Water Availability in Central Wisconsin—An Area of Near-Surface Crystalline Rock

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2022

Prepared in cooperation with
University Extension—
the University of Wisconsin
Geological and Natural
History Survey

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By E. A. BELL *and* M. G. SHERRILL

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By E. A. BELL and M. G. SHERRILL

ABSTRACT

Available ground water in much of central Wisconsin is limited to discharge through wells of low yield. Aquifers that yield small amounts of water to wells include fractured crystalline rock at or near surface in the eastern part of the area, sandstone overlying crystalline rock in the southern and western parts, and glacial till that covers the area north and west of the Marshfield moraine. Many wells in crystalline rock yield less than 2 gpm (gallons per minute). About 90 percent of the wells in sandstone and most wells in glacial till yield 5–20 gpm.

Outwash sand and gravel in segments of some bedrock channels, however, yield large supplies of water to wells. Wells in surficial sand and gravel in the lower valleys of major tributaries to the Wisconsin River yield as much as 450 gpm. Sand and gravel in segments of bedrock channels, many of which were delineated during this project, are covered by till or alluvium; wells in these sand and gravel deposits yield 100–400 gpm.

Induced recharge to buried aquifers by infiltration of water through the beds of overlying streams is feasible at six sites within 8 miles of Marshfield. Infiltration through the streambed of Little Eau Pleine River about 7 miles northeast of Marshfield was about 200 gpm when the ground-water level was lowered temporarily. Additional recharge through ponding is possible at other sites.

Streamflows in the area generally are not dependable sources of municipal or industrial supplies without storage. Nearly one-third of the flows measured in August 1969 were less than 0.01 cubic foot per second per square mile. Annual flows, however, would provide adequate within-year storage.

Chemical quality of water in the area is suitable for most uses. Ground water is hard, contains objectionable concentrations of iron, and locally is high in nitrate content. Surface water has an average dissolved-solids content of about 100 milligrams per liter.

INTRODUCTION

Water for public and industrial supplies is limited in a large part of central Wisconsin. Yields of ground water and natural streamflows during dry seasons are too low to sustain large supplies. In some towns and villages public water supplies are inadequate; in others they are barely adequate and cannot sustain the increase of future needs. Seventeen municipalities in the area use ground water; only Neillsville uses surface water.

Limited ground-water storage potential and rapid surface runoff deprive the area of much water that otherwise would be available (the average annual precipitation at Marshfield is 31.29 inches). Only a small part of the total water yield, excluding surface-water reservoir potential, is available for large public supplies. Soils of low permeability impede downward seepage and promote rapid surface runoff. Crystalline rock at or near the surface, generally covered by thin deposits of low permeability, limit the ground-water storage potential. The result is a water-poor area in a water-rich State.

Potentially available surface water is abundant, although resorvoir storage must be provided for dependable year-round supplies.

PURPOSE AND SCOPE

This appraisal is intended to aid those responsible for planning the development of the water resources in this area of central Wisconsin. The project was designed to (1) locate and describe buried bedrock channels filled with saturated permeable outwash sand and gravel, which may furnish dependable supplies of ground water to municipalities in the area; (2) determine the feasibility of developing surface-water sources as supplies; and (3) determine the possibility of inducing infiltration to the sand and gravel deposits in the buried bedrock channels. Special emphasis is given to ground water because satisfactory supplies from ground water can be attained with moderate treatment facilities, although surface water is evaluated as an alternate source.

This report describes the distribution and availability of water in the area, as determined from studies of the geology, hydrology, and water quality. An inventory of wells was made to obtain information on ground-water levels and subsurface geology. Test drilling and seismic and resistivity surveys were used to define the bedrock surface. Field investigations were supplemented by interpretations of aerial photographs, soils maps, and topographic maps.

DESCRIPTION OF AREA

The area of investigation (fig. 1) in central Wisconsin comprises parts of Clark, Jackson, Lincoln, Marathon, Portage, Taylor, and Wood Counties. The area is bounded on the east by the Wisconsin River, on the west by the west edge of the Black River basin, on the south by the south township line 22 N., and on the north by the north township line 31 N. Outside those boundaries problems of water supply are less acute than within the defined study area. The study area, 3,010 square miles, lies in parts of two of Martin's (1932) geographical provinces, the Northern Highland and the Central Plain. As

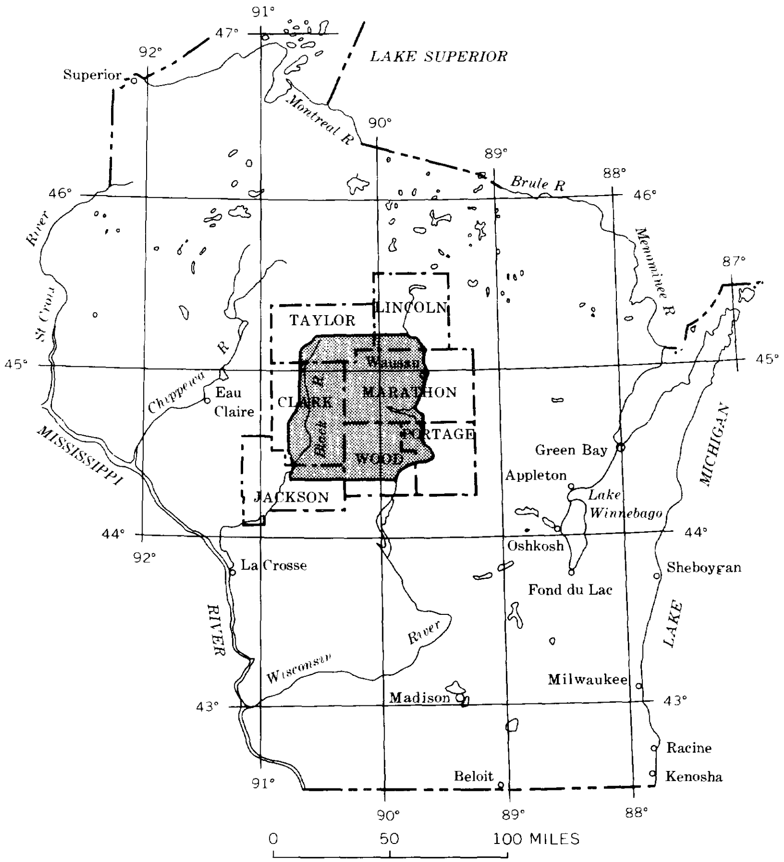

FIGURE 1.—Location of study area in central Wisconsin.

used in this report, "central Wisconsin" defines the area described above.

The land surface is mostly flat or gently rolling. The surface slopes downward in all directions from topographic highs near Abbotsford and Dorchester. The net decrease in altitude toward the south and southeast is about 400 feet. Generally the most pronounced relief is along the Black, Rib, and Wisconsin Rivers. Isolated sandstone mounds in the Black River basin rise abruptly several hundred feet. Rib Mountain, near Wausau, rises more than 700 feet above the adjacent flood plain of the Wisconsin River.

PREVIOUS INVESTIGATIONS

The geology and hydrology of central Wisconsin are described in many reports. General geology is described by Chamberlin (1877, 1882), Weidman (1907), Martin (1932), and Bean (1949). Glacial geology was outlined by Leverett (1929), Hole (1943), and Thwaites (1946). Information on the water resources of the area is included in reports by Kirchoffer (1905), Weidman and Schultz (1915), Wisconsin Bureau of Sanitary Engineering (1935), Drescher (1956), Holt (1965), and Devaul and Green (1971).

COOPERATION AND ACKNOWLEDGMENTS

This study is part of the statewide cooperative program of the U.S. Geological Survey and the University Extension—the University of Wisconsin Geological and Natural History Survey.

The assistance of many officials of the State, counties, and cities, drilling consultants, contractors, and well owners in providing pertinent information for this report is gratefully acknowledged. Special acknowledgment is made to Mr. Thomas Calabresa, Wisconsin Department of Natural Resources, for making available much information on wells; to Mr. Norman Dietrich, manager, Marshfield Electric and Water Department, for providing many well logs and records; and to officials of other municipal water departments for information concerning their water supplies. Special thanks are due Dr. Carl Dutton, U.S. Geological Survey, for his interpretation of Precambrian rocks; also to personnel of the U.S. Department of Agriculture, Soil Conservation Service, for making available information on soils. The courtesy of Mr. James Seymour, manager, Soiltest, Inc., Baraboo, Wis., for lending equipment for much of the seismic testing is greatly appreciated.

GEOLOGIC ENVIRONMENT

ROCKS AND THEIR WATER-YIELDING CHARACTERISTICS

Rock types in the area include crystalline rocks, sandstone, and alluvium. Crystalline rocks of Precambrian age (pl. 1) are at or near land surface throughout central Wisconsin. Thin layers of Cambrian sandstone overlie the crystalline rocks in the southern and western parts of the study area. Glacial, alluvial, and residual deposits of differing thicknesses overlie most of the bedrock. The geologic map (pl. 2) shows the types and thicknesses of surficial rock units for the entire study area. A more detailed map and a geologic section of the area near Marshfield (pl. 3) illustrate both surface and subsurface relationships of the rock units.

Bedrock and weathered bedrock at or near land surface are shown as the surficial units on plates 2 and 3. For these bedrock units, any cover generally is residual soil developed directly from the bedrock, but in some places there may be a thin discontinuous mantle of glacial till or outwash over what is called sandstone or crystalline rock on the maps. This mantle is generally less than 1 foot thick. Because of interpretative differences of the above conditions and the fact that new data in the form of drillers' logs and soils maps were available for this study, plate 2 differs somewhat from the surficial geologic map shown by Holt (1965) and from the drift boundaries shown by Hole (1943).

PRECAMBRIAN CRYSTALLINE ROCKS

Nearly impermeable crystalline rocks of Precambrian age form the practical lower limit of water-yielding rocks in central Wisconsin. Depths to these rocks range from zero in the eastern third of the area, where numerous outcrops occur, to nearly 140 feet in the Wisconsin River valley and moraine areas (pls. 2 and 3). The crystalline rocks consist of granite, gneiss, schist, slate, quartzite, and greenstone. For the purposes of this report, the crystalline rocks are not differentiated. Dutton and Bradley (1970) have mapped and described the Precambrian rocks.

