated (ft)	Number of tests
	Max.	Min.	Med.	Avg.	Max.	Min.	Med.	Avg.		
Alluvium and drift	7.5	0.2	2.2	2.5	27	0.2	1.4	5.9	96	16
Do [3]	1,250	12	120	291	2,358	29	100	402	90	10
Platteville-Galena unit	7.5	.2	1.5	2.5	47	.2	6.7	8.7	52	29
Platteville-Galena unit, and St. Peter sandstone	5.0	.2	1.0	1.4	11	.2	1.8	2.5	64	25
St. Peter sandstone	12.5	.5	2.0	2.9	92	1.7	8.2	12.7	33	36
Upper Cambrian series	7.5	.1	.9	1.9	34	.5	3.0	10.7	25	9
Do [4]	19.4	5.2	8.3	10.1	2.4	1.0	1.4	1.6	645	8

[1] Gallons per minute per foot of drawdown.

[2] $\frac{\text{Specific capacity} \times 100}{\text{Thickness of aquifer penetrated (feet)}}$.

[3] Large-diameter, high-capacity wells, in outwash.

[4] High-capacity wells.

Examination of drill cuttings and analysis of aquifer-test data indicate that the permeability of the Eau Claire and Mount Simon sandstone is greater than that of the overlying St. Peter sandstone, Trempealeau formation, and Franconia and Galesville sandstone. For example, well Ro-4/10/27-467 at Evansville was test pumped at 600 gpm (gallons per minute) at a depth of 400 feet, when the well had not yet reached the top of the Eau Claire. At this depth the specific capacity was only 3.3 gpm per ft. The well was then deepened through the Eau Claire and into the Mount Simon sandstone and pumped at 1,270 gpm. The specific capacity of the well during this test had increased to 13 gpm per ft, indicating a substantially higher permeability for the Eau Claire and Mount Simon sandstone. Table 3 shows the geologists' log of well Ro-4/10/27-467, at Evansville.

TABLE 3.—*Materials penetrated by well Ro-4/10/27-467 at Evansville, Rock County, Wis.*

	Thickness (ft)	Depth (ft)
Glacial drift:		
Soil, brown, nondolomitic, loess	5	5
Gravel, fine-grained, sandy, tan, much dolomite	25	30
Sand, medium-grained, light-brown-gray, slightly dolomitic, more than 90 percent quartz sand grains	50	80
St. Peter sandstone:		
Sandstone, medium-grained, light-gray, some pale-orange, slightly dolomitic (weathered?)	20	100
Sandstone, fine- to medium-grained, light-gray	15	115
Sandstone, coarse-grained, buff (rust-stained?); a little very dolomitic blue-gray siltstone and shale	25	140
Sandstone, fine-grained, pale-red, dolomitic	15	155
Sandstone, fine-grained, dark-red, dolomitic	10	165
Sandstone, medium-grained, dark-red-brown, dolomitic	30	195
No sample	15	210
Conglomerate: white chert; red siltstone; pink sandstone	5	215
Sandstone, fine- to coarse-grained, red; conglomerate of white chert	10	225
No sample	10	235
Upper Cambrian series:		
Trempealeau formation:		
Dolomite, light- to medium-gray and purplish-gray, slightly sandy and glauconitic, very sandy; some green shale near base	50	285
Franconia sandstone:		
No sample	25	310
Sandstone, fine-grained to very fine grained, silty, very dolomitic, glauconitic, dark-red, some green-gray	20	330
Sandstone, fine-grained to very fine grained, pale-red and light-gray, very dolomitic, glauconitic	15	345
Sandstone, fine-grained to very fine grained, green-gray, a little pale-red, dolomitic, glauconitic	25	370
Galesville sandstone:		
Sandstone, fine- to coarse-grained, light-gray	30	400
Sandstone, fine- to coarse-grained, light-gray	10	410
Sandstone, coarse-grained, light-gray	15	425
Sandstone, fine- to medium-grained, light-gray	70	495

TABLE 3.—*Materials penetrated by well Ro-4/10/27-467 at Evansville, Rock County, Wis.*—Continued

	Thickness (ft)	Depth (ft)
Upper Cambrian series—Continued		
Eau Claire sandstone:		
Siltstone, light-gray, green-gray, and blue-gray, sandy, shaly, dolomitic	20	515
Sandstone, coarse-grained, some fine-grained, light-gray, silty, shaly, glauconitic, dolomitic	15	530
Sandstone, medium-grained, light-gray	45	575
Sandstone, medium-grained, light-gray, dolomitic; some light-gray dolomite	40	615
Sandstone, fine- to medium-grained, light-gray	10	625
Sandstone, medium-grained, light-gray, dolomitic	20	645
Sandstone, fine- to medium-grained, light-gray, dolomitic	20	665
Sandstone, medium-grained, light-gray; some medium-gray sandy dolomite	50	715
Sandstone, fine- to medium-grained, light-gray, slightly dolomitic	35	750
Sandstone, medium-grained, light-gray	15	765
Sandstone, medium-grained, light-gray, dolomitic; some medium-gray dolomite	15	780
Sandstone, medium-grained, light-gray, dolomitic	15	795
Mount Simon sandstone:		
Sandstone, fine- to medium-grained, light-gray	20	815
Sandstone, very fine grained to coarse-grained, light-gray	30	845
Sandstone, fine- to coarse-grained light-gray	25	870
Sandstone, fine- to medium-grained, light-medium-gray	15	885
Sandstone, fine-grained to very coarse grained, light-gray	75	960
Sandstone, coarse-grained to very coarse grained, a little fine-grained at 970–980 ft, light-gray	35	995

ORDOVICIAN SYSTEM

PRAIRIE DU CHIEN GROUP

The yellowish-brown to gray cherty dolomite of the Prairie du Chien group is reported in only six sample logs in Rock County. The thickness of this group ranges from 60 feet at Edgerton to 10 feet at Janesville and Brodhead, and at Footville and Milton the reported thicknesses are 35 feet and 18 feet, respectively. In all other deep wells in the county, the unit is absent and the overyling St. Peter sandstone is in contact with the rocks of the Upper Cambrian series. The Prairie du Chien group has been included in the Upper Cambrian series on the geologic map (pl. 1) because of the similarity of its water-bearing properties to those of the dolomite in the underlying Trempealeau formation. Where it is present, the unit may yield some water to wells from joints enlarged by solution and from bedding planes, but the Prairie du Chien group is not important as a source of water in Rock County.

ST. PETER SANDSTONE

The St. Peter sandstone is present everywhere in Rock County except where it has been removed by erosion in the Rock and Sugar River valleys (pl. 1). In the eastern third of the county, the St. Peter sandstone is overlain by the Platteville-Galena unit. West of the Rock River the St. Peter is exposed at the base of cliffs formed by the Platteville-Galena unit. In valleys and other low areas it directly underlies unconsolidated Pleistocene and Recent deposits. In well logs, the St. Peter is reported to be a fine- to medium-grained yellowish-gray to white sandstone, commonly containing zones of white chert, chert conglomerate, and some red shale. Where exposed, it is a massive friable commonly iron-stained sandstone having a prominent well-cemented zone of iron concretions at the top. Where this well-cemented zone is sufficiently thick, a joint system generally is present.

The St. Peter sands were deposited on the uneven erosional surface of the Prairie du Chien group and rocks of Late Cambrian age; thus the thickness of the formation varies considerably. The thickest section reported in Rock County wells is 185 feet in well Ro-2/10/24-452, at Orfordville (pl. 2). The upper surface of the St. Peter sandstone slopes generally toward the east (fig. 7). From the northwestern part

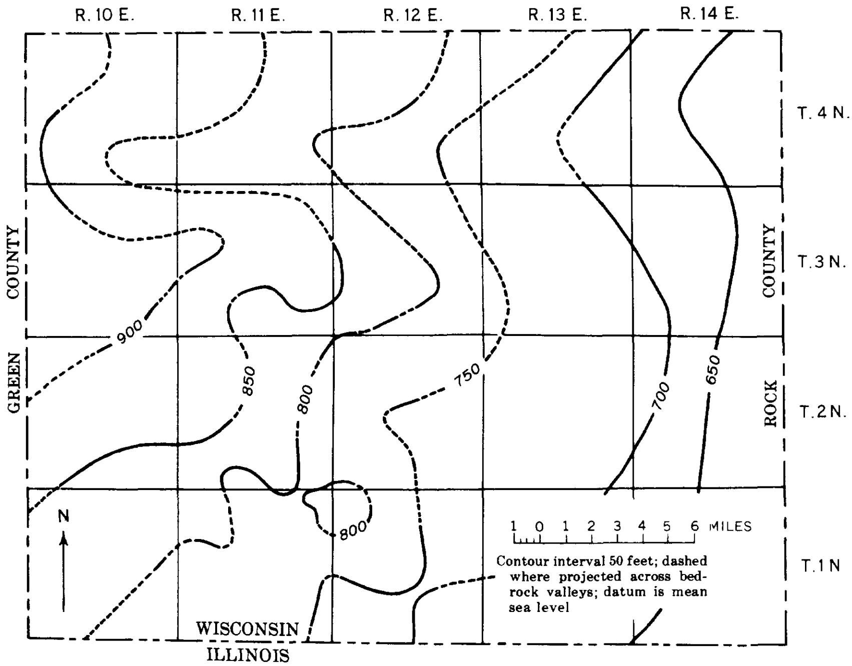


FIGURE 7.—Map showing contours of the St. Peter sandstone-Platteville formation contact, Rock County, Wis.

of the county to the southeastern part, the altitude of this upper surface ranges from more than 900 feet to less than 600 feet.

In Rs. 10–12 E., domestic, stock, and small industrial wells obtain water principally from the St. Peter sandstone. In Rs. 13 and 14 E., the overlying Platteville-Galena unit generally yields an adequate supply of water, and for this reason few wells have been drilled into the St. Peter sandstone. Specific capacities and yield factors of the St. Peter are relatively high, which indicates that the formation is quite permeable and readily transmits water to wells. As shown in table 2, the average specific capacity of wells tapping the St. Peter sandstone is exceeded only by that of high-capacity wells in the rocks of Late Cambrian age and in the unconsolidated Quaternary deposits. The average yield factor of wells tapping the St. Peter sandstone is second only to that of high-capacity wells in the unconsolidated deposits.

PLATTEVILLE-GALENA UNIT

The Platteville-Galena unit overlies all the consolidated rock units throughout most of the area east of the Rock River (pl. 1). West of the Rock River the unit caps hills and ridges and is exposed in vertical cliffs above the less resistant St. Peter sandstone. The unit probably includes the Decorah formation (Agnew and others, 1956), but the Decorah has not been differentiated in well logs or in surface mapping in Rock County.

The Platteville-Galena unit is described in sample logs as a light-gray, blue-gray, or yellowish-gray dolomite with fine- to medium-grained sandstone and green shale near the base. The greatest thickness of the dolomite penetrated by a well in Rock County is 288 feet, in well Ro–1/14/8–20, at Clinton (pl. 2). Most well drillers in the area describe the dolomite as a limestone because of its appearance and physical properties. Chemically, however, it consists of calcium magnesium carbonate rather than calcium carbonate, which constitutes a pure limestone.

Where exposed in Rock County, the Platteville-Galena unit is a thick- to thin-bedded well-jointed dense dolomite, becoming gradually more sandy toward the base. In a few places the dolomite grades downward from sandy dolomite through dolomitic sandstone to white sandstone. The joints in the dolomite are nearly vertical and trend northeastward or southeastward. This joint system apparently persists throughout the county.

East of the Rock River the Platteville-Galena unit is the principal source of water to domestic and stock wells. In this area, east of the Rock River, it is seldom necessary to drill into the St. Peter sandstone to obtain an adequate water supply. The permeability of the dolomite varies considerably according to the size and degree of interconnection of joints and solution openings. In Tps. 3 and 4 N., R. 14 E., for example, sinkholes and blowing wells are indicative of large solution openings above the water table. Table 2 shows, however, that specific capacities and yield factors generally are relatively low. Wells that tap both the Platteville-Galena unit and the St. Peter sandstone have lower specific capacity and yield factor than those that tap only the Platteville-Galena unit. This probably is because the wells that tap the St. Peter also were drilled into an impermeable section of the Platteville-Galena unit and had to be deepened to include some of the underlying sandstone to obtain an adequate supply of water. West of the Rock River, where the Platteville-Galena unit caps hills and ridges, much of the unit may be above the zone of saturation, and hence it seldom yields adequate amounts of water to wells.

QUATERNARY SYSTEM

PLEISTOCENE DEPOSITS

Rock County was covered by glacial ice at least twice during the Pleistocene epoch. During each ice withdrawal there were periods of erosion in which much of the material deposited by the ice was moved.

As the next ice sheet advanced it transported material deposited by previous ice sheets, so that today the evidences of glacial deposition are essentially those of the last ice advances. The ice advances that are evident in Rock County are those of the Wisconsin stage, and perhaps the earlier Illinoian stage (Alden, 1918). At present there is some question as to the age of the glacial deposits in the southern two-thirds of the county. Shaffer (1956) has interpreted the deposits called Illinoian as being early Wisconsin in age. The age of the deposits will not be considered in this report.

Glacial features may be erosional or depositional and may be classified by form and composition. For this reason, the map showing the location of the four physiographic areas in Rock County (fig. 3) will be referred to in discussing the Pleistocene deposits.