Small amounts of water are obtained from weathered crystalline rock and from fractures within the rock. Yields depend on the degree and depth of weathering and the size and interconnection of fractures (fig. 2). Weathered rock ranges from a slightly disintegrated granite to a residual clay; the clay represents the end product of decomposition. Pleistocene glaciation removed much of the preglacial weathered rock and exposed unweathered rock at the surface in many places.

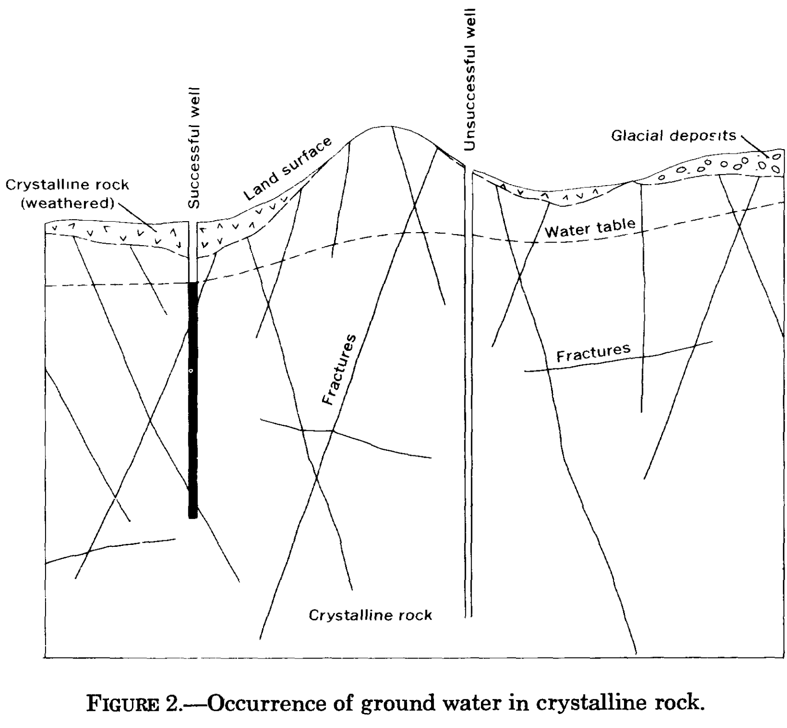

FIGURE 2.—Occurrence of ground water in crystalline rock.

Deep weathering has not had sufficient time to reestablish itself since Pleistocene time, and the present depth of weathering is generally less than 20 feet.

Fractures, although fairly numerous and well developed near the surface, diminish in size and number with depth. Major fracture patterns in the area are oriented N. 75° W.–N. 30° E. and N. 30° W.–N. 85° E.

Yields from wells in crystalline rock in the western two-thirds of the area, where sandstone and glacial deposits occur, are less than in the eastern one-third, where crystalline rock lies at or near the surface. The exposed crystalline rock may contain locally enlarged fractures that increase yields.

Somewhat higher yields normally can be expected in valleys where depth of weathering is greater than on hillsides and ridges where unweathered rock is likely to be closer to the surface.

CAMBRIAN SANDSTONE

Sandstone of Late Cambrian age overlies crystalline rock in the southern and western third of the study area (pl. 1). The sandstone consists chiefly of fine- to coarse-grained quartz sand; locally it contains large amounts of micaceous shale. It ranges in character from a dense clayey sandstone of low permeability to a clean poorly cemented sandstone of high permeability. The sandstone dips about 15 feet per mile to the southwest.

The average thickness of the sandstone is about 30 feet in the west and southwest and about 20 feet in the south. Mounds and broken ridges of sandstone 50 feet or more in thickness in the south and southwest are resistant erosional remnants of a widespread and thicker sandstone that once covered the entire area. Christie Mound (fig. 3), about 6 miles north of Neillsville, and the linear bedrock highs between Marshfield and Neillsville (pl. 1) are examples of these remnants. The bedrock highs, covered with or adjacent to thick deposits of glacial till, form what is commonly called the "Marshfield moraine" (pls. 1 and 2). This physiographic feature has been called both an end moraine (Weidman, 1907; Leverett, 1929) and a sandstone ridge (Bean, written communs., 1916, 1918), but actually it is a combination of the two. Figure 4 shows a sandstone roadcut near the top of the "moraine," about 1 mile east of Granton. The hydrologic significance of the Marshfield moraine is discussed in a later section.

GLACIAL DRIFT

Unconsolidated glacial drift is of two types, outwash sand and gravel that generally is stratified and till that generally is unstratified. Outwash materials are sorted and have been deposited by melt waters associated with glacial ice. Stratified outwash provides the most readily available source of ground water in the project area. Till is heterogeneous unsorted mixtures of cobbles, gravel, sand, silt, and clay that have been deposited by glacial ice. Stratified and unstratified drift in the project area are often found together: till over outwash, sand and gravel lenses within the till, or outwash over till. The distribution and thickness of glacial drift are shown on plates 2 and 3.

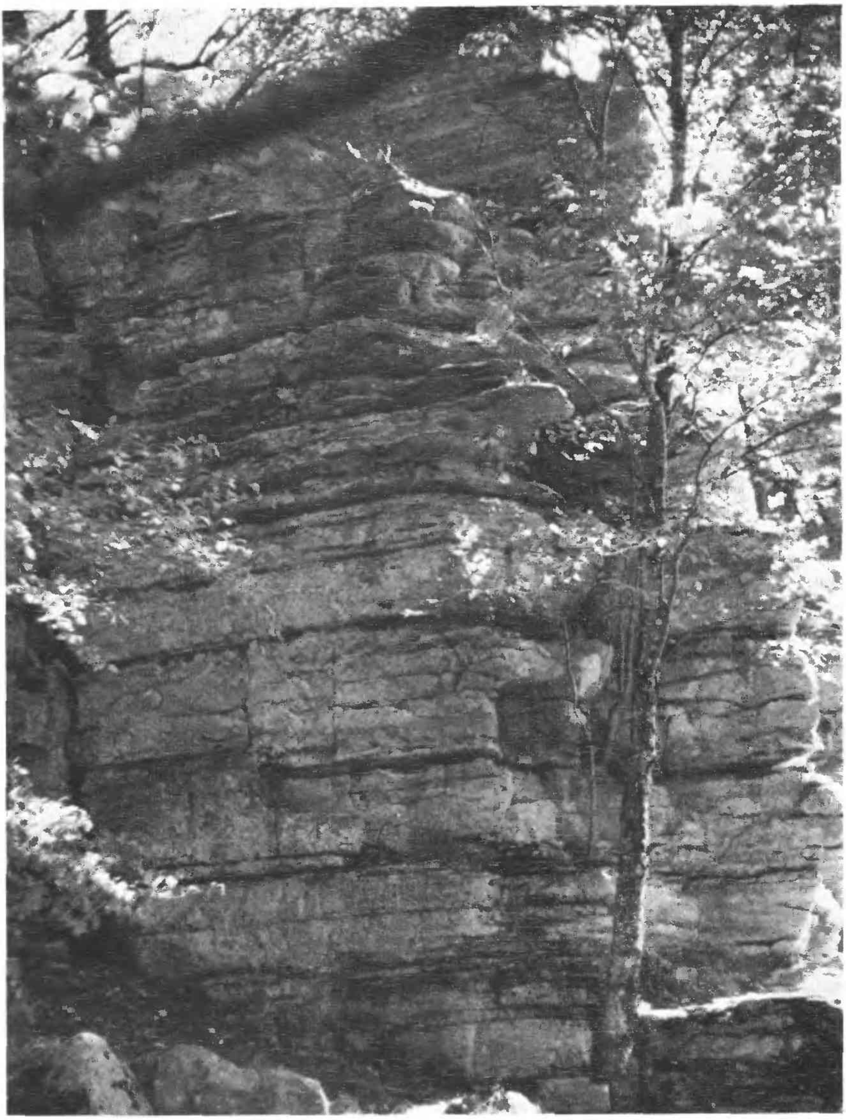

FIGURE 3.—Sandstone erosional remnant near Christie.

FIGURE 4.—Sandstone outcrop 1 mile east of Granton.

STRATIFIED MATERIALS

Outwash sand and gravel is the most important source of ground water in the project area. The outwash is formed in two ways: (1) as broad outwash plains of coalescing fans, and (2) by deposition in long narrow drainageways. Outwash plains are found in the southeast corner of the study area and represent the northwestern edge of the central sand plain (Holt, 1965). Outwash in long drainageways is common in existing river valleys and in numerous bedrock channels. Outwash is normally better sorted and more uniform in size in the Wisconsin and lower Rib River valleys than in the central part of the study area (fig. 5). Outwash deposits in the Wisconsin River valley in Marathon County are more than 100 feet thick, and wells in these deposits may yield as much as 1,000 gpm (gallons per minute). The extent and thickness of surficial outwash deposits are shown on the surficial geologic map (pls. 2 and 3).

Particle-size distribution curves for outwash materials are shown and compared with other glacial drift materials in figure 5. Curves with the steepest slopes represent materials with the best sorting. Well-sorted sand or gravel has greater water yields than well-sorted clay or silt, or poorly sorted sand or gravel.

Outwash deposits in the central part of the project area occur in the bottom of preglacial valleys or glacial drainageways. These deposits commonly are covered or buried by glacial till or alluvial

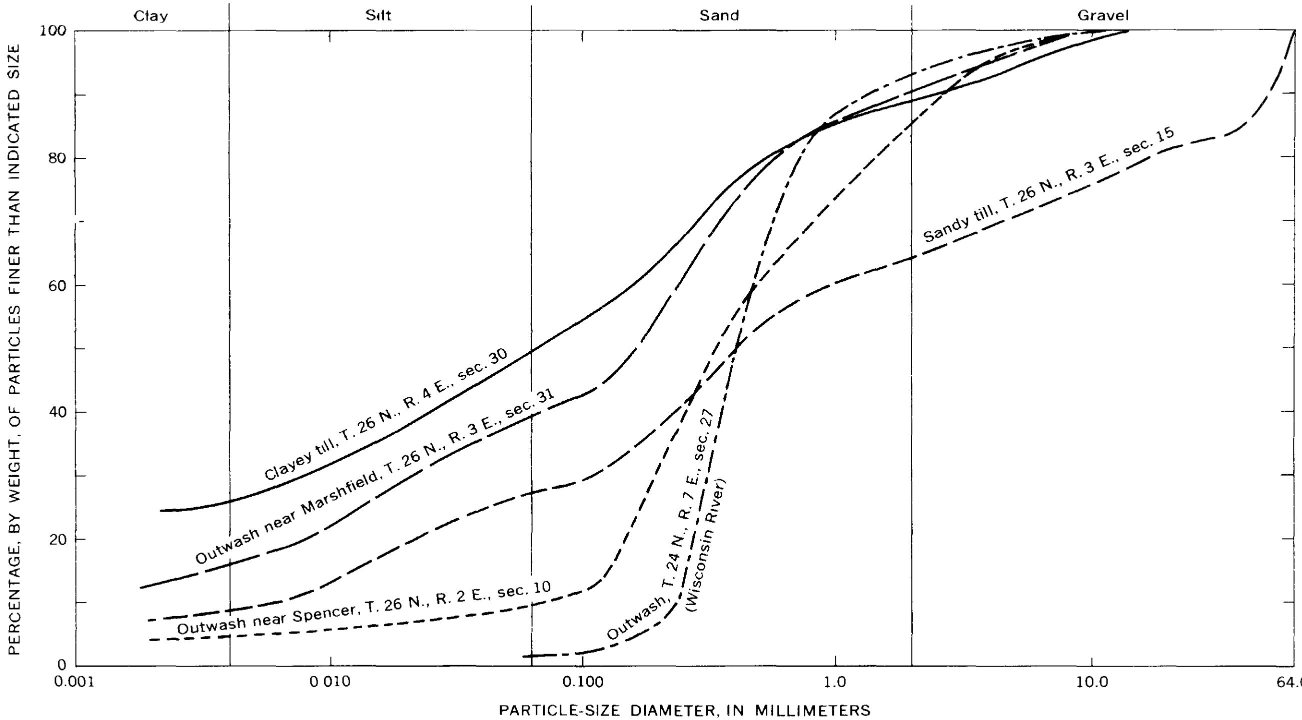

FIGURE 5.—Particle-size distribution curves for selected unconsolidated deposits.

materials. In some areas thin layers of organic materials are interbedded with the outwash. The outwash in most of the buried channels is only a few hundred feet wide, even though the bedrock valleys themselves may average about one-quarter mile in width (pls. 1 and 4). Moderate sustained yields of 100 gpm or more are available from these channels where the saturated thickness of sand and gravel is 50–60 feet.

TILL

Glacial till covers about 60 percent of the project area. The till is generally of two types: clayey till and sandy till. The clayey till, composed primarily of clay and gravel, is only poorly permeable. The less extensive and thinner sandy till generally overlies the clayey till and has a greater percentage of sand and gravel and generally greater permeability (fig. 5). Total thickness of the till ranges from almost zero to 100 feet. The thickness gradually increases from southeast to northwest.

Water is obtained from lenses of sand and gravel within the till north and west of the Marshfield moraine (pls. 2 and 3). East and south of the moraine the till is absent or is too thin to be a source of ground water.

Average yields from the till range from about 2 to 20 gpm. Such yields generally are adequate for domestic and stock supplies but not for municipal supplies.

POSTGLACIAL DEPOSITS

Postglacial (Holocene) deposits (pls. 2 and 3) include unconsolidated alluvial materials consisting of silt, sandy clay, and gravel. They are generally reworked glacial deposits that have been deposited in the channels and on the flood plains of major streams and their tributaries. Postglacial deposits also include organic clay, silt, and peat in marsh areas.

Alluvium and outwash sand and gravel are similar in character and are hydrologically connected. For this report the water-yielding characteristics of the two are considered the same.

BEDROCK SURFACE AND BURIED CHANNELS

Bedrock in the study area consists of undifferentiated Precambrian crystalline rock and the overlying Cambrian sandstone. The bedrock surface maps (pls. 1 and 4) represent the geology and topography that could be observed if the soil and unconsolidated sediments were stripped away. The bedrock surface closely resembles the present land surface except in the central and northwestern parts of the area where glacial drift obscures the bedrock (pls. 2 and 3). The bedrock surface slopes generally to the south, southeast, and southwest, and locally toward the Wisconsin and Black Rivers. This surface has less relief in the west and south, where the sandstone is present, than in the north and east, where crystalline rocks (pl. 1) are at or near the surface.

Bedrock altitudes generally range from about 1,450 feet above mean sea level in the northern part of the area to about 950 feet in the southern part. Extreme altitudes are about 1,940 feet on Rib Mountain, near Wausau, and less than 900 feet in the Black River valley, in the southwest corner of the area.

Buried bedrock channels are drainageways that existed before or during glaciation and that are partly or totally filled with Pleistocene and Holocene sand, gravel, silt, and clay. In many places, such as the channels northeast of Marshfield, the fill material is intermixed with or is overlain by glacial till. Present-day streams in much of the area generally coincide with the preglacial bedrock channels. This coincidence is due to the relatively thin drift over bedrock, which generally did not completely fill the bedrock channels.

The most prominent buried bedrock channel in the area extends from near Owen to the Marshfield moraine near Marshfield (pl. 1). An unconsolidated deposit as much as 80 feet thick within this channel extends both west and southeast of Spencer (pl. 3). Although some modification may have occurred from ice advances, the Marshfield-Owen channel probably represents the preglacial course of the Little Eau Pleine River southeastward to the preglacial Wisconsin River.

A buried-channel system east and northeast of the Marshfield moraine (pls. 3 and 4) is located in the multichannel drainageway of the preglacial Little Eau Pleine River. This preglacial river flowed nearly parallel to and about 2½ miles south (pls. 3 and 4) of its present course north of Marshfield. Since the discovery of this channel system, considerable test drilling and geophysical exploration, mainly for the municipalities of Marshfield and Spencer, have delineated other sections. A major bedrock channel about 80 feet deep is generally continuous in McMillan Marsh and through the Marshfield moraine in secs. 28, 29, and 33, T. 26 N., R. 3 E., about 1½ miles north of Marshfield (pl. 4). As the channel passes through the moraine, it is constricted in width, and the permeable outwash may be covered with 100 feet or more of clay till.

A second major buried channel extends out of McMillan Marsh into sec. 31, T. 26 N., R. 3 E. (pl. 4). Additional testing would be necessary to define the system, but it probably is continuous into the channel in the Wildwood Park area (Marshfield's south well field) of sec. 18 south of Marshfield, or it joins the channel in sec. 4 east of Marshfield.

Buried-channel deposits in the lower reaches of the McMillan Marsh area just northwest of the Marshfield moraine are generally thicker but less permeable than those in the upper reaches of the marsh or east of the moraine. Outwash deposits 2 miles east of Spencer, in the SE¼ sec. 10, T. 26 N., R. 2 E. (pl. 3), are clean medium-coarse sand at a minimum depth of 25 feet. Also, the NE¼ sec. 10 and NW¼ sec. 11, in the same township, contain 25–30 feet of silty clayey sand overlain by glacial till. Further investigation may show that these last two areas have ground-water potential.

Parts of a system of bedrock channels east of the Marshfield moraine (pls. 3 and 4) were known before this study. Generally these channels (pl. 4) are the different paths that were taken by the glacial and postglacial Little Eau Pleine River or its major tributaries as a result of morainal buildup during glaciation. The most recent shift of the Little Eau Pleine River is around the north end of the thicker moraine where the present river flows in bedrock.

A channel in T. 25 N., R. 3 E. trends east and northeast from about sec. 20 into sec. 11, and it eventually reaches the present Little Eau Pleine River near County Highway M (pls. 3 and 4). A test hole in the south-central part of sec. 11 showed 60 feet of saturated sand with interbedded silt and clay.

Two bedrock channels are associated with the preglacial Little Eau Pleine River. One channel trends northwest from Owen (pl. 1). Another channel nearly coincides with the present Little Eau Pleine River from just north of sec. 28, T. 26 N., R. 4 E. to the Wisconsin River. Test holes in this reach indicate a gradual thickening of the channel fill toward the Wisconsin River.

The buried channel southwest of Withee contains 100 feet of sand and silty sand. This channel is of special interest as a potential municipal supply for Withee.

Outwash sand and gravel deposits in the lower Rib River and lower Mill Creek bedrock channels (pls. 1 and 2) are not buried by glacial till. At Marathon, on the Rib River, an 80-foot thickness of fill contains sand and gravel intermixed with silt and clay. Downstream from Marathon the valley fill thickens and has a greater percentage of sand and gravel; upstream toward Edgar the fill thins to about 50 feet and has more silt and clay. West of Stevens Point in the Mill Creek valley, a test hole in the SW¼ sec. 27, T. 24 N., R. 7 E. showed 35 feet of saturated medium-coarse sand (fig. 5).

Other probable bedrock channels or parts of channels north and southwest of Medford and west of Merrill are indicated on plates 1 and 2.

GROUND WATER

Ground water in the study area moves through the saturated zones of crystalline rock, sandstone, glacial deposits, and alluvium. These materials generally are connected hydraulically to form a single ground-water reservoir, although their water-bearing characteristics differ. The water in storage, as it moves slowly from areas of recharge to areas of discharge into streams, is available for withdrawal by wells.

The amount of ground water renewed annually is indicated by annual base flow, which represents the ground-water contribution to streams. An examination of low-flow analyses of the major streams in the area (excluding the Wisconsin River) shows that average base flows (discharge 90 percent of the time) are about 25 percent of the average annual flow. This percentage contrasts with 75 percent—the average ground-water contribution to all streams in Portage County (Holt, 1965, p. 52). The total annual water yield in the study area is 10–11 inches, of which the average amount of ground water renewed annually is 2–3 inches.

Little or no net change in ground-water storage occurs in unpumped areas during long periods, as indicated by hydrographs of wells Mr–28/2E/18–8[1] at Colby and Pt–24/6E/2–82 at Junction City (fig. 6), 1953–69 and 1950–69, respectively. Water-level changes in well Ck–26/3W/4–1 near Greenwood (outside area of map) reflect variations in annual precipitation. The hydrograph of well Ck–26/3W/4–1 (fig. 6) approximates, with a timelag, the curve of cumulative departure from normal of annual precipitation at Marshfield.