The moraine area of high relief is underlain by till, an unsorted mixture of clay, silt, sand, and gravel deposited by an ice sheet. Large remnants of moraines are found also in the bedrock and drift area northwest of Janesville, east and south of Footville, and in the vicinity of Orfordville. In the morainal areas, many small domestic and stock wells have been completed in small lenses of stratified and sorted sand and gravel.

Deposits of stratified sand and gravel occur in the outwash area. These sediments were transported by glacial melt waters, which carried away in suspension much of the silt and clay but deposited as much as 396 feet of sand and gravel in preexisting valleys (well

Ro–4/13/30–279). The outwash deposits in the buried Rock River valley are the most productive source of ground water in the county. They are valuable because of their great saturated thickness, high permeability, and storage capacity. Plate 3 shows the saturated thickness of the outwash deposits in the buried Rock River valley and its major tributaries as of June and July 1958. In the deepest parts of the valley the thickness of saturated sand and gravel exceeds 300 feet.

The glacial deposits in the valley are recharged directly by precipitation and by ground water moving into the unconsolidated deposits from the bedrock aquifers.

The Pleistocene deposits are tapped by eight large-diameter, high-capacity wells. Specific capacity and yield factor are so high that these deposits are in a class apart from the other water-bearing units (table 2). For example, well Ro–3/12/24–43, at the Parker Pen Co., in Janesville, yielded 1,250 gpm for 24 hours and had a reported drawdown of 1 foot; Janesville municipal well Ro–2/13/6–46 yielded 5,450 gpm for 24 hours with 7 feet of drawdown; and well Ro–1/12/35–343, at Beloit, was tested for 10 hours at 4,500 gpm with a drawdown of about 16 feet. It should not be assumed from these statistics, however, that any well drilled into the fill of the Rock River valley will yield large amounts of water. The quantity of water available to a well can be determined only by drilling, because the water-bearing material varies considerably in thickness, grain size, composition, and degree of sorting from place to place.

F. T. Thwaites suggests (oral communication) that the coarser valley fill should be found along the west side of the valley, where the Rock River is flowing at present. Figure 8 shows that this is true for five samples of valley fill collected from pits and road cuts. These samples were taken at intervals across the valley from west to east. The westernmost sample contained an almost equal percentage of sand and gravel. The percentage of gravel decreased toward the east and the percentage of sand increased; however, many more analyses would have to be made of samples collected at various depths to establish the hypothesis. The clay and silt percentages did not change significantly.

Highly permeable outwash deposits are present also in the Sugar River valley and in a narrow valley extending east and west from Milton. In the northern half of T. 3 N., R. 14 E., and the southern half of T. 4 N., R. 14 E., the succession of materials penetrated by wells is usually clay, gravel, and limestone, according to well drillers. The gravel, although in the moraine area of high relief, may represent an older buried outwash that could supply substantial amounts of water to properly developed wells.

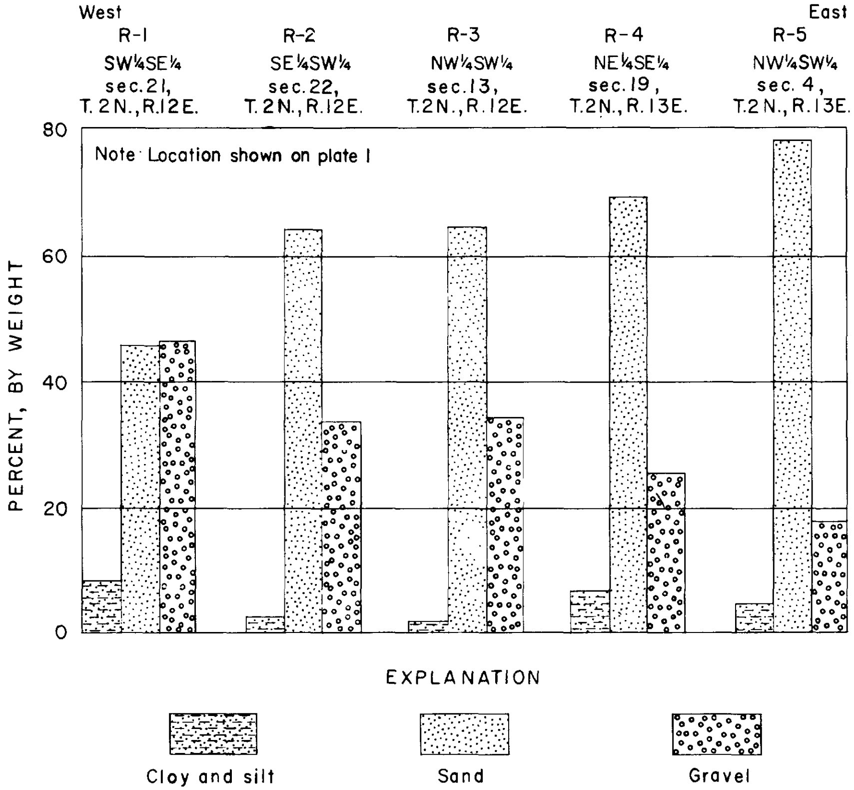


FIGURE 8.—Particle-size distribution in five samples of Pleistocene outwash, Rock County, Wis.

The moraine area of low relief in the southeastern part of the county consists of relatively thick ground-moraine and drumlin deposits. Ground moraines are deposited beneath the advancing ice sheet and are similar in composition to end moraines, but they form a gentler topography. Drumlins are low hills of generally unstratified material, elongated in the direction of movement of the advancing ice sheet.

Ground moraine is found also in the area of bedrock and drift in the southwestern part of the county, but it is usually much thinner here than it is in the southeastern part.

Wells in the morainal deposits, both end moraine and ground moraine, are included under "Alluvium and drift" in table 2. Yields from wells in morainal deposits are usually small and specific capacities and yield factors are low.

In addition to Pleistocene deposits described above, thin terrace deposits of sand and gravel are found along many of the streams, and peat and marl are present in some of the low, swampy areas. In the southwestern part of T. 1 N., R. 11 E., there is an area of wind-blown sand that probably was transported eastward from the Sugar River valley. None of these deposits are considered important as sources of ground water.

BEDROCK TOPOGRAPHY

The contour map (pl. 4) of the bedrock surface reveals the landscape as it would appear if the unconsolidated deposits were removed. Data from well logs, field observations, altimeter traverses, and topographic maps were used in compiling this map. Because the bedrock surface west of the Rock River is rugged and topographic control is poor, it was not contoured above the 800-foot altitude. Unconsolidated material on the bedrock ridges in this area west of the Rock River is generally so thin that the bedrock surface practically coincides with the land surface.

The most significant feature of the bedrock surface in Rock County is the ancestral Rock River valley, which has been filled with glacial outwash to a depth of at least 396 feet below the present land surface at well Ro-4/13/30-279. Below the 500-foot contour, the buried valley ranges in width from about ½ mile to about 2 miles.

The modern Rock River leaves the old valley at the south end of Lake Koshkonong, flows southwestward, and cuts across bedrock in several places. From about 5 miles south of Edgerton, it follows the buried ancestral Yahara River valley to a point north of Janesville, where it returns to the ancestral Rock River valley. A tributary to the buried Yahara River valley near Evansville has been filled to a depth of at least 262 feet (Ro-4/10/25-282) with stratified outwash deposited by glacial melt waters. From Janesville to Beloit the Rock River flows along the extreme west edge of the buried ancestral Rock River valley. At several places (pl. 1) the river leaves the old valley and cuts through rock spurs in a more recent channel.

East of the buried Rock River valley, the bedrock surface is relatively undissected. Four topographically high areas (fig. 8) correspond roughly to the high areas on the piezometric surface (pl. 5). Three small valleys originate between these highs and continue westward to join the buried valley of the Rock River.

The bedrock surface west of the buried Rock River valley is generally a rugged, highly dissected complex of ridges and deep, steep-sided valleys resembling the present topography of the unglaciated area in southwestern Wisconsin. The bedrock valleys of Bass Creek, Coon Creek, and Sugar River were cut at least 170 to 190 feet below the present floors of the valleys and subsequently were filled with unconsolidated alluvial material.

GROUND WATER

SOURCE AND OCCURRENCE

The source of practically all ground water in Rock County is precipitation. Of the total precipitation, part flows into streams and lakes as direct runoff, part returns to the atmosphere by evaporation and transpiration, and the remainder seeps downward through the soil and rocks to the zone of saturation. The surface of the zone of saturation is called the water table, and its position is shown by the level at which water stands in nonartesian wells. All openings in the zone of saturation are filled with water, and it is water in the zone of saturation that is tapped by wells and flows from springs.

Ground water occurs in pores, fractures, and bedding-plane openings in the rocks below the water table. The size, shape, and distribution of the openings in the rocks vary considerably from place to place and control the storage and movement of water. The amount of water that can be stored in a rock depends on its porosity. The "porosity" of a rock refers to its state of containing interstices or open spaces, and is the ratio, generally expressed as a percentage, of the open space in a rock to its total volume. Rock units that contain and transmit enough ground water to supply wells adequately are called aquifers.

In Rock County, ground water occurs under both water-table and artesian conditions. Water in the unconsolidated beds of sand and gravel is generally unconfined and is said to occur under water-table conditions. Artesian conditions exist locally where the sand and gravel deposits are confined by layers of silt or clay. Water in the consolidated rocks is unconfined in the areas where these rocks crop out or where they are covered by only a thin mantle of Pleistocene deposits. Downdip from the areas of outcrop, the water in the permeable rock units may be confined (under artesian conditions) by layers of dense dolomite, cemented sandstone, or nearly impermeable shale. The confining material is not totally impermeable, and there is much slow leakage through the beds, so that over a long period of time, the water in both the permeable and impermeable units may be considered as a single water body, rather than several water bodies, that has a common piezometric surface (imaginary surface that everywhere coincides with the static level of water in the aquifer).

Unconfined water in the zone of saturation moves through the rocks in a direction determined by the slope of the water table. The water table is not a flat or stationary surface but changes with location and time as a result of the geographic differences in permeability and structure of the rocks, of the variable rates of discharge from wells and springs, and of the recharge from intermittent and irregular amounts of precipitation.

When a well penetrates a confined aquifer down the hydraulic gradient from its intake area, hydrostatic pressure causes the water to rise in the well above the bottom of the confining rock layer. An artesian well will flow if the hydrostatic pressure causes the water in the well to rise above the land surface.

The form of the upper surface of the ground-water body in Rock County in late June and early July 1958 is shown by the piezometric contours in plate 5. The map was constructed by using depth-to-water measurements from about 230 wells and surface-water altitudes at about 65 locations where the levels of the surface-water sources are maintained by discharge from the ground-water body. The records for selected wells are given in table 4; records for all other wells are on open file at the U.S. Geological Survey, 175 Science Hall, Madison, Wis. The location of wells for which records are available is shown in figure 6.

RECHARGE

Ground-water recharge in Rock County is derived directly from precipitation that percolates downward to become a part of the ground-water body and from ground water that moves into the area in the buried bedrock valleys. Between Shopiere and Beloit, some recharge may be also by infiltration from Turtle Creek. In this area Turtle Creek flows across the buried Rock River valley at an altitude about 20 feet above the general surface of the ground-water body. This area of recharge is indicated (pl. 5) by the mound described by the 760- and 780-foot contours.

The bedrock is recharged most easily in areas where there is little or no overlying material. The piezometric map (pl. 5) shows three ground-water mounds in the eastern part of the county and ground-water ridges along State Highways 13 and 81 in the southwestern and western parts of the county. In these areas the Platteville-Galena unit is generally near the surface, and precipitation percolates downward into this rock unit and is transmitted to the underlying St. Peter sandstone. West of Rock River the St. Peter sandstone is at or near the surface in many places and is recharged directly by precipitation.

Recharge to the unconsolidated Pleistocene glacial material occurs most readily in areas of outwash deposits (fig. 3). A natural drainage system has not developed on the outwash deposits east of the

Rock River, which indicates that most of the precipitation infiltrates the soil and rocks. The Waukesha gravelly, sandy, and silty loams (Whitson and others, 1922, p. 22, 49, 51), which have formed on the outwash deposits, readily transmit water to the underlying stratified sand and gravel. The most rapid recharge to the unconsolidated deposits in the Sugar River valley is in areas where the stratified sand of the valley fill is overlain by very premeable soil (Waukesha sand).

The average annual precipitation in Rock County is about 32 inches, or about 1,100 mgd. In the Rock River basin about 22 percent of this precipitation reaches the Rock River, either as surface runoff or, for the most part, as ground-water discharge into the river. Except for industrial and domestic consumptive use (the percentage of ground water that is used and not returned) and temporary increases in ground-water storage, the remaining precipitation is returned to the atmosphere through evaporation or by transpiration by natural vegetation. Most of the recharge occurs in the early spring, when the soil-moisture content is high and evapotranspiration is low. During late spring, summer, and early fall, precipitation is generally returned to the atmosphere by evapotranspiration or is used to restore depleted soil moisture. Some recharge may occur in the late fall after the end of the growing season and before the ground freezes, but during the winter months, when the ground is frozen and the precipitation is in the form of snow, there is practically no recharge.