The areal extent of water-level declines depends on the rate and duration of pumping. The water level of well Mr–26/3E/33–7 near Marshfield, (fig. 6) in the glacial outwash sand and gravel, declined in response to nearby pumping but recovered, to a great extent, after the center of pumping shifted.

Ground water moves through the ground-water reservoir from areas of recharge to areas of discharge. The water table (pl. 5) slopes regionally from near Merrill and Medford southward and eastward toward the Wisconsin River valley and southwestward toward the Black River valley. The water table is approximately parallel to the land surface over much of the area, and local ground-water movement is toward the nearest stream. Thus, much of the water moves only short distances through the ground-water reservoir. In some places ground water discharges through springs and hillside seeps; in other places it is visible in wetlands that occupy flat low terrain.

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[1]Wells in Wisconsin are designated by a three-segment identification: the first segment is the county abbreviation; the second segment is the well location by township north of the base line, range east (E) or west (W) of the principal meridian and section; and the third segment is the well's serial number within the county. Abbreviations of county names are Ck, Clark; Ja, Jackson; Ln, Lincoln; Mr, Marathon; Pt, Portage; Ta, Taylor; and Wd, Wood.

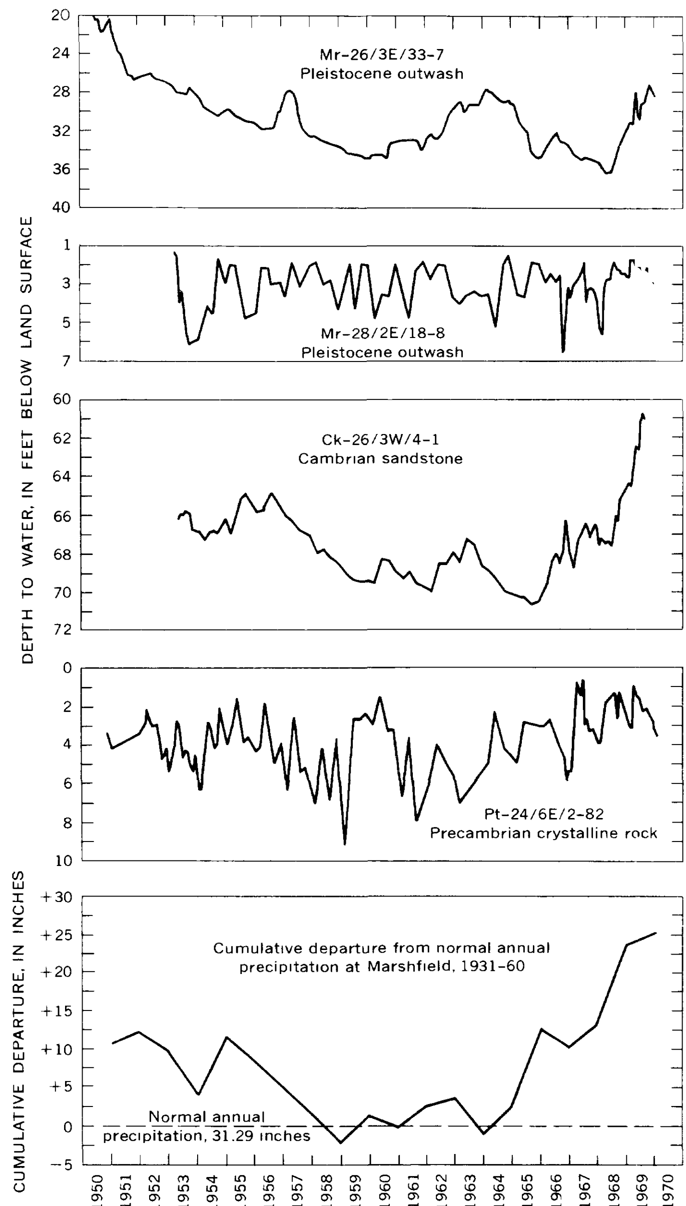

FIGURE 6.—Relation of water levels in four selected wells to cumulative departure from the 1931–60 normal annual precipitation at Marshfield.

AVAILABILITY

The availability of ground water as shown on plate 5 is a reliable guide of potential yields throughout the study area. The yields are valid in accordance with the present (1969) use of water in the area. Only outwash sand and gravel and alluvium yield enough water to sustain continuous high rates of withdrawal.

The study of 1,344 well records of yields and specific capacities was the basis of these interpretations. Most reported yields were from short-term pumping tests, and most drawdowns were substantial. The tests generally lasted 4–6 hours. A 24-hour or longer test for low-capacity wells was rare. A few tests in the glacial outwash sand and gravel in bedrock channels included 72 hours of pumping, plus a shorter period of recovery.

Ground-water sources in the western two-thirds of the area generally are adequate for domestic and stock supplies, but in the eastern one-third they generally are inadequate. In the eastern one-third, yields to domestic and stock wells are commonly less than 2 gpm and may be as low as ½ gpm. Yields in this low range may necessitate two or more wells or water management on an individual basis. For example, a dairy farmer might have to allow for water-level recovery in a well between periods of pumping or provide facilities to store water for use between periods of pumping.

Many municipal supplies in the study area, including Colby, Dorchester, Edgar, Greenwood, Owen, and Stratford, are barely adequate for present needs during dry seasons. Additional supplies will be required for future increased needs. Only those municipalities located favorably with respect to good sand and gravel outwash (Marathon City, Marshfield, Medford, and those in the Wisconsin River valley) can reasonably expect to obtain yields of 200–300 gpm from individual wells. Others less favorably located may develop combinations of till, sandstone, and crystalline aquifers. Because yields from wells in these aquifers are commonly less than 50 gpm, multiple wells must be installed for all but the smallest villages; otherwise some municipalities may have to seek surface-water supplies.

CRYSTALLINE ROCKS

Nearly two-thirds of the wells in the area penetrate crystalline rocks, although many are open also to the overlying glacial drift. More than half of the wells obtaining water from crystalline rocks are in Marathon County west of the Wisconsin River valley.

Ground-water availability is limited by the low porosity and permeability of the crystalline rocks except where water is stored in rock fractures. Storage and availability diminish with increasing depth below the weathered zone. Supplies from crystalline rocks are from water stored and moving in rock fractures or in overlying deposits.

Although crystalline rocks are the least productive aquifer in the area, they are the sole source of ground water in much of the eastern part. Of the 905 wells inventoried that penetrated crystalline rock, 167 (18 percent) yielded less than 2 gpm. The yields of 21 wells that were pumped longer than 12 hours ranged from 0.02 to 15 gpm, although only two of them exceeded 8 gpm. Eight wells (table 1) penetrating crystalline rocks in Marathon, Wood, and Lincoln Counties yielded 50 gpm or more in 2- to 10-hour pumping tests. The higher yields were from wells in areas where overlying materials afforded greater than average recharge or from deep wells in which drawdowns were great.

TABLE 1.—*Specific capacities of wells having large yields from the crystalline rocks*

Well No.	Depth (ft)	Penetration of crystalline rocks (ft)	Rate of pumping (gpm)	Drawdown (ft)	Duration of pumping (hr)	Specific capacity (gpm per ft of drawdown)
Mr–27/3E/32–267	166	146	50	126	10	0.4
28/4E/23–548	118	61	125	93	6	1.3
28/5E/18–374	75	15	70	14	6	5.0
29/2E/33–420	182	87	80	38	4	2.1
29/6E/12–651	65	50	50	7	2	7.1
Wd–25/2E/36–279	114	92	60	105	2	.4
25/4E/27–260	60	36	50	53	2	.9
Ln–31/6E/25– 46	85	73	50	71	8	.7

SANDSTONE

Sandstone in the southern and western parts of the study area is a dependable aquifer for small or moderate yields. Yields from wells penetrating the sandstone range from 1 to 75 gpm. Although nearly 90 percent of the yields range from 5 to 20 gpm, the average is about 10 gpm. Of the 1,344 wells inventoried in the area, 243 wells obtain water from the sandstone. Most yields exceeding 20 gpm from sandstone are in eastern Clark County. Many wells are open to both the sandstone and underlying crystalline rocks. The specific capacity is greater than 1 gpm per foot of drawdown in nearly one-half of the wells obtaining water from the sandstone. The saturated thickness of sandstone in the southern part of the area and in the western part south of the Marshfield moraine averages about 15 feet; in the western part of the area north of and including the Marshfield moraine the saturated thickness averages about 20 feet.

Well yields depend on the saturated thickness, continuity, and permeability of the sandstone. Supplies from sandstone generally are adequate for domestic and small village requirements but are inadequate for large municipalities. In the western part of the area, municipal wells are developed in a combination of sandstone, crystalline rock, and unconsolidated deposits; in the eastern part, sandstone is absent.

GLACIAL DEPOSITS AND ALLUVIUM

Ground water is available in small to large amounts from glacial till, alluvium, and glacial outwash. Well yields are least, usually less than 20 gpm, in the poorly sorted till in end moraines and ground moraines. Yields of 20 gpm or less are available from the fine-grained alluvium along some small tributary stream valleys. The greatest yields, as much as 3,400 gpm, are from outwash and alluvium along the Wisconsin River. Yields of as much as 500 gpm can be expected from some outwash sand and gravel in drainage systems of the major tributaries.

Glacial till, which covers about two-thirds of the study area, is of low permeability and forms aquifers of low yields. The saturated thickness of till east and south of the Marshfield moraine is small. The saturated thickness increases toward the northwestern part of the area where it exceeds 100 feet at several places. The till generally is adequate for domestic and stock water supplies, although many wells yield less than 2 gpm. A few wells in thick till yield more than 20 gpm.

Permeable sand and gravel lies beneath the valley of the Wisconsin River and the lowest reaches of its tributaries. The geology and hydrology of areas along the Wisconsin River are described by Holt (1965) and Devaul and Green (1971). The glacial outwash in the tributaries is thickest in the lowest reaches and thins upstream.

Sand and gravel in the lower parts of the Rib River and other tributaries of the Wisconsin River are major sources of water supplies. Two wells in the Rib River valley at Marathon City yield 350 gpm each, and a well downstream near the Wisconsin River yields 450 gpm.

High yields, however, are not obtained throughout these tributary valleys. A well on Scotch Creek (a tributary of the Rib River) at Edgar, about 6 miles upstream from Marathon City, yields 60 gpm. The river valley at Edgar is narrower, contains less permeable sand and gravel, and the saturated thickness is thinner than at Marathon City. Accordingly, well yields are less.

In the Rib River valley between Marathon City and Medford, the outwash decreases in permeability and thickness. Wells in that part of the valley generally yield less than 20 gpm. Near Medford and beyond the limits of the study area, more permeable and thicker deposits yield moderate to large amounts of water. Two wells at Medford yield 190 gpm and 250 gpm (not shown on pl. 5).

Buried outwash sand and gravel in some preglacial or glacial drainageways, particularly the preglacial Little Eau Pleine drainageway, forms important aquifers in the central part of the area. The buried outwash deposits in the channels are covered and mixed with finer grained materials and are less permeable than the surficial outwash deposits in the Wisconsin River valley. The amount of water in the outwash sand and gravel in buried channels, however, is adequate for moderately large municipal supplies. Estimates of transmissivity of the sand and gravel range from less than 40,000 to more than 100,000 gpd (gallons per day) per foot (from drillers' tests). The estimates are not precise because the complex geometry of the channels is not fully known, although allowance was made for the restricted channel widths.

The best delineated and most highly developed buried-channel aquifers are near Marshfield. The city of Marshfield obtains its water supply from wells in buried outwash sand and gravel. Well fields were developed first at Wildwood Park and, later, in sec. 20 south of town and near the old brickyard in sec. 29 north of town (pl. 4). After World War II the city began a testing program to determine favorable sites for additional or replacement municipal wells. The testing included seismic and resistivity surveys and a continuous program of test drilling.

The five newest municipal wells of Marshfield are developed in a buried-channel system northeast of town (pl. 4). These wells, in outwash sand and gravel, are along a 3-mile reach of a narrow bedrock channel. In general the narrow (about 1,000 ft) bedrock channel requires that wells be spaced along the channel and about one-quarter mile apart to minimize well interference. Multiple wells (crossing the channel) would result in excessive well interference.

Undeveloped aquifers in the buried-channel system east and northeast of Marshfield (pl. 4) probably offer the best potential for additional supplies. Yields of test and production wells in developed parts of the system generally are in the 100–400 gpm range. Comparable yields can be expected from wells in the undeveloped parts of the system.

The potential of other buried-channel aquifers was not determined, although high yields from some wells are reported. Several wells at or near Spencer yield 100–200 gpm. A test well one-half mile south of Withee pumped 90 gpm at a specific capacity of 1.66 gpm per foot of drawdown. All these wells are along the preglacial Little Eau Pleine River valley. The high yields indicate a permeable aquifer, although its full extent was not delineated.

Glacial deposits in the Big Eau Pleine River valley generally are thin. In much of the valley they are less than 20 feet thick and of low permeability. Yields to wells generally are low.

Thin glacial deposits that yield small amounts of water are characteristic of most of the Black River valley in the study area.

Many municipalities, including most towns along the Big Eau Pleine and Black Rivers, are distant from permeable sand and gravel.

RECHARGE BY INDUCED INFILTRATION TO BURIED CHANNEL DEPOSITS OF SAND AND GRAVEL

Recharge to buried-channel aquifers may be induced from overlying streams at many locations in central Wisconsin. Infiltration from the river along a quarter-mile stretch can be induced to the aquifer where the buried channel partly lies under the Little Eau Pleine River at County Highway M, 7 miles northeast of Marshfield. About 200 gpm infiltrated through the riverbed to that aquifer when the ground-water level was lowered by pumping a well near the river during a winter low flow. This infiltration rate cannot be sustained, however, because low flow in the Little Eau Pleine River at that site is sometimes less than 0.1 cfs (cubic foot per second) (about 45 gpm). The infiltration rate probably would be much greater than 200 gpm during high flow.

Recharge to the buried sand and gravel in a narrow bedrock channel east of State Highway 97, about 2 miles northeast of Marshfield, is possible through ponding and infiltration. Runoff from a drainage area of about 1 square mile can be intercepted as potential recharge. Ten inches of runoff, the estimated annual water yield, is 173 million gallons or about 300 gpm from the 1-square-mile area. The total potential recharge at the site would be less than 300 gpm because of the variability of seasonal streamflow.

Although the intermittent flow in the small stream overlying the buried channel east of State Highway 97 is too variable to be a dependable source of infiltration, potential recharge can be retained by ponding. If one or more low dams were built across the small stream to detain water in storage, rapid stream runoff would be reduced and potential recharge increased. An excavation as deep as 15 feet would remove the cover of clayey material that impedes recharge and would create a pond having good hydraulic connection with the aquifer. Corresponding water-level fluctuations indicate a good hydraulic connection between the aquifer and a sand and gravel pit near the aquifer (James Trierweiler, oral commun., 1968).

If potential recharge from the stream is channeled to an excavation adjacent to the buried channel, infiltration can be induced to the aquifer. The recharge available would depend on the streamflow and would be limited by the size of the excavation. Recharge from the pond would be induced when ground-water levels were lowered.

Infiltration into sand and gravel aquifers is induced from the Wisconsin River and the lower reaches of its tributaries, especially the Rib River at Marathon City. Recharge occurs when streams are at high stages and when the ground-water level is drawn down by heavy pumping. A good hydraulic connection between the Wisconsin River and the adjacent sand and gravel aquifer at Wausau was indicated by corresponding fluctuations of the river and wells near the river.

Five additional short reaches along the Little Eau Pleine River and its tributaries north and east of Marshfield are areas of potential induced recharge to the sand and gravel aquifer in buried bedrock channels. These are gaining reaches and normally do not recharge the underlying aquifers. However, recharge may be induced from the streams where a hydraulic gradient is created from the stream toward a pumping well.

The following reaches of streams cross or overlie buried channels (pl. 4) and are potential recharge sites:

1. The Little Eau Pleine River through secs. 29, 30, and 32, T. 26 N., R. 4 E.
2. A tributary of the Little Eau Pleine River through secs. 35 and 36, T. 26 N., R. 3 E.
3. A southern tributary of the Little Eau Pleine River through sec. 34, T. 26 N., R. 3 E., and secs. 2 and 3, T. 25 N., R. 3 E.
4. A secondary tributary through sec. 1, T. 25 N., R. 3 E.
5. A tributary of the Little Eau Pleine River through secs. 5 and 6, T. 25 N., R. 4 E., and secs. 28, 32, and 33, T. 26 N., R. 4 E.

Recharge to the sand and gravel probably can be induced at other sites although the recharge rates would differ. The thickness of the till or alluvium covering the sand and gravel influences the hydraulic connection between the stream and the buried aquifers. The till or alluvium is about 20–25 feet thick in the localities of the reaches listed above, although the till cover may be thinner above the sand and gravel in the valleys. About 7 feet of till covers the sand and gravel in the Little Eau Pleine River valley at County Highway M. Along the southern tributary (number 3 above), the till cover ranges in thickness from 9 to 16 feet. The low flows in the streams limit the water available for recharge.

QUALITY OF GROUND WATER

Ground water in the area is chiefly of the calcium magnesium bicarbonate type (pl. 6). From analyses of 12 water samples collected during October 1969 the hardness, as $CaCO_3$, ranged from 69 to 183 mg/l (milligrams per liter), and the dissolved solids ranged from 111 to 256 mg/l. The softest and least mineralized water was in the glacial outwash in the Rib River valley at Marathon City, and the hardest and most highly mineralized water sampled was in the sandstone and crystalline rocks near Greenwood.

The concentration of iron ranged from 0.02 to 3.0 mg/l, with objectionable concentrations of iron (more than 0.3 mg/l) common in the glacial material.

Relatively high concentrations of nitrate (table 2) appear to be localized and generally occur where bedrock is near the land surface. The nitrate content of water from 80 wells in thin drift and fractured crystalline rock in T. 29 N., R. 4 E., and R. 5 E., Marathon County, was monitored from March 1968 to May 1969 (Crabtree, 1970). Seventy percent of the wells contained more than 45 mg/l of nitrate at least once during the study period, and about 45 percent of the wells contained more than 45 mg/l of nitrate throughout the period. Farmyard runoff is believed to contribute significantly to the high nitrate concentrations. Water with concentrations of nitrate exceeding 45 mg/l is not recommended for human consumption (U.S. Public Health Service, 1962, p. 47).

The ground-water temperature in October 1969 averaged about 10°C (50°F); this average is slightly above the annual average air temperature of the area.

SURFACE WATER

Drainage of the area is by overland runoff and ground-water runoff. The surficial clayey materials promote rapid overland runoff, and the low hydraulic conductivity of most aquifers retards ground-water runoff. Consequently, overland runoff is much greater than ground-water runoff in the study area.

The runoff resulting from the mean annual precipitation of about 31 inches (31.29 inches at Marshfield) approximately equals the annual water yield of 10–11 inches. Overland runoff is about 8 inches of the total annual streamflow. The highest flows, which generally occur in March, April, or May, result from snowmelt; severe flooding may occur when heavy rains coincide with the thaws. The lowest flows, which generally occur in January and February when streams are frozen or during dry seasons in August, September, or October, are essentially ground-water runoff.

TABLE 2.—*High nitrate content in ground-water samples collected during 1969*
[Analyses by U.S. Geological Survey]

Well location	Nitrate, NO_3 (mg/l)	Bedrock aquifer
Sec. 29, T. 29 N., R. 6 E., near Rudolph	31	Precambrian.
Sec. 23, T. 25 N., R. 1 E., at Chile	17	Cambrian.
Sec. 14, T. 25 N., R. 2 W., near Greenwood	25	Cambrian and Precambrian.
Sec. 23, T. 27 N., R. 5 E., near Edgar	55	Precambrian.