MOVEMENT

The piezometric map (pl. 5) indicates the direction of ground-water movement. Ground water moves down the hydraulic gradient normal to the contours, from areas of recharge to areas of discharge. In eastern Rock County the ground water moves generally westward toward the Rock River from three ground-water highs in R. 14 E., except near Turtle Creek, where the water moves toward the creek. Between State Highway 13 and the Rock River the water moves generally toward the Rock and Yahara Rivers and Bass Creek. West of State Highway 13 the ground water moves toward the many small streams and westward toward the Sugar River. Closely spaced contours indicate a steep gradient, which is generally the result of water moving through material of low permeability. Widely spaced contours, as in the buried Rock River valley between Janesville, Milton, and Edgerton, indicates that water is moving through more permeable material.

TABLE 4.—*Records of selected wells in Rock County, Wis.*

Geologic unit: Q, Pleistocene deposits; Ogp, Platteville, Decorah, and Galena formation, undifferentiated; Osp, St. Peter sandstone; Ꞓu, sandstone of Cambrian age.

Well number: Ro, in Rock County, Wis.; Gn, in Green County, Wis.; Wg., in Winnebago County, Ill.

Use: Ac, air conditioning; D, domestic; Ind, industrial· PS, public supply; S, stock; Un, unused; Sc, screened interval; C, chemical analyses in table 6. The use of geologic unit symbol in the remarks column indicates that the unit also yields water to the well.

Well Ro–	Location in section	Owner	Year drilled	Altitude of land surface (ft)	Depth of well (ft)	Depth of casing (ft)	Diameter of casing (in.)	Principal aquifer: Geologic unit	Principal aquifer: Depth to top (ft)	Principal aquifer: Thickness penetrated (ft)	Water level: Below land surface (ft)	Water level: Date of measurement	Use	Remarks
1/10/3-310	NE¼NE¼	Paul Foss	1949	861	72	26	6	Osp	10	62	42.52	6-27-56	D	
23-315	NE¼NW¼	Mrs. H. Timm	1946	812	75	45	6	Osp	45	29	19.10	7-24-56	S	
30-311	NE¼SE¼	Curtis Haroldson	1956	767	170	170	6	Q	162	8	11.52	7-24-56	D	
1/11/1-244	NW¼SW¼	Mrs. C. E. Smith	1947	930	204	40	6	Osp	100	104	125	3- -47	D	Ogp
18-320	SW¼SE¼	H. Halverson	1951	847	242	210	6	Osp	190	52	54.38	6-27-58	S	
25-199	NE¼NE¼	Richard Garland	1952	833	98	35	6	Osp	84	10	54.82	4-23-57	D	Ogp
1/12/1-23	NW¼NW¼	Wisconsin Power & Light Co	1955	756	100	80	10	Q	0	100	12	1955	Ind	Sc 80-100; C
-45	NW¼NW¼	do	1952	756	110	92	10	Q	0	110	15	1952	Ind	Sc 92-110; C
11-375	SE¼SW¼	City of Beloit	1955	897	270	180	6	Osp	160	110	150	6- -55	PS	
15-371	NW¼NE¼	Town of Beloit	1954	849	110	110	6	Osp	96	14	86.94	5-20-57	PS	
21-458	NE¼NE¼	Town View School Dist. #9	1957	889	290	154	8	Osp	136	154	100	6- -57	PS	
34-240	NE¼NW¼	Beloit Mattress Co		793			6				32.02	6-22-56	Un	
35-21	NE¼NE¼	Wisconsin Power & Light Co	1920	751	100	100	8	Q	0	100			PS	Group of wells; C.
-22	NE¼NE¼	do	1924	751	100	100	8	Q	0	100			PS	Group of wells; C.
-24	NE¼NE¼	do	1926	751	967	256	18	Ꞓu	248	719			PS	C
-25	NW¼NW¼	do	1927	782	1,225	170	18	Ꞓu	265	960			PS	C
-26	SE¼NE¼	do	1945	749	140	90	24	Q	7	133	20	8- -45	PS	Sc 90-140; C
1/12/35-343	SW¼SE¼	do	1956	743	113	53	26	Q	0	113	9.74	12- 8-56	PS	Sc 53-113; C
1/13/2-215	NW¼NW¼	Edmund W. Howard	1955	843	160	75	6	Osp	142	18	40	8- -55	D	Ogp
9-238	NE¼NE¼	E. L. Betker	1956	829	90	42	6	Ogp	4	86	33.67	6-22-56	D	
19-27	SW¼SW¼	Wisconsin Power & Light Co	1951	801	1,130	282	20	Ꞓu	282	848	50	1951	PS	C
28-232	NW¼NW¼	H. F. Halverson	1955	816	155	66	6	Osp	135	20	34.39	6-22-56	D, S	Ogp
30-231	SW¼SE¼	East Lawn Cemetery	1939	786	900	278	10	Ꞓu	409	491	30.02	6-22-56	D	
32-202	SE¼NW¼	L. Dalvit	1950	834	195	168	6	Osp	160	35	71.61	9-26-58	D	
1/14/8-20	SW¼NE¼	Village of Clinton	1941	1,006	880	370	16	Ꞓu	490	390	105.32	4-30-52	PS	Osp; C
											113.01	9- 8-55		
24-80	NW¼NE¼	Theodore McGovern	1949	954	220	85	6	Ogp	85	135	45	6- -49	D, S	
2/10/3-209	SW¼SW¼	R. L. Staffeld	1950	908	105	32	6	Osp	10	95	50	12- -50	D, S	
14-280	SE¼SW¼	Hans Heyerdahl	1946	868	151	116	5	Osp	116	9	29.66	9- 6-56	D, S	

24-44	NW¼NE¼	Village of Orfordville	1938	884	492	62	12	Ꞓu	190	302	27	4- -38	PS	Osp; C
-452	SE¼NE¼	do	1957	908	528	60	12	Ꞓu	250	278	66.16	12-12-57	PS	Osp; C
31-144	SW¼SE¼	Robert M. Lee	1947	896	118	36	6	Osp	55	63	66.82	5-31-56	D,S	Ogp
2/11/5-28	NE¼NE¼	Village of Footville	1932	817	251	91	10	Ꞓu	140	111	14	1932	PS	Osp; C
7-52	SE¼SE¼	Garden Club of Footville		807	11			Q			+6.8	9-19-55	PS	Flows
19-454	SW¼NW¼	D. H. Burtness	1954	920	122	77	6	Osp	55	67	71.67	11-14-57	D	
22-357	NE¼NW¼	Ehrlinger Bros	1948	839	178	154	6	Osp	140	38	48.06	9- 6-56	D	
35-379	NW¼SW¼	Nels Renly	1954	995	220	40	6	Osp	180	40	165.66	6- 6-57	D	Ogp
2/12/1-30	NE¼NE¼	City of Janesville	1937	767	1,125	342	16	Ꞓu	230	895	+8.66	7-25-52	PS	C; flows
2/12/2-3	SW¼NE¼	State of Wisconsin	1930	833	470	113	10	Ꞓu	260	210			PS	Osp
10-273	SW¼NE¼	G. A. Jakoubek	1947	819	235	200	6	Ꞓu	200	35	58.61	9-13-56	D	
19-345	NE¼NW¼	Nick Bucako	1946	783	211	197	5	Ꞓu	196	14	14.03	8-22-56	D, S	
28-338	SE¼NE¼	Afton School Dist. #4	1942	758	47	47	5	Q	0	47	8.18	7-26-56	PS	
36-418	SW¼SE¼	Mid-City Outdoor Theatre	1950	753	52	52	6	Q	4	48	9.30	7-17-57	PS	
2/13/3-64	SW¼NW¼	Lyle Schaffer	1950	869	62	62	6	Q	32	30	47.37	3-22-56	D	
6-46	NW¼NW¼	City of Janesville	1954	766	105	45	26	Q	0	105	4.5	1954	PS	Sc 45-105
21-60	SE¼NW¼	LaPrairie-Rock School Dist. #1.	1955	844	775	62	6	Ogp	62	13	42.02	12-28-55	PS	
2/14/3-91	SE¼SE¼	W. J. Florin & Son	1954	965	135	37	6	Ogp	36	99	39.83	5- 1-56	D, S	
8-97	SW¼NE¼	Tracy & Son Farms	1954	976	100	45	6	Ogp	8	92	17.93	5- 7-56	Un	
17-94	NE¼SE¼	Bradford - LaPrairie School Dist. #2.	1955	960	159	70	6	Ogp	8	151	42.12	7- 7-58	PS	
22-123	NE¼NE¼	Bradford School Dist. #5	1946	917	135	41	5	Ogp	30	105	21.20	5-22-56	Un	
27-87	NW¼NW¼	Anna & Thora Thompson	1947	917	169	45	6	Ogp	2	167	16.94	5- 1-56	D, S	
3/10/3-158	SW¼NW¼	Walter Wilcox	1949	923	118	85	5	Osp	70	38	57.73	6- -56	D, S	Ogp
15-157	SW¼SE¼	Clarence Hoesly	1945	948	76	55	6	Osp	30	46	29.29	6-15-56	D, S	
27-166	SW¼SE¼	Drew School Dist. #6	1951	1,035	156	40	6	Osp	120	36	133	8- -51	PS	Ogp
36-168	NE¼NW¼	Thomas Drew	1954	914	156	120	6	Osp	120	36	45.04	6-19-56	D, S	
3/11/16-183	SW¼NE¼	Charles Sarow	1952	978	139	30	6	Osp	100	39	87.05	8-24-54	D, S	Ogp
21-296	SW¼SW¼	Elmer Keehan	1947	915	150	108	6	Osp	140	10	43.82	3- 1-57	D, S	Ogp
22-298	NE¼SE¼	Arthur Bladorn	1949	946	122	35	6	Osp	95	27	80.94	5- 1-57	D, S	Ogp
35-172	SW¼SW¼	Glen Berger	1954	829	207	182	6	Osp	182	25	15.55	6-19-56	D, S	
3/12/1-445	NW¼SW¼	Kenneth Demrow	1955	953	197	195	6	Q	120	77	166.54	7-23-57	D	Sc 195-197
13-4	NW¼NW¼	Rock County Hospital	1927	893	772	258	10	Ꞓu			161	1927	PS	C
-5	NW¼NW¼	do		893	430		0						PS	C
14-32	SW¼SE¼	City of Janesville	1937	771	925	200	8	Ꞓu	120	925	+4.88	4- 2-57	PS	Flows
20-434	SW¼SW¼	West Janesville Consolidated School Dist. #4.	1956	1,007	295	63	6	Osp	175	120	167.68	7- -58	PS	Ogp
23-33	NE¼SE¼	City of Janesville	1937	773	958	147	8	Ꞓu	150	808	7.94	4- 2-57	PS	
24-43	SW¼SW¼	Parker Pen Co.	1952	815	94	94	24	Q	0	94	41.65	1-12-56	Ac	Sc 70-93
											41.65	3- 6-56		
25-66	SW¼SW¼	Lichtfus Coal Co	1900	804	650			Ꞓu					Un	C
36-29	SW¼SE¼	City of Janesville	1890	774	1,087	254	8	Ꞓu			+	9-13-55	PS	C; flows
-31	NW¼SE¼	do	1945	763	98	60	26	Q	0	98	3	7- -52	PS	Sc 37-98; C
-54	SW¼SE¼	do	1898	766	1,031		8	Ꞓu			+	9-13-55	PS	C; flows
-55	SW¼SE¼	do		766	25		30	Q	0	25			PS	C