The average flows of the principal streams, shown on the duration curves in figure 8, are equaled or exceeded only 20 percent of the time or less. Flows in the Black River at Neillsville and in the Rib River at Rib Falls are average or greater about 20 percent of the time, whereas flows in the Yellow River at Babcock and in the Big Eau Pleine River near Stratford and near Colby are average or greater less than 20 percent of the time.

Mean flows during the 1969 water year at two supplemental gaging stations, Mill Creek near Stevens Point and Little Eau Pleine River near Marshfield, were 1.22 cfs per square mile and 0.84 cfs per square mile, respectively (table 3). The mean flow of Big Eau Pleine River near Stratford during the 1969 water year was 0.84 cfs per square mile compared to a long-term average of 0.76 cfs per square mile.

Evaluation of water availability from streams in the area is made from the magnitude and frequency of low flows and, to some extent, from the duration of flow.

LOW FLOWS

The low-flow characteristics of four streams are indicated by 7-day low-flow frequency curves (fig. 7). The low-flow frequency curves show the expected recurrence intervals (in years) for the indicated minimum flows. For example, the curve shows that, on the average, a 7-day mean flow of about 0.7 cfs in Big Eau Pleine River near Stratford can be expected once every 10 years.

Low flows at 70 sites (pl. 6) were measured during October 1968 and August 1969. The base flows in 1969 were substantially lower than those in 1968. Nearly one-third of the flows measured in 1969 (pl. 6) were less than 0.01 cfs per square mile of drainage area. Four of these flows (fig. 8) range from about 80 to 93 percent of duration; or, expressed another way, the flows at those four stations are expected to be lower than the 1969 flows 7–20 percent of the time. The low flows at the other sites probably are in the same range on the duration curve.

The 7-day low flows in 1969 in the Black River at Neillsville and in Big Eau Pleine River near Stratford (fig. 7) plot at a recurrence interval of less than 2 years. Low flows equal to or less than those of 1969 probably will occur in the area, on the average, more often than every 2 years.

TABLE 3.—*Mean daily discharge in selected streams in central Wisconsin, 1969 water year*

Gaging station	Drainage area (sq mi)	Mean daily discharge (cfs)	(cfs per sq mi)
Mill Creek near Stevens Point	107	131	1.22
Little Eau Pleine River near Marshfield	73.1	61	.84
Big Eau Pleine River near Stratford	224	189	.84

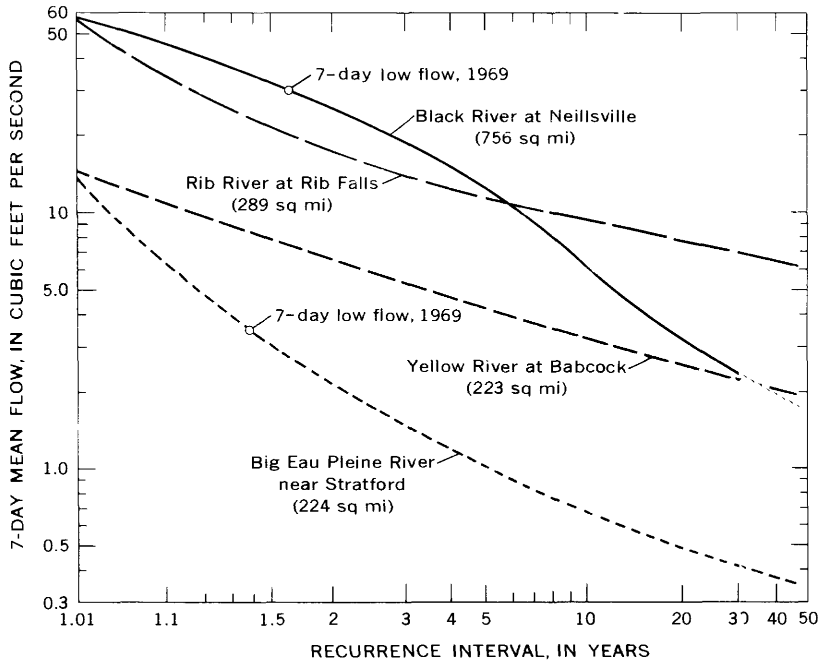

FIGURE 7.—Low-flow frequency curves for selected streams.

DURATION OF FLOW

Runoff characteristics of five of the drainage basins (pl. 6) in the area are indicated by the shapes of their flow-duration curves (fig. 8). Each curve, by its general steep slope, indicates a basin of rapid runoff and a lack of well-sustained low flows, although the characteristics differ in degree. For example, Rib River at Rib Falls, which drains an area of till and glacial outwash, yields a base flow greater than 10 cfs more than 99 percent of the time. In contrast, Big Eau Pleine River near Stratford, which drains an area chiefly of till overlying crystalline rock, yields a base flow less than 9 cfs more than 30 percent of the time and has ceased to flow during the dry season.

QUALITY OF SURFACE WATER

Surface-water quality in the area generally is good. The water is normally of the calcium bicarbonate type. Concentrations of magnesium and sodium are about equal and are about one-half that of calcium; the concentration of dissolved solids is about 100 mg/l. The chemical character of surface water under low-flow conditions, shown on plate 6, generally is similar to that of ground water in the same drainage area. The chemical character of water from Rib River at Rib Falls and from well Mr–28/6E/6–721 is similar (pl. 6). Also, the

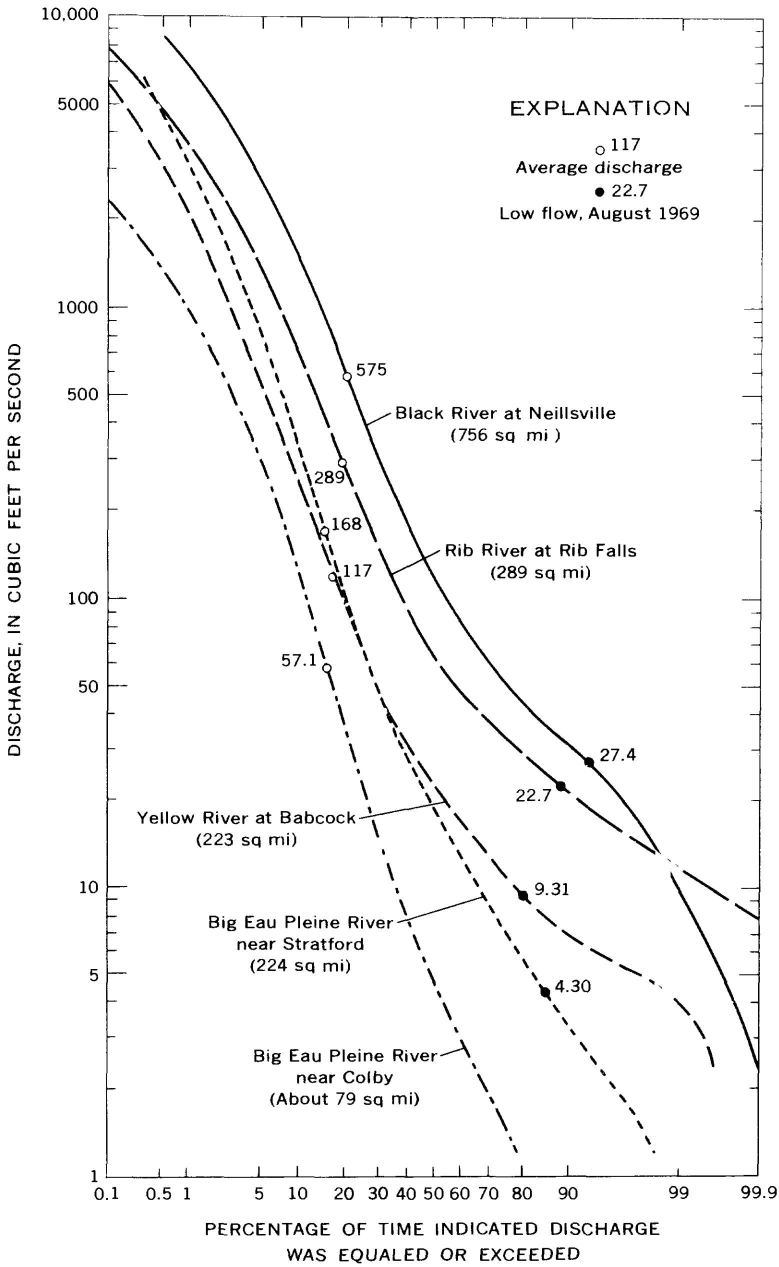

FIGURE 8.—Duration curves of daily flows of selected streams.

chemical character of water from the Black River at Neillsville and from well Ck–26/2W/14–245 is similar, although the ground water is more highly mineralized.

Concentrations of chloride, nitrate, and phosphate in the surface water (table 4) are not high enough to indicate definite pollution. Although the concentration of phosphate is favorable for algal growth, the concentrations of chloride, nitrate, and phosphate in general have not reached the level that would deter developing the water for supplies.

Color of the water in Black River at Neillsville, where the municipal supply is from surface water, was 80 (standard units of the platinum-cobalt scale) on October 25, 1968. A color of 5 or less represents clear water. Color is caused by the presence of sediments and organic acids; it is not harmful but may be esthetically objectionable.

DEVELOPMENT FOR SUPPLIES

Water supplies developed in the area have been small because water needs were small. Nearly all the area was used for farming—either for dairying, which requires little water, or for the growing of grain. Because most towns and villages were small and had little demand for industrial water, small municipal supplies were satisfactory in the past. Now (1969), however, many municipal supplies are barely adequate and will be inadequate for increased water needs. Most of the industries are concentrated in the Wisconsin River valley where water is abundant.