TABLE 4.—*Record of selected wells in Rock County, Wis.*—Continued

Well Ro–	Location in section	Owner	Year drilled	Altitude of land surface (ft)	Depth of well (ft)	Depth of casing (ft)	Diameter of casing (in.)	Principal aquifer: Geologic unit	Principal aquifer: Depth to top (ft)	Principal aquifer: Thickness penetrated (ft)	Water level: Below land surface (ft)	Water level: Date of measurement	Use	Remarks
3/13/6-395	NW¼SW¼	Robert Redenius	1955	992	274	271	6	Q	190	84	204.92	6-12-57	D	Sc 271-274
10-134	SE¼SE¼	B. P. Koch	1946	925	159	159	6	Q	150	9	111.25	5-24-56	D, S	
19-201	SW¼SE¼	C. A. Berg	1945	881	341	341	5	Q	0	341	97.14	6-12-56	D	
											96.30	9-12-56		
											97.74	7- 8-58		
21-147	SE¼SE¼	Howarth School Dist. #3	1951	879	103	57	6	Ogp	49	54	73.12	6-12-56	PS	
29-149	SW¼NW¼	C. S. Jackman	1946	864	393	344	6	Cn	343	49	91.72	6-12-56	D, S	
30-200	SW¼SE¼	D. G. Frazer	1952	855	144	144	5	Q	0	144	76.12	6-12-56	D	
3/14/2-100	SE¼SE¼	Ben Hake	1953	983	165	84	6	Ogp	84	81	70.39	5- 8-56	D, S	
											75.12	6-28-56		
											76.01	9-11-56		
15-105	SE¼NW¼	Wm. R Merrian	1955	977	160	75	6	Ogp	75	85	57.09	5- 8-56	S	
											56.44	6-28-56		
											56.83	9-11-56		
3/14/23-119	SE¼SW¼	Virgil Schoonover	1953	952	110	54	6	Ogp	54	56	48.05	5-22-56	D	
29-107	SW¼SW¼	Frank Wellnitz	1937	903	236	185	6	Osp	200	36	28.95	5- 8-56	D, S	Ogp
4/10/5-111	SE¼NW¼	Richards Bros.	1954	954	219	198	6	Osp	198	21	22.11	5-16-56	S	
20-114	SW¼SW¼	Pleasant Prairie School Dist. #7	1951	1,009	121	115	6	Ogp	115	6	53.94	5-16-56	PS	
25-282	NW¼SW¼	Frank Croak	1944	921	262	262	6	Q	257	5	36.66	4-30-57	D, S	
27-37	NE¼SE¼	City of Evansville	1929	897	1,014	347	12	Ꞓu	215	799	11.42	9- 8-55	PS	Osp, perforated 160-178; C.
-53	NE¼SE¼	do		896	27	27	96	Q	0	27	8.93	9- 8-55	PS	C
-150	SW¼NE¼	Waeffler Frozen Foods Co.	1953	901	56	30	6	Ogp	9	47	5.95	5-25-56	PS	
-467	SE¼SE¼	Village of Evansville	1958	894	997	115	16	Ꞓu	235	762	38.08	12- 5-58	PS	Osp
4/11/4-291	NW¼SE¼	Lyle Viney	1945	852	296	240	6	Ꞓu	240	56	24.52	4-30-57	D, S	
14-289	SE¼NE¼	Louis A. Falligant	1954	837	118	114	6		114	4	36.56	4-30-57	D, S	
32-284	SE¼NW¼	Oscar E. Martin	1956	922	63	63	6	Q			31.40	4-30-57	D	
4/12/3-34	NE¼SW¼	Edgerton Shoe Co.	1935	817	500	174	10	Ꞓu	85	415	19.36	9- 9-55	Ind	
10-1	NE¼NW¼	City of Edgerton	1892	816	949		6	Ꞓu			6.57	8-23-46	PS	C
-2	NE¼NW¼	do	1926	813	880	277	12	Ꞓu	160	720	12.99	8-23-46	PS	C
14-410	NW¼NE¼	Wisconsin State Conservation Commission.	1952	781	167	167	7	Q	156	10	4.75	7- 9-57	D	
24-397	NW¼NW¼	Earl A. Kidder	1949	865	286	240	6	Ꞓu	240	46	85.13	6-12-57	D, S	
34-393	SE¼SE¼	Wm. F. Olin	1953	896	170	116	6	Osp	136	34	112.04	6-12-57	D, S	Ogp
4/13/23-403	NW¼SW¼	Jerry Van Falkenstein	1953	901	130	51	6	Ogp	48	82	92.43	7- 9-57	D, S	
27-7	SE¼SE¼	Village of Milton	1923	876	703	268	12	Ꞓu	283	417	58	4-21-50	PS	C

-8	SE¼SE¼	do	1948	877	722	276	12	Ꞓu	275	447	60.15	4-30-52	PS	
4/13/29-364	NW¼NE¼	Ralph Arnold		877	417	400	6	Ꞓu	382	34	84.58	9-14-56	D, S	
30-279	SW¼SW¼	Paul Collins	1953	930	411	396	6	Ꞓu	396	15	137.32	9-14-56	D, S	
31-13	SW¼SW¼	M. Bingham		931	163		5	Q			133.79	4-28-50	Un	
4/14/11-253	NW¼NE¼	Wm. Kyle	1954	904	168	38	6	Ogp	2	166	43.03	8-23-56	D	
12-252	SE¼SE¼	Evan Diehls	1952	898	350	40	6	Osp	285	65	48.20	8-23-56	D, S	Ogp
22-260	SW¼SE¼	Lima State Graded School Joint Dist. #9.	1948	896	125	80	6	Ogp	80	45	12	9- -48	PS	
28-256	SE¼SE¼	Arnie Agnew	1954	926	184	60	6	Ogp	178	167	32.81	8-23-56	D	
Gn-														
2/9/25-12	SE¼NW¼	Brodhead Power & Light Co.	1935	780	995	301	20	Ꞓu	155	840	18.00	3-21-57	PS	C
-21	SE¼NW¼	do		780	147	147	6	Q	0	147			PS	C
4/9/1-22	SE¼NE¼	Village of Brooklyn	1957	965	615	300	10	Ꞓu	240	375	65.88	4-10-57	PS	
Wg-														
46/2/5-1	SW¼NW¼	Wisconsin Power & Light Co.	1938	743	1,190	230	18	Ꞓu	235	955			PS	Osp; C

The quantity of water moving in the sandstones of Cambrian age toward the buried Rock River was computed by applying Darcy's law to the area on both sides of the river between the 800- and 820-foot contours (pl. 5). From Darcy's law it follows that the quantity of water discharged in a unit of time (Q) is equal to the product of the average permeability of the material (P), the hydraulic gradient (I), and the cross-sectional area through which the water moves (A). It may be written in the form $Q=TIL$, where T is the coefficient of transmissibility (permeability $\times$ thickness of the aquifer) and L is the length of the section perpendicular to the direction of flow. An approximate T of 30,000 gpd per ft (gallons per day per foot) was computed from pumping tests at Orfordville, Janesville, and Evansville. The average gradient, I, is determined by dividing the area between the contours by L, the average length of the contours. The amount of water moving between the 800- and 820-foot contours was calculated to be about 44 mgd. This is equivalent to about 0.6 mgd per mile of contour length. Smith and Larson (1948) report that in the Rockford, Ill., area, movement of water in the sandstone also is at the rate of 0.6 mgd per mile of contour. By using a coefficient of transmissibility of 1,000,000 gpd per computed ft for the unconsolidated valley fill at Beloit, the amount of water moving out of the county as underflow in the buried Rock River valley was calculated to be about 40 mgd.

DISCHARGE

Natural discharge of ground water in Rock County occurs by springflow and seepage and by evapotranspiration. Water also moves out of Rock County as underflow beneath the Rock River valley. Artificial discharge is through wells and drainage ditches.

It is estimated that about 800 to 900 mgd (about 70 to 80 percent of the precipitation) is returned to the atmosphere by evapotranspiration, that about 123 mgd is discharged by springflow or seepage into the Rock River, and that about 40 mgd moves out of the area as underflow beneath the Rock River valley. In addition, many springs and seeps discharge an underetermined amount of ground water into stream valleys and low areas. No estimate was made of the amount of ground water discharged by drainage ditches; however, Whitson and others (1922) reported that 16 percent of the county was poorly drained in 1921, and the Wisconsin State Department of Agriculture (1953) reported that less than 8 percent was poorly drained in 1952.

About 23 mgd was pumped from wells in 1957. Nearly 90 percent of the pumpage, or approximately 20 mgd, was withdrawn in the heavily populated and industrialized area along the Rock River.

The pumpage from wells represents only about 12 percent of the water that could be withdrawn perennially from the ground-water reservoir. Municipal and industrial pumpage from the outwash in the Rock River valley is about 14 mgd.

WATER-LEVEL FLUCTUATIONS

Water-level fluctuations in wells indicate that the ground-water reservoir adjusts to changes in storage due to variations in recharge and discharge. According to whether recharge exceeds, equals, or is less than discharge, water levels in wells rise, remain static, or decline. A knowledge of these fluctuations is necessary to determine long-term water-level trends and changes in ground-water storage. Other factors that affect water levels, such as atmospheric pressure and changes in surface loading, generally have only a temporary effect and indicate only a slight change in the actual quantity of water stored in the aquifer.

A network of observation wells (pl. 1) was established in Rock County to determine the magnitude and general pattern of water-level fluctuations and to provide data for correlation of these fluctuations with seasonal variations in recharge and discharge. Water-level fluctuations were measured continuously by recording gages in wells Ro–1/12/34–240 and Ro–2/10/24–452. The fluctuations in water levels were caused by local pumping, natural recharge and discharge, and changes in atmospheric pressure. Hydrographs show long-term trends of water levels in wells Ro–2/12/2–3 and Ro–4/13/27–8 since 1947 and 1952, respectively (fig. 9).

The hydrographs for wells Ro–2/12/2–3 and Ro–4/13/27–8 and a curve of the cumulative departure from normal precipitation are shown in figure 9. On the cumulative-departure curve a rising line represents a wet year, a level line represents a normal year, and a falling line represents a dry year. Precipitation was about normal during 1947, below normal in 1948 and 1949, and above normal in 1950–52. The trend of the cumulative-departure curve correlates with the hydrograph of well Ro–2/12/2–3. From 1952 through 1958 the trend of precipitation and of the hydrographs is generally downward. The illustration (fig. 9) shows a definite relation between long-term precipitation patterns and long-term trends in water levels. Both water-level records illustrated on figure 9 show a long-term decline during the period of deficient precipitation from 1952 onward.

Water levels in well Ro–1/13/9–238 (fig. 10) are generally highest in the spring when recharge is greatest, lower through the summer, and lowest during the fall and winter. In the spring of 1957 the

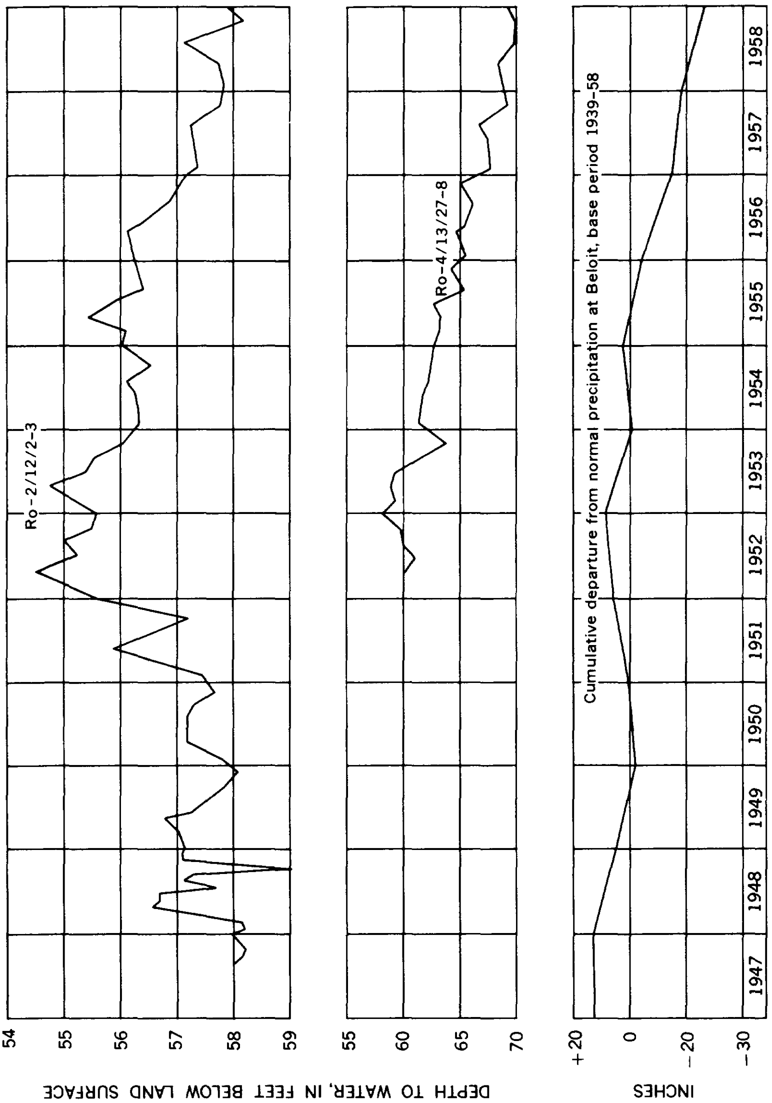


FIGURE 9.—Hydrographs of wells Ro-2/12/2-3 and Ro-4/13/27-8 and cumulative departure from normal precipitation.

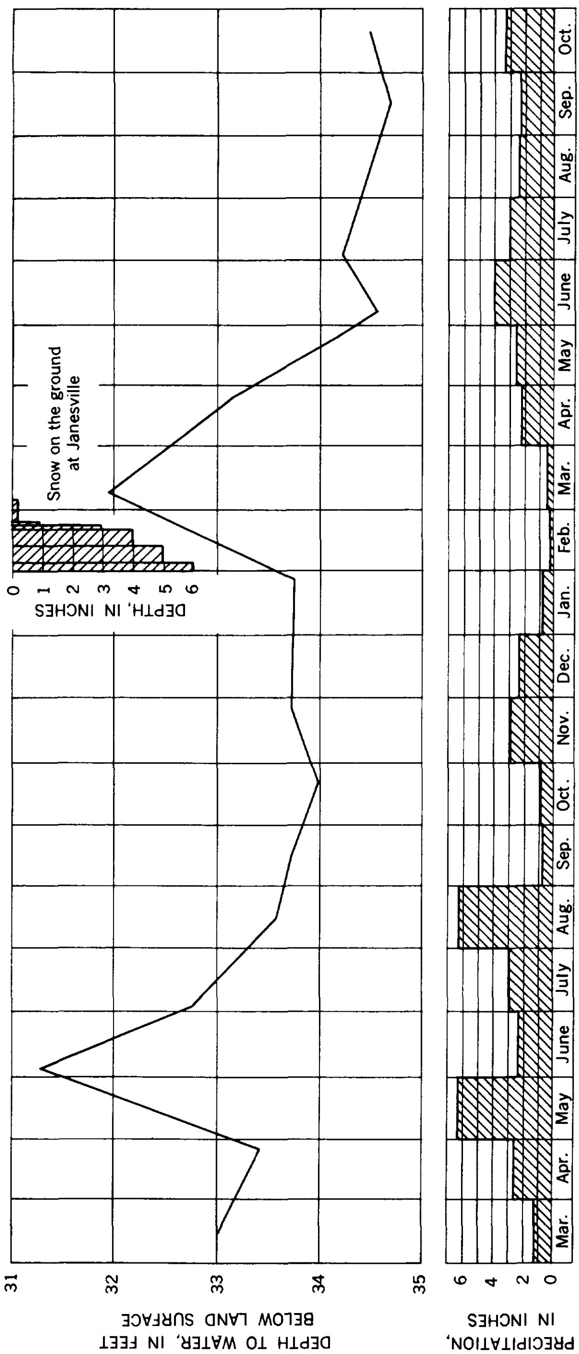


FIGURE 10.—Hydrograph of well Ro–1/13/9–238, monthly precipitation at Beloit, and snow on the ground at Janesville, Wis.

water level reached a low in April. It rose more than 2 feet during May as the result of 6.33 inches of precipitation. The normal decline, caused by increased evapotranspiration and spring discharge, began in May and continued into October. The decline was evident during August even though precipitation was considerably above normal during that month—about equal to that in May. Despite the greater precipitation, recharge to the ground-water body was considerably less in August because of the higher evapotranspiration. The water level rose slightly during November owing to above-normal precipitation. In 1958 the spring rise occurred earlier than in 1957 and was in response to recharge from snowmelt. Precipitation was negligible during February, but there was 6 inches of snow on the ground at Janesville at the beginning of the month. The snow cover thinned gradually until at the end of the month there was little more than a trace of snow on the ground. Most of the recharge from the melting snow occurred during the last week of February, when the temperature was above freezing. The water level declined again during the summer and fall.

The daily high and low water levels taken from automatic-recorder charts at well Ro–1/12/34–240 and daily precipitation at Beloit are shown in figure 11. The major water level fluctuations and the seasonal trends result from recharge and natural discharge; the minor daily fluctuations are caused by the pumping of several small wells in the vicinity. Precipitation during the first 6 months of 1956 was 5.2 inches below normal. Only 1.7 inches of rainfall (2.8 inches below normal) was recorded during June. The first large rainfall in July 1956 did not result in a significant rise of the water level because much of the potential recharge was required to replenish the depleted soil moisture. This rain, however, did replenish the soil moisture so that the following rainfall of nearly 2.5 inches resulted in a water-level rise in the well of about 2 feet. From this high water level, 30 feet below the land surface, the water level declined during the remainder of the summer and fall. A 1-inch rainfall on August 31 had little effect on the water level. The total rainfall during September and October was less than 0.7 inch and the soil-moisture content was so depleted that two heavy rains in November had almost no effect on the hydrograph of the well. The water level in the well continued to decline through December 1956, and through January and the first week of February 1957, a period when the ground was frozen and recharge was at a minimum. Snow 3 to 5 inches deep was on the ground on February 6. Most of the snow melted during February 7–14 and resulted in a water-level rise of more than 1 foot. Precipitation dur-

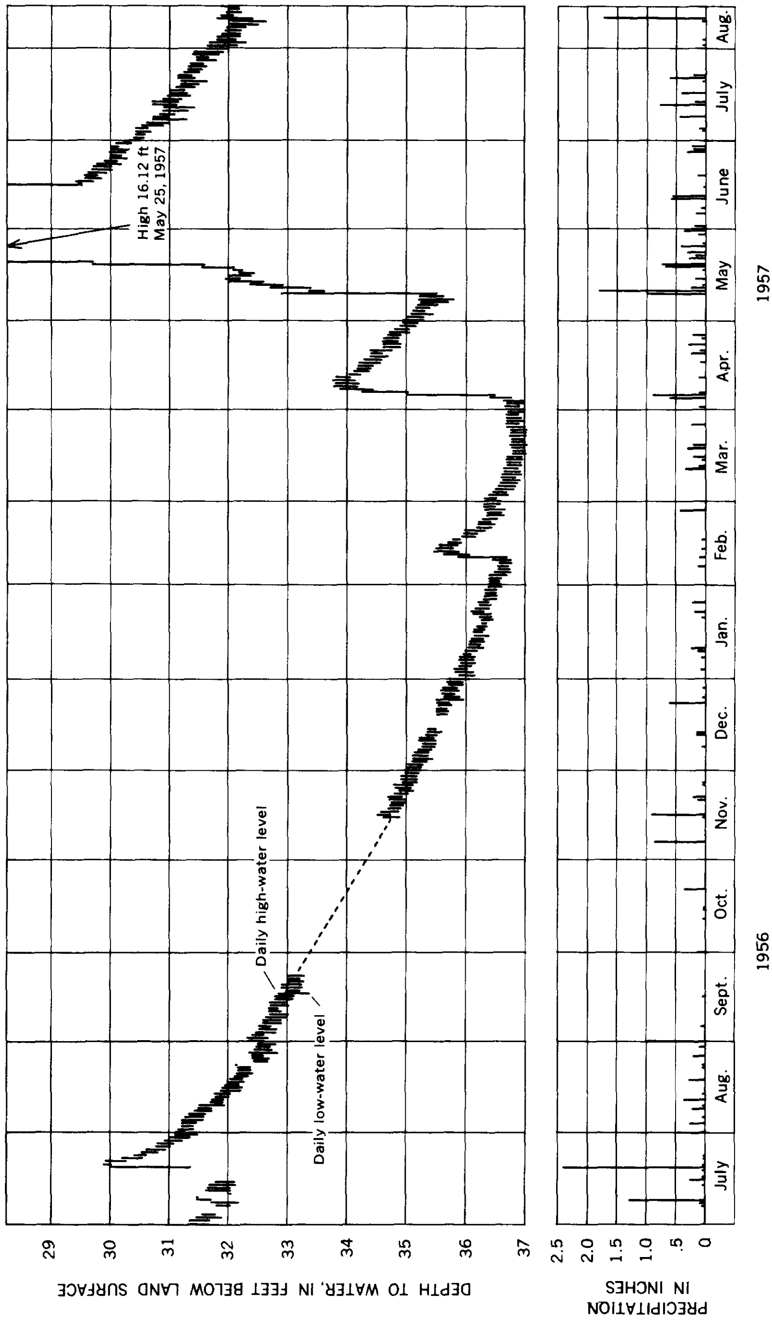


FIGURE 11.—Hydrograph of well Ro–1/12/34–240 and daily precipitation at Beloit, Wis., July 1956–August 1957.

ing March was sufficient to maintain the water level and the soil moisture, so that the precipitation in the first week of April resulted in a water-level rise of more than 3 feet. In May, as the result of an exceptional amount of rainfall (6.33 inches), the water level in the well rose nearly 20 feet to a high of 16.12 feet below the land surface. No interpretation of the sharp rise and the rapid decline about a month later could be made from the available data. From the middle of June through July and into August, the water level declined rapidly owing to natural discharge and evapotranspiration. The precipitation during this period had little immediate effect on the water level in the well.

The hydrograph of well Ro–1/12/34–240 for March–June 1958 is shown in figure 12. The water level declined in March because precipitation was deficient, totaling only 0.33 inch. A rainfall of about 1 inch in early April resulted in a rise of nearly 1 foot in the water level, because evapotranspiration was low and the moisture content of the soil was high. The total precipitation for the first 30 days of May 1958 was only 0.19 inch, but on May 31 and June 1, 2.8 inches of rain fell. This precipitation resulted in a water-level rise of about 1.5 feet in the well. The same amount of rain in May 1957 (fig. 11), after a normally wet spring, caused a water-level rise of more than 3 feet.

Short-term, nearly instantaneous responses of water levels to atmospheric-pressure changes have been recognized in some wells. These fluctuations generally are temporary and are small in comparison to fluctuations caused by changes in storage due to fluctuations of natural recharge and discharge and to pumping. Water-level fluctuations in well Ro–2/10/24–452, resulting from barometric changes on April 23–24, 1958, are shown in figure 13. The barometric pressure was recorded at Madison, about 32 miles north of the well. The time difference between the "highs" and "lows" may reflect the distance between the well and the barograph. As the barometric pressure decreased during the afternoon of April 23, the water level in the well rose 0.3 foot. On figure 13, note that the barogram has been inverted for comparison with the hydrograph. A small temporary pressure increase during the evening of April 23 was followed by a temporary decline in water level. During the morning of April 24, the barometric pressure rose and the water level in the well declined about 0.5 foot in 11 hours. The atmospheric-pressure change acts instantaneously upon the surface of the water in an open well, and creates a pressure differential between the water in the well and water in the aquifer immediately outside the well.

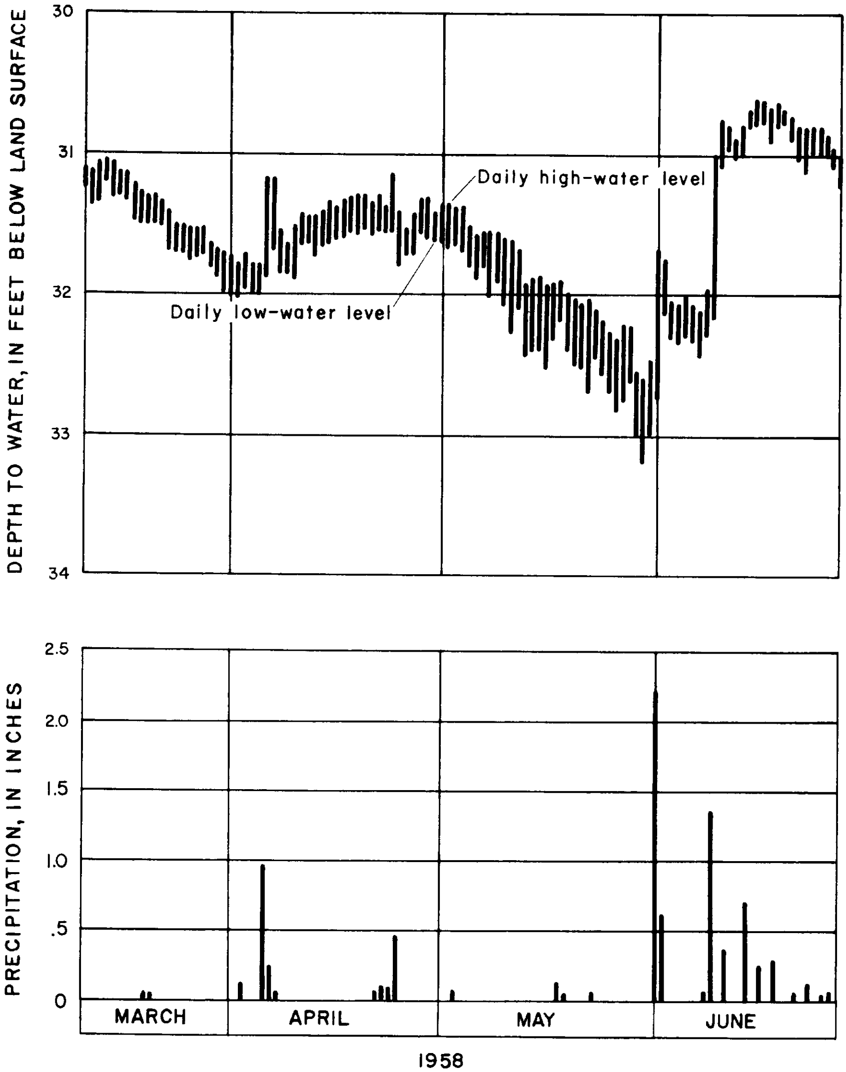


FIGURE 12.—Hydrograph of well Ro–1/12/34–240 and daily precipitation at Beloit, Wis., March–June 1958.

AQUIFER TESTS

Aquifer tests were made on the sandstones of Late Cambrian age at Orfordville, Janesville, and Evansville, and on the outwash deposits of Pleistocene age at Beloit. The purpose of the tests was to determine the hydraulic characteristics—the coefficients of transmissibility and storage—of the aquifers. These coefficients in turn can be used to predict the expected amount and rate at which water levels would decline at various rates of pumping.