Water supplies in central Wisconsin are primarily ground water. Low-capacity wells and a few springs supply most of the water for domestic and stock uses in the agricultural areas. All but one of the

TABLE 4.—*Concentrations of chloride, nitrate, and phosphate in surface water*
[Concentrations in milligrams per liter]

Location	May 1968			October 1968			August 1969		
	Chloride Cl	Nitrate NO_3	Phosphate PO_4	Chloride Cl	Nitrate NO_3	Phosphate PO_4	Chloride Cl	Nitrate NO_3	Phosphate PO_4
Rib River at Rib Falls	2.0	0.8	0.14	3.0	0.7	....	3.0	1.0	0.05
Big Eau Pleine River near Stratford	10	.9	.35	9.0	.6	....	10	2.0	.33
Little Eau Pleine River near Marshfield	4.0	.9	.60	8.0	1.0	....	8.0	1.8	.52
Mill Creek near Stevens Point	18	2.5	1.1	15	1.6	....	16	3.0	.74
Black River near Neillsville	4.0	.8	.38	4.0	.9	....	8.0	1.5	.82
Yellow River at Babcock	6.0	1.4	.28	7.0	1.2	....	6.0	3.6	.10

municipal supplies in central Wisconsin tap the ground water. Water used by most industries is obtained from municipal supplies, although many small cheese-processing plants have their own private wells.

Very little surface water is used for supplies in the area. The only significant surface-water supply in central Wisconsin is the municipal supply from the Black River at Neillsville. Some small streams and ponds are used for watering stock. To satisfy future demands, a potential source of supply can be obtained by storing streamflow in reservoirs.

GROUND WATER

Domestic and farm wells generally are drilled wells, 6 inches in diameter, with open-end casing, and equipped with submersible pumps. Many wells in bedrock probably obtain much of the water from directly overlying glacial materials.

The source of municipal water supplies of nearly all villages and cities is ground water. Many test holes have been drilled in the area to identify favorable drilling sites for public-supply wells. Municipal wells generally are larger in diameter than domestic wells; most of them are screened and better developed than domestic wells. Many municipal wells are closer to streams and penetrate more permeable materials than domestic wells. Because of these conditions, municipal wells have higher yields than domestic wells, although they do not assure an adequate supply of water.

A summary of pumpage in 1969 from municipal wells in the area, except pumpage from wells in the Wisconsin River valley, is shown in table 5. Each municipal supply furnishes water to nearly all industries located within the area of its distribution system.

SURFACE WATER

The natural flows of most streams in the area are too low during dry seasons to be used for municipal water supplies. The municipal water supply at Neillsville draws water from the Black River, which normally has sufficient flow to supply the city. The withdrawal in 1969 was 76.3 million gallons (210,000 gpd). However, the minimum flow of record (0.6 cfs) would probably be inadequate to supply the city.

The flow in the lower Rib River downstream from Marathon City, where the riverbed is glacial outwash sand and gravel, is an exception. Sustained flow in that reach of the river could be developed for dependable moderate supplies. The discharge of 27.5 cfs in the Rib River at Marathon City is the highest discharge of all streams measured during the low-flow measurements in August 1969. The flow-duration curves (fig. 8) and the low-flow frequency curves (fig. 7) show that the Rib River has more sustained base flow than other streams in the area.

TABLE 5.—*Ground-water pumpage in 1969 from municipal wells*

Municipality	Pumpage: 1969 total (million gallons)	Pumpage: Daily average (thousand gpd)	Pumpage: Average (gpm)	Industrial use (million gallons)	Principal source
Abbotsford	51.8	142	99	18.0	Sand and gravel.
Athens	18.6	51	35	......	Sand and gravel and crystalline rock.
Colby	30.0	82	57	9.5	Sand and gravel.
Dorchester	12.5	34	24	2.3	Do.
Edgar	34.3	94	65	13.9	Sand and gravel and crystalline rock.
Granton	4.8	13	9	......	Sandstone.
Greenwood	31.0	85	59	15.0	Sand and gravel.
Junction City	6.2	17	12	......	Crystalline rock.
Loyal	25.8	71	49	......	Sand and gravel.
Marathon City	80.6	221	155	57.3	Sand and gravel (outwash).
Marshfield	480.0	1,320	920	169.5	Do.
Medford	147.4	404	280	33.5	Sand and gravel.
Owen	73.2	200	140	27.7	Do.
Pittsville	25.5	70	49	......	Do.
Spencer	34.6	95	66	2.2	Do.
Stratford	22.3	61	42	.2	Sand and gravel and crystalline rock.
Withee	9.4	26	18	.1	Sand and gravel.
Total	1,088.0	2,986	2,079	349.2	

The lowest annual mean flow of 34.1 cfs, or 0.15 cfs per square mile, in Yellow River at Babcock, is the least annual mean of long-term record at the four primary gaging stations (table 6). This amount is about seven times as great as the total municipal use of water in 1969, about 3.2 mgd (million gallons per day). The average flow in Yellow River at Babcock is 128 cfs or about 25 times the 1969 municipal use.

The amount of surface water potentially available greatly exceeds present and probable future needs for municipal and other supplies. However, large amounts of overland runoff moves away too rapidly to be used for supplies; on the other hand, a large amount of ground water is stored but moves too slowly through the aquifers to be withdrawn for adequate municipal supplies.

Because of the seasonal and annual variability of streamflow, storage must be provided for dependable year-round supplies. Using procedures of streamflow analysis (Riggs, 1964), storage requirements to satisfy uniform draft rates were estimated for streams at the four primary gaging stations (fig. 9). Because losses from evaporation and seepage are design factors, they are not included in the estimates.

The draft-storage curves (fig. 9) show the reservoir storage required

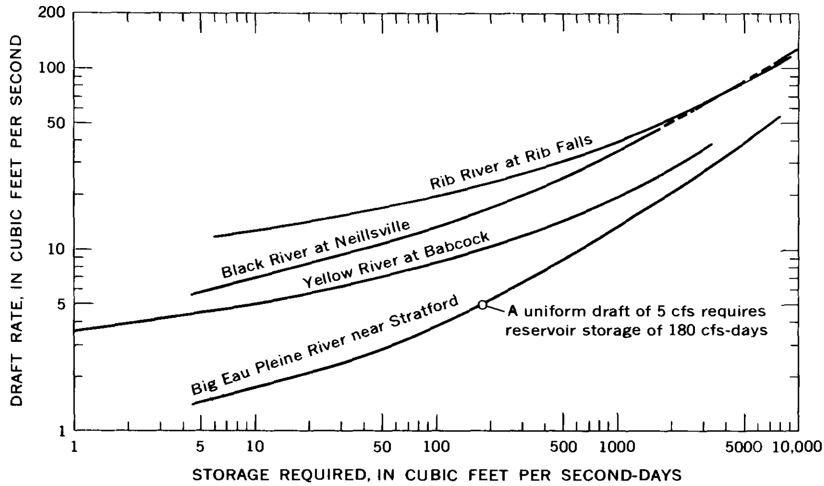

FIGURE 9.—Draft-storage curves for a drought recurrence interval of 20 years.

to maintain a given uniform draft (withdrawal) of water. The curves are based on a drought recurrence interval of 20 years and are for within-year storage. That is, storage will be replenished within the year on the average of 19 of each 20 years by the high flow of the stream. This water can be released during succeeding periods of low flow. The draft is the rate of withdrawal in cubic feet per second, and the required storage is the volume of water in cfs-days. (A cfs-day is the volume of water represented by a flow of 1 cfs for 24 hours.) For example, if a reservoir were built on Big Eau Pleine River near Stratford, data from table 6 and figure 9 would provide approximate estimates of storage required within the prescribed limits of draft. Suppose a water supply of about 5 cfs (3.2 mgd) were desired. On Big Eau Pleine River near Stratford the required storage corresponding to the draft rate of 5 cfs is about 180 cfs-days for the drainage area. This amount represents a storage of about 36 days supply. Some flows in small tributaries of the area also are available for storage, although they are much less than that in any of the four streams

TABLE 6.—*Average discharge and lowest annual mean discharge at four primary gaging stations*

Location	Discharge area (sq mi)	Average discharge (cfs)	Average discharge (cfs per sq mi)	Lowest annual mean discharge (cfs per sq mi)
Rib River at Rib Falls	309	294	0.951	0.35
Black River at Neillsville	756	565	.747	.22
Yellow River at Babcock	223	128	.574	.15
Big Eau Pleine River near Stratford	224	171	.763	.21

listed in table 6. Storage at most possible sites along the tributaries probably would sustain small drafts.

CONCLUSIONS

Outwash sand and gravel deposits form the most productive aquifer in central Wisconsin and furnish dependable supplies of water to some municipalities. Outwash sand and gravel in the Rib River valley yields as much as 350 gpm to wells at Marathon City. Downstream deposits of sand and gravel are thicker, and well yields are as much as 450 gpm near the Wisconsin River.

Some buried preglacial or glacial channels in the central part of the area contain outwash sand and gravel, principally in parts of the preglacial Little Eau Pleine River from near Owen southeastward to Marshfield and eastward to the Wisconsin River valley.

The most highly developed buried sand and gravel deposit is in a channel system north and east of Marshfield. The most important channel extends from secs. 33 and 34, T. 26 N., R. 3 E. through secs. 1, 2, and 3, T. 25 N., R. 3 E. and northeastward to join the Little Eau Pleine River valley at secs. 29 and 32, T. 26 N., R. 4 E. Wells in that channel, with yields ranging from 100 to 400 gpm, provide part of the Marshfield municipal supply. Further development in this channel and in another channel in secs. 11 through 20, T. 25 N., R. 3 E., probably will sustain an adequate municipal supply for Marshfield for many years.

Upstream in the preglacial Little Eau Pleine River valley, wells in buried sand and gravel at Spencer yield 100–200 gpm. Wells in sand and gravel deposit one-half mile south of Withee yield about 100 gpm. Deposits in another channel north and southwest of Medford are tapped by wells yielding as much as 250 gpm.

Because the outwash sand and gravel in bedrock channels is limited areally, many municipalities in the area cannot benefit from the aquifers. Most towns in the Big Eau Pleine River and Black River basins within the area are distant from permeable sand and gravel.

Surface water is available in amounts that exceed the 1969 municipal needs in the area; however, because of the seasonal and annual variability of streamflow, storage must be provided for dependable year-round supplies. The lowest annual mean flow in the Yellow River at Babcock, 34.1 cfs, was about seven times the 3.2 mgd of water used in 1969 by all municipalities in the area (excluding those in the Wisconsin River valley). The lowest annual flow in the Big Eau Pleine River near Stratford, 47.5 cfs, was about 10 times as much; in the Rib River at Rib Falls, 108 cfs, was about 20 times as much; and in the Black River at Neillsville, 167 cfs, was about 30 times as much.