The coefficient of transmissibility is expressed as the rate of flow of water at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated height of the aquifer, under a hydraulic gradient of 100 percent (1 ft per ft). The coefficient of storage of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Each aquifer test consisted of pumping a well at a uniform rate of discharge and observing the rate of drawdown, and of stopping the pump and observing the rate of recovery. The results of the tests were analyzed by the nonequilibrium formula (Theis, 1935), or by

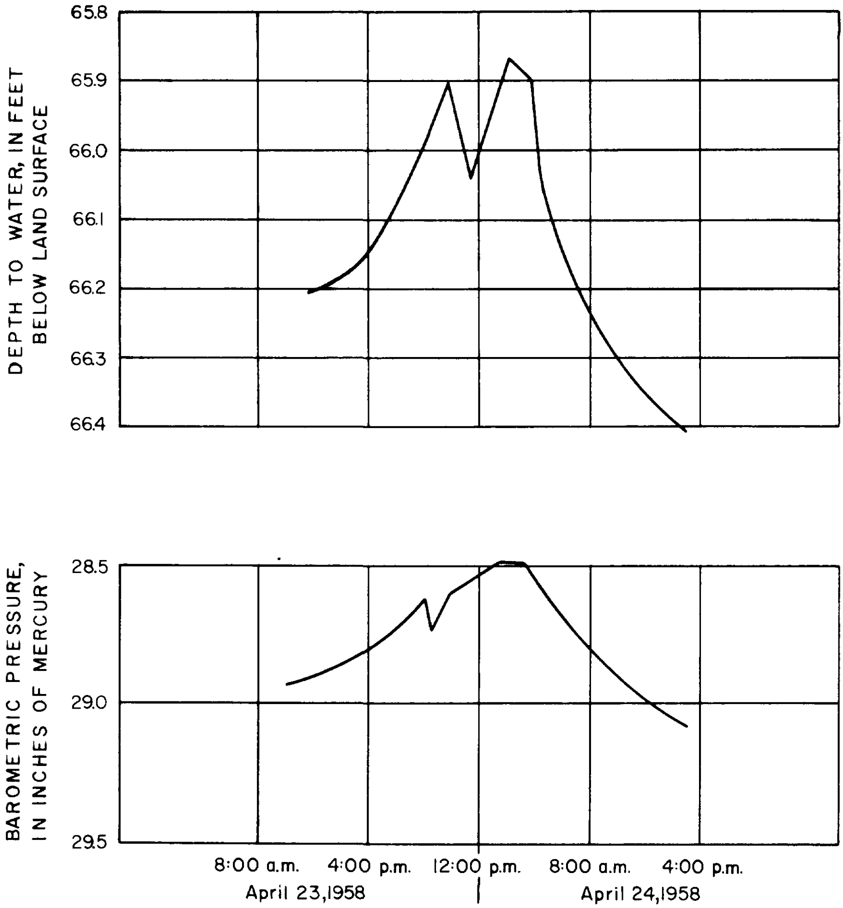


FIGURE 13.—Hydrograph of well Ro–2/10/24–452 and changes in barometric pressure at Madison, Wis.

the modified nonequilibrium formula (Jacob, 1950) or the recovery formula (Theis, 1935), which are adaptations of the nonequilibrium formula.

The nonequilibrium formula assumes that the aquifer is infinite in areal extent, that it is homogeneous and isotropic (transmits water in all directions with equal facility), that its coefficients of transmissibility and storage are constant, that it is confined between impermeable beds, that the discharging well penetrates the entire thickness of the aquifer, and that the discharged water is released from storage instantaneously with decline in head. These conditions are not fully met in nature, and considerable judgment is necessary to decide the extent to which they can be assumed to apply in any particular area.

A summary of the coefficient of transmissibility values determined from the aquifer tests in Rock County follows.

Well	Location	Length of aquifer test (hrs)	Discharge of well being pumped (gpm)	Coefficient of transmissibility (gpd/ft)
Sandstone of Late Cambrian age				
Ro-3/12/14-32	Janesville	24	25	32,000
Ro-3/12/23-33	do	20	50	37,000
Ro-2/10/24-452	Orfordville	17	530	32,000
Ro-4/10/27-467	Evansville	22	1,270	33,000
Average				34,000
Outwash deposits of Pleistocene age				
Ro-1/12/35-343	Beloit	10	4,500	1,200,000

The coefficient of storage could not be computed, as nearby observation wells were not available at any of the test sites. The results of 15 aquifer tests made on the sandstones of Late Cambrian age in nearby Dane, Green, Jefferson, and Walworth Counties indicate that the coefficient of storage in those areas averages about 0.00035.

USE

Withdrawal of ground water in Rock County for all purposes averaged about 23 mgd in 1957. One-half of this was pumped from municipal supply wells (table 5), one-third from privately owned industrial wells, and one-sixth from domestic and stock wells. About nine-tenths of the ground water was pumped in the heavily populated and industrialized area along the Rock River.

In Beloit most industries have their own water supply. Industrial pumpage from privately owned wells was about 6 mgd in 1957. Most of this pumpage (5.2 mgd in 1956) was from three wells tapping the valley fill. In Janesville most of the water for industrial purposes is supplied by the city.

TABLE 5.—*Municipal pumpage of ground water in 1957 in Rock County, Wis.*

[Data compiled by Wisconsin Public Service Commission. Maximum and minimum daily pumpage at Beloit approximate]

Location	Daily pumpage (mgd)		
	Max.	Min.	Avg.
Janesville	10.49	3.91	6.3
Beloit (including South Beloit, Ill.)	8	3.5	4.4
Edgerton	.65	.21	.33
Evansville	.54	.07	.29
Brodhead (Green County)	.27	.14	.18
Milton	.28	.16	.15
Clinton	.20	.07	.11
Footville	------	------	.05
Orfordville	.09	.03	.04
Brooklyn (pumpage for 1958)	.12	.01	.02

QUALITY

Ground water contains mineral matter that has been dissolved from the atmosphere and the earth, or that has resulted from chemical reactions in the zone of saturation. A knowledge of the concentrations of various mineral constituents in ground water is useful in determining the source and movement of the water, and its suitability for industrial and domestic use.

Table 6 gives selected chemical analyses of water in Rock County. Table 7 summarizes the chemical quality of the water. The latter table shows that the water is generally a hard calcium magnesium bicarbonate type which is slightly alkaline. The hydrogen-ion concentration, expressed in terms of pH units, indicates the degree of acidity or alkalinity of water. Water having a pH value below 7.0 is acid; water having a pH value above 7.0 is alkaline. Iron is not a serious problem, although concentrations as high as 5.4 ppm (parts per million) have been reported.

Ground water from the several water-bearing units in Rock County is similar in chemical quality. To illustrate this fact, the values for the principal anions and cations from 26 water samples have been plotted on hexagonal diagrams in figures 14 and 15. The patterns have been grouped according to the source of the water—"A," sandstone of Cambrian age; "B," St. Peter sandstone and sandstone of Cambrian age; "C," Pleistocene deposits; and "D," surface water.

TABLE 6.—*Chemical analyses of water in Rock County, Wis.*

[Results in parts per million except pH; analyses by Wisconsin State Board of Health]

Well Ro–	Owner	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Total hardness as $CaCO_3$	pH
1/12/1-23	Wisconsin Power and Light Co.	[1] 9- -56	17	0.4				329	29	8				7.8
-45	do	[1] 12-27-56	17	.1				332	33	2				7.8
35-21	do	6-15-45		.2	65	32	7.4	306	42	8.5	0.1	230	355	7.3
-22	do	1935						307	21	12		349	280	
-24	do	5-27-52	9.5	.0	59	37	2.6	354	10	2	.1	302	295	7.4
-25	do	5-27-52	9.3	.0	51	35	3.5	317	10	2.5	.1	262	268	7.6
-26	do	5-27-52	18	.0	71	31	2.2	325	30	5.5	.9	320	304	7.7
-343	do	12- 8-56		.0	62	32	1.0	300	32	10		306	290	7.6
1/13/19-27	do	[2] 10-20-55	10	.1	57	34	3.8	348	7	1.2	.1	280	282	7.5
1/14/8-20	Village of Clinton	3-28-46		.8	73	34	.9	364	10	12	.1	370	335	7.4
2/10/24-44	Village of Orfordville	3-19-46		.0	66	36	.0	277	52	17	.1	360	295	7.4
-452	do	11-20-57		.0	61	30	4.4	288	9.3	6.0	.1	334	288	7.5
2/11/5-28	Village of Footville	12-20-45		.0	58	26	6.2	288	18	6.5	.1	282	275	7.2
2/12/1-30	City of Janesville	3- 6-46		.0	68	50	6.4	460	6.0	4.5	.1	372	386	7.2
3/12/13-4	Rock County Hospital	4-30-46		.2	63	36	7.6	381	5.5	3.0	.1	302	295	7.3
-5	do	4-30-46		.2	56	36	8.5	366	3.0	3.0	.1	288	310	7.3
3/12/25-66	Lichtfus Coal Co.	[3] 1906			49	32	10	311	11	7.0		262		
36-29	City of Janesville	(3)	9.1	.4	50	36	6.2	337	5.6	4.9		285		
-31	do	12- 4-47		.0	70	28	12	350	15	8.0	.1	342	310	7.8
-54	do	[3] 1900			64	38	5.3	380	14	1.4		310		
-55	do	3- 6-46		.0	69	31	5.5	351	15	6.5	.1	336	317	7.4
4/11/27-37	Village of Evansville	4-30-46		1.2	69	33	9.9	384	7.5	4.0	.1	316	345	7.3
-53	do	[3] 1902	17.9		68	36	2.1	351	30	7.6		345		
4/12/10-1	Village of Edgerton	6-17-45		.2	60	36	10	359	14	6	.1	300	375	7.6
-2	do	6-17-45		4.0	59	36	13	364	13	6	.2	320	355	7.3
4/13/27-7	Village of Milton	6- 5-47		.0	71	32	14	388	9.5	8.5	.1	324	325	7.4
Gn–														
2/9/25-12	Village of Brodhead	7-16-47		.2	51	32	9.0	312	10	6.0	.1	280	260	7.5
-21	do	1935		1.0				344	8	3		294	280	
Illinois Wg–														
46/2/5-1	Wisconsin Power and Light Co.	5-27-52	8.9	.1	56	36	3.8	344	8.5	3.0	.1	288	286	7.7
Turtle Creek at Beloit.		[3] 1912			52	33	13	329	15	7.3		283		
Rock River at Rockford.		[3] 1909	15	.4	45	25	10	252	22	4.6		250		

[1] National Aluminate Co., Chicago, Ill. [2] Analysis by U.S. Geological Survey. [3] Weidman, Samuel, and Schultz, A. R., 1915, p. 542-543.

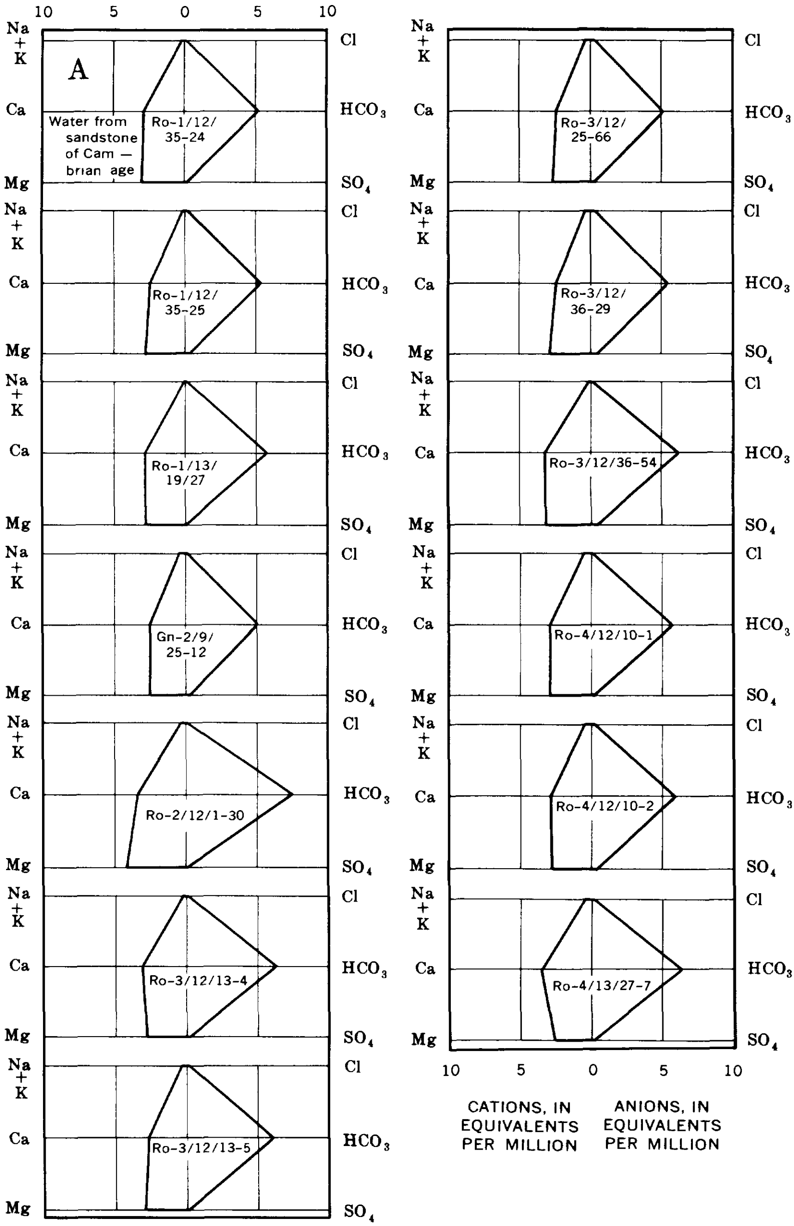


FIGURE 14.—Pattern diagrams—group A—for water-analysis data, Rock County, Wis.

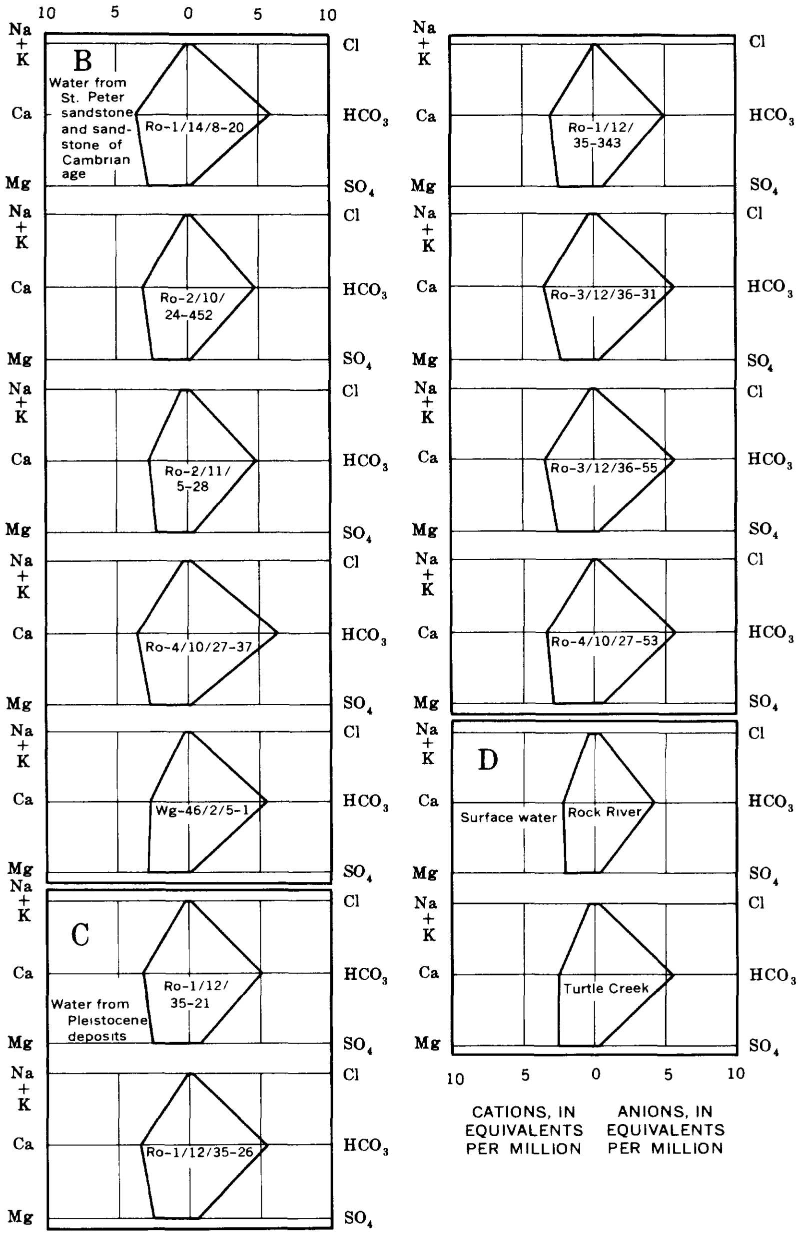


FIGURE 15.—Pattern diagrams—groups B, C, and D—for water-analysis data, Rock County, Wis.

TABLE 7.—*Summary of chemical constituents of ground water in Rock County, Wis.*

[In parts per million, except pH]

	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$	pH
Average	12	0.6	60	34	6.9	343	14	6.4	310	317	7.5
Maximum	18	5.4	73	50	15	460	52	17	422	386	7.8
Median	9.8	.2	60	34	6.3	345	9.4	6.0	304	310	7.4
Minimum	8.4	.0	49	26	.0	277	.0	1.2	230	260	7.2
Number of analyses	10	33	30	30	30	44	44	44	42	37	27

The similarity in shape of the patterns illustrates the similarity in chemical character of the water samples. Despite the overall similarity, there are differences that distinguish water of the deeper water-bearing units from that of the shallower units. For example, in group "C" patterns the magnesium calcium line slants upward to the left while the magnesium calcium line in group "A" patterns usually slants upward to the right or is vertical. The magnesium calcium line in group "B" is similar to that in group "C," indicating that wells open in both the St. Peter sandstone and the sandstone of Cambrian age may receive more water from the shallow St. Peter sandstone than from the deeper sandstone of Cambrian age.

The slope of the magnesium calcium line is indicative of the calcium magnesium ratio in the water. The ratio is 1:1 when the line is vertical. The ratio is greater than 1 when the line slopes upward to the left, and less than 1 when it slopes upward to the right. Hem (1959, p. 82) states that the ratio of calcium to magnesium in natural water, computed using equivalents per million, commonly ranges from 5:1 to about 1:1. High values of the ratio indicate that the water has been in contact with limestone. Low values suggest that the water has been in contact with dolomitic rocks. As computed from the results of 60 water analyses, the calcium: magnesium ratio of ground water in Rock County is 1.0:1.1. This reflects the dolomitic character of the rocks through which the water has passed.

The high bicarbonate (HCO_3) concentration in most of the ground water is another indication of the predominance of carbonate rocks (dolomite) in the area. The range of bicarbonate concentrations in natural water is from 0 to more than 1,000 ppm, but concentrations of more than 500 ppm are rare (Hem, 1959, p. 97). In Rock County (table 7) the range was from 277 to 460 ppm, and the average concentration, based on 44 analyses, was 343 ppm.

The variation in sulfate (SO_4) concentration among water samples from the several water-bearing units is not immediately evident from the pattern diagrams of figures 14 and 15. Table 8, which summarizes the sulfate content of ground water in Rock County, indicates that the sulfate content generally is higher in water from the Pleistocene deposits than in water from the St. Peter sandstone and sandstones of Cambrian age.

TABLE 8.—*Summary of sulfate concentration in ground water from three water-bearing units in Rock County, Wis.*

[In parts per million]

Degree of concentration	Pleistocene deposits	St. Peter sandstone and sandstones of Cambrian age	Sandstones of Cambrian age
Average	25	12	9
Maximum	44	19	14
Median	29	10	10
Minimum	6	8	0
Number of analyses	12	7	21

The two hexagon patterns in group "D" (figs. 14 and 15, representing analyses of surface water, are similar to those representing ground water. Most of the water in Turtle Creek has passed through or over carbonate rocks that crop out along its bank (pl. 1). This probably accounts for the relatively high concentration of bicarbonate in the water. Much of the water in the Rock River has fallen as rain and has passed through or over only the unconsolidated Pleistocene deposits on its way to the river, resulting in a relatively lower concentration of bicarbonate.

The principal advantage of using ground water for industrial purposes is its relatively constant temperature and quality. In Rock County, the difference between the highest and lowest measured well-water temperature was only about 5° F. In wells where the temperature was measured at intervals throughout the year, the temperature variation was 0.1° to 0.6° F. The temperature of water from deep wells in the Rock River valley averages 52.3° F, and that from shallow wells averages 51.6° F. Water temperature in shallow wells outside the Rock River valley averages 50° F.

Surface-water temperature fluctuates more rapidly and through a wider range than ground-water temperature. Although the Rock River is constantly receiving ground water, there is a close correlation between the temperatures of air and of river water (fig. 16). The average river temperature for the period September 1954–September 1955 was 54.5° F (Love, 1959, p. 64), which is about 3° F higher than the average well-water temperature. The annual range in river temperature was 57° F as compared to 0.6° F or less for water from wells. On a particular day, for example on July 17, 1955, there was a difference of 12° F between the maximum and minimum temperatures of the river.

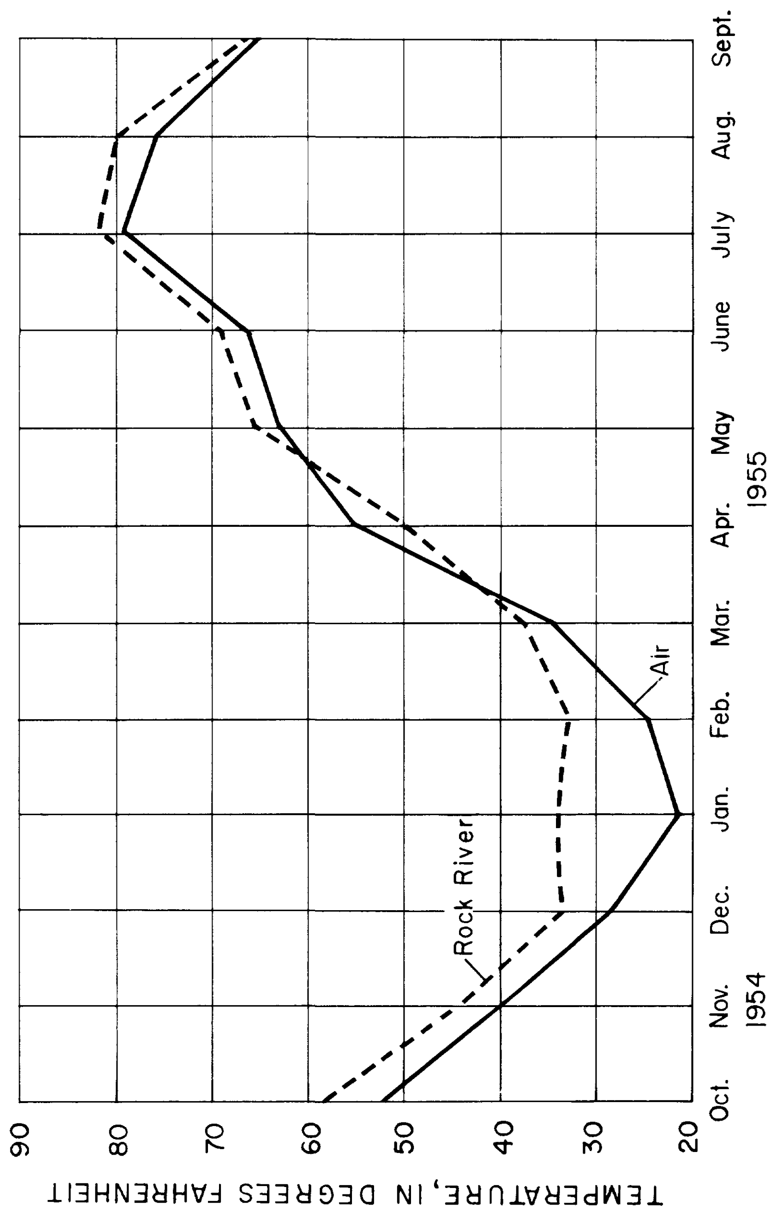


FIGURE 16.—Average monthly air temperature and water temperature of Rock River.

SUMMARY

Adequate supplies of ground water for domestic or stock use are available throughout Rock County. Most of the domestic and stock wells obtain water from the St. Peter sandstone, the Platteville-Galena unit, or the unconsolidated Pleistocene deposits.

The two principal aquifers tapped by high-capacity wells are the deeply buried consolidated rocks of the Upper Cambrian series, which underlie the entire county, and well-sorted unconsolidated glacial outwash in the buried Rock River valley. As of 1957, all the cities and villages in Rock County obtained at least part of their water from the rocks of the Upper Cambrian series, yet withdrawals from this source averaged only about 5 mgd. Total municipal pumpage in Rock County is about 12 mgd. Municipal and industrial pumpage from the outwash in the Rock River valley is about 14 mgd. Total pumpage from all sources in the Rock River valley is estimated to be 20 mgd. This is about 12 percent of the ground water that moves toward the Rock River and out of the county as underflow in the valley.

Ground water in Rock County is generally a hard calcium magnesium bicarbonate type which is slightly alkaline. The chief advantage of using ground water for industrial purposes is its relatively constant temperature and quality. The annual temperature range of water from wells is less than 1° F, as compared to 57° for the Rock River in 1954–55.

REFERENCES

Agnew, A. F., Heyl, A. V., Jr., Behre, C. H., Jr., and Lyons, E. J., 1956, Stratigraphy of Middle Ordovician rocks in the zinc-lead district of Wisconsin, Illinois, and Iowa: U.S. Geol. Survey Prof. Paper 274–K, p. 251–312.

Alden, W. C., 1918, The Quaternary geology of southeastern Wisconsin, with a chapter on the older rock formations: U.S. Geol. Survey Prof. Paper 106, 356 p.

Bean, E. F., 1949, Geologic map of Wisconsin: Wisconsin Geol. and Nat. History Survey.

Chamberlin, T. C., 1877, Geology of eastern Wisconsin, *in* Geology of Wisconsin: Wisconsin Geol. and Nat. History Survey, v. 2, pt. 2, p. 91–405.

——— 1883, General geology, *in* Geology of Wisconsin: Wisconsin Geol. and Nat. History Survey, v. 1, pt. 1, p. 3–300.

Hem, John D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Jacob, C. E., 1950, Flow of ground water, chap. 5 *in* Engineering hydraulics: New York, John Wiley & Sons, p. 321–386.

Love, S. K., and others, 1959, Quality of surface waters of the United States, 1955, Pts. 5 and 6. Hudson Bay and upper Mississippi River basin, and Missouri River basin: U.S. Geol. Survey Water-Supply Paper 1401, 305 p.

MacKichan, K. A., 1957, Estimated use of water in the United States, 1955: U.S. Geol. Survey Circ. 398, 18 p.

Martin, Lawrence, 1916, The physical geography of Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 36, 549 p.; repr. 1932, 609 p.

Shaffer, P. R., 1956, Farmdale drift in northwestern Illinois: Illinois Geol. Survey Rept. Inv. 198, 25 p.