A water supply of 5 cfs (3.2 mgd) from the Big Eau Pleine River near Stratford would require a reservoir storage of 180 cfs-days, or about a 36-day supply. A water supply adequate for small communities probably could be sustained by reservoir storage on many small streams; however, the quality of water in small streams might be temporarily poor.

Recharge to buried sand and gravel in bedrock channels generally is practicable by induced infiltration from overlying streams. Although most of these overlying streams are gaining, gradients created by pumping wells may intersect the streams and induce infiltration. Infiltration rates to most buried sand and gravel aquifers probably would be small because of the low permeability of overlying materials. Because of favorable conditions, infiltration from the Big Eau Pleine River at County Highway M was induced to the sand and gravel at the rate of about 200 gpm by pumping a well near the river. Infiltration was effective along a reach about one-quarter mile long. Another site favorable for induced recharge by ponding and pumping is located east of State Highway 97 about 2 miles northeast of Marshfield. The potential recharge at that site would be less than 300 gpm, the runoff from the 1-square-mile drainage area.

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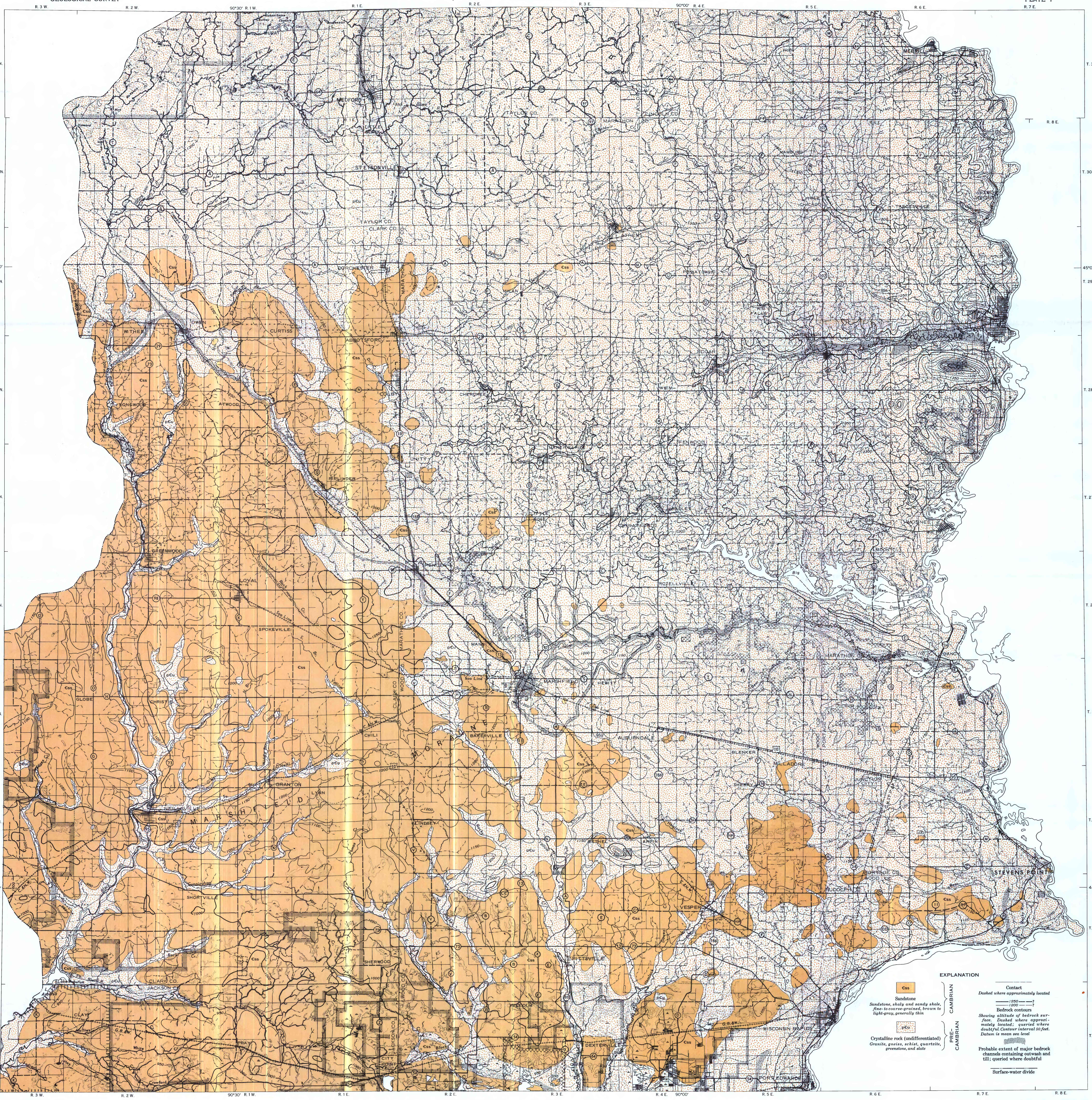
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
UNIVERSITY EXTENSION-THE UNIVERSITY OF WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY

WATER-SUPPLY PAPER 2022
PLATE 1



Base from State of Wisconsin Department of Resource Development, 1964

SCALE 1:125 000

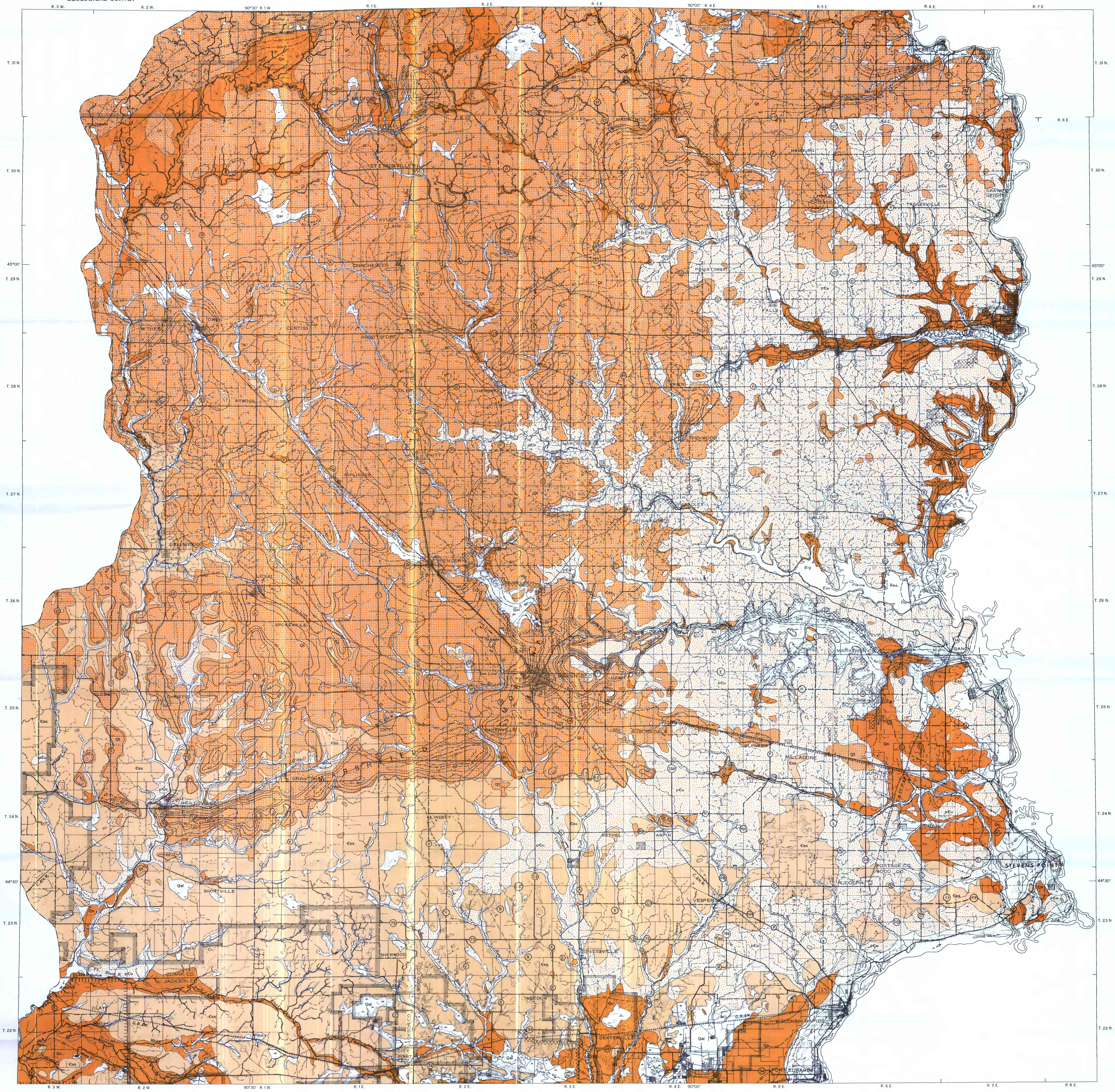
Geology by Marvin G. Sherrill, 1969

BEDROCK GEOLOGIC MAP SHOWING CONFIGURATION OF BEDROCK SURFACE IN CENTRAL WISCONSIN

522-120 O - 74 (In pocket) No. 1

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
UNIVERSITY EXTENSION-THE UNIVERSITY OF WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY



EXPLANATION

POSTGLACIAL

Holocene

Qal — **Alluvium and peat**
Silt, sandy clay, and gravel, stratified; located in present drainageways. Peat and muck in marsh areas

GLACIAL

Pleistocene

Qo — **Outwash**
Sand and gravel, stratified; deposited as broad flood plains or in bedrock channels

Qt — **Till**
Clay, sand, silt, gravel, and cobbles, unstratified; forms a thin mantle (ground moraine) over bedrock, with ridges (end moraines) of uneven, thicker deposits

QUATERNARY

PREGLACIAL

Єss — **Sandstone**
Sandstone and weathered sandstone, shaly and sandy shale, fine- to coarse-grained, brown to light-gray, generally thin

CAMBRIAN

pЄu — **Crystalline rock and weathered crystalline rock (undifferentiated)**
Granite, gneiss, schist