Smith, H. F., and Larson, T. E., 1948, Ground-water resources in Winnebago County, with specific reference to conditions at Rockford: Illinois Water Survey Div., Rept. Inv. 2, 35 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, p. 519–524.

Thwaites, F. T., 1940, Buried Precambrian of Wisconsin: Wisconsin Acad. Sci., Arts, and Letters Trans., v. 32, p. 233–242.

U.S. Department of Commerce, 1958, County business patterns, first quarter, 1956: pt. 4, p. 425–427.

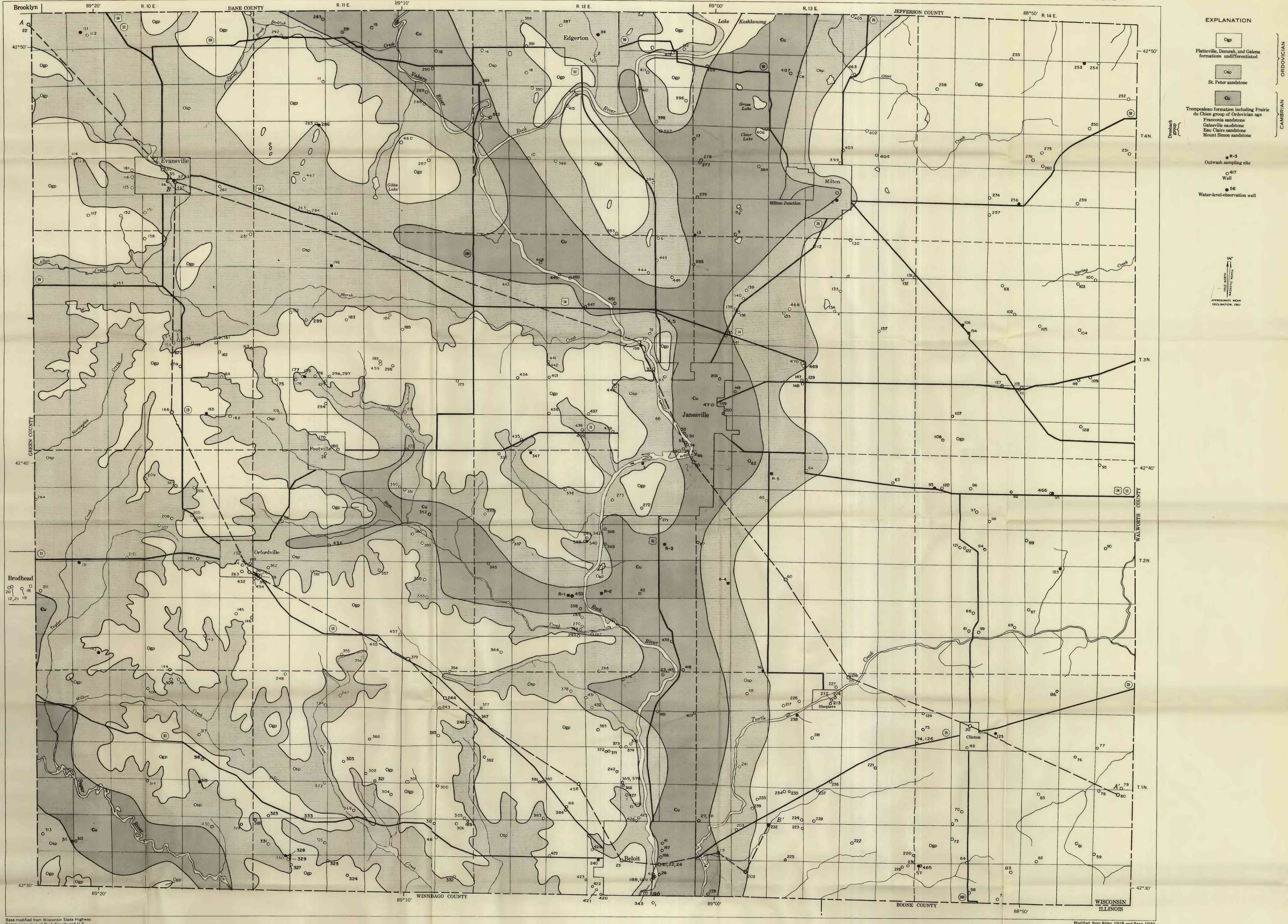
Weidman, Samuel, and Schultz, A. R., 1915, The underground and surface water supplies of Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 35, 664 p.

Wells, J. V. B., and others, 1958, Surface water supply of the United States, 1956, Pt. 5, Hudson Bay and upper Mississippi River basins: U.S. Geol. Survey Water-Supply Paper 1438, 575 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

Whitson, A. R., and others, 1922, Soil survey of Rock County, Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 53–B, Soil serv. 21, 80 p.

Wisconsin Department of Agriculture, 1953, Rock County agriculture: County Agr. Statistics ser., 56 p.



Base modified from Wisconsin State Highway Commission map of Rock County and U.S. Geological Survey topographic maps

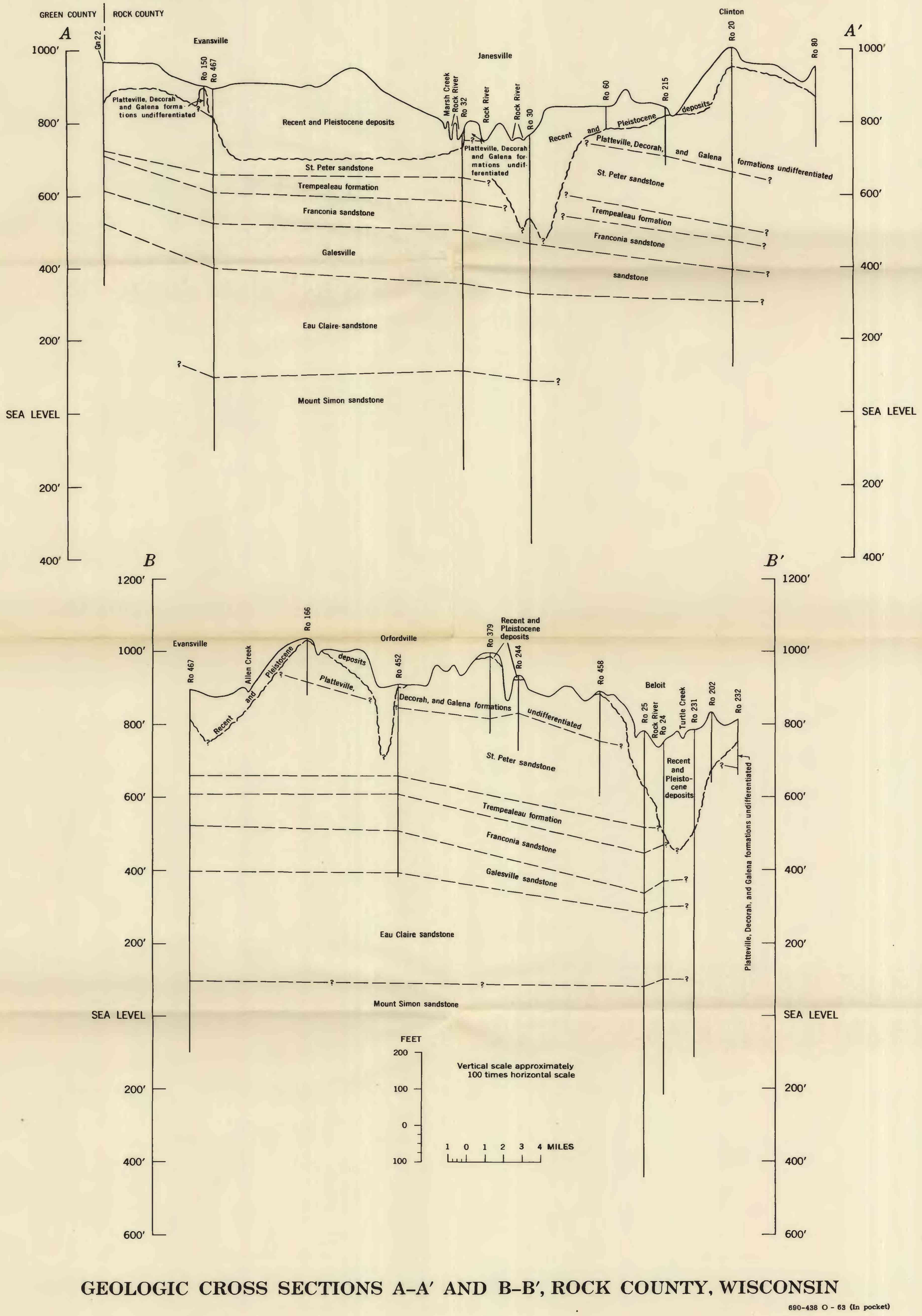
Modified from Alden 1918, and Bean 1949, by E. F. LeRoux, 1959

MAP OF BEDROCK GEOLOGY SHOWING LOCATION OF WELLS, ROCK COUNTY, WISCONSIN

SCALE 1:63360

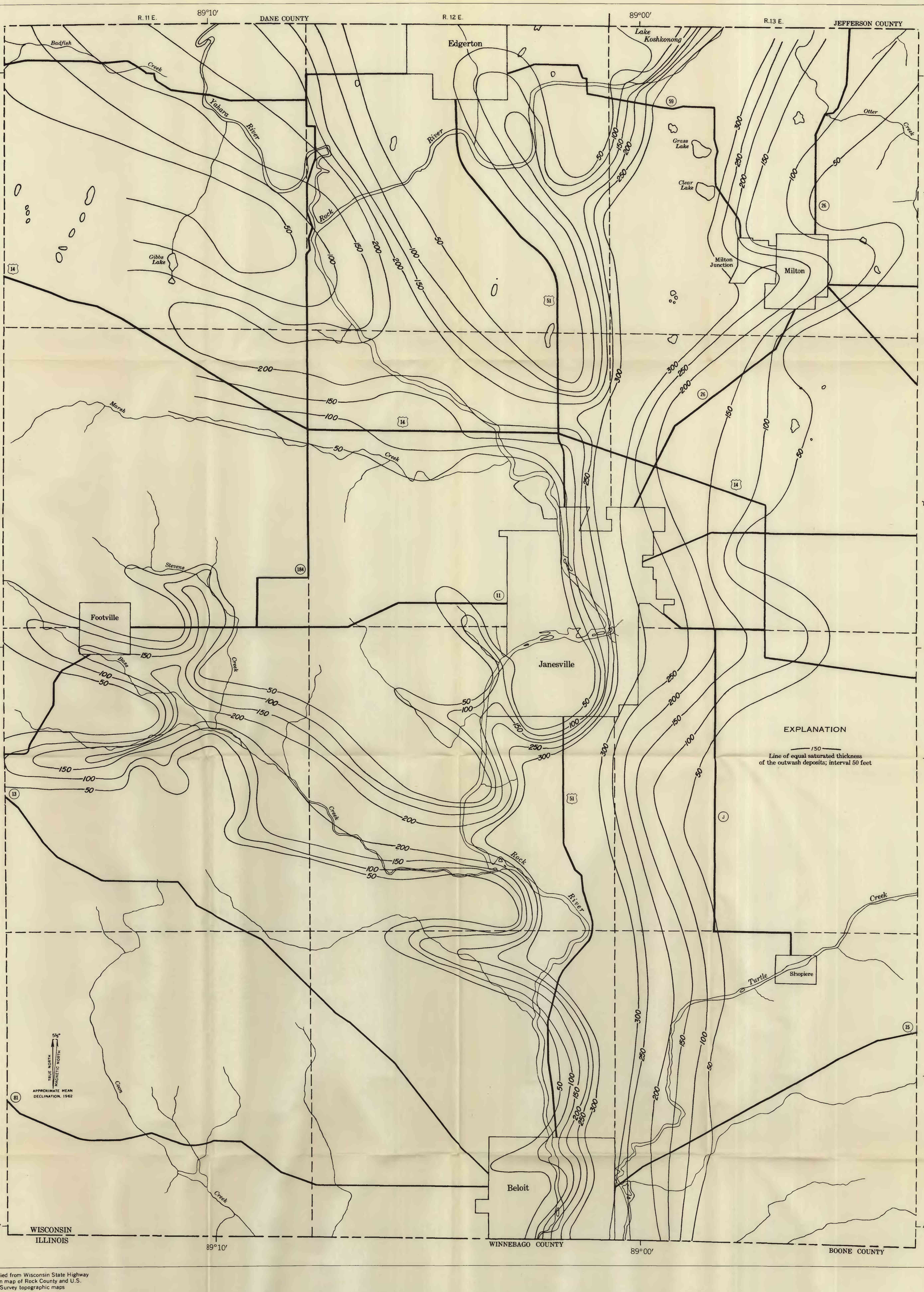
1 0 1 2 3 MILES

690-438 O - 63 (In pocket)



GEOLOGIC CROSS SECTIONS A–A′ AND B–B′, ROCK COUNTY, WISCONSIN

690-438 O - 63 (In pocket)



Base modified from Wisconsin State Highway Commission map of Rock County and U.S. Geological Survey topographic maps

MAP SHOWING SATURATED THICKNESS OF OUTWASH DEPOSITS IN THE BURIED ROCK RIVER VALLEY, ROCK COUNTY, WISCONSIN

SCALE 1:63360

1 0 1 2 3 MILES

690-438 O - 63 (In pocket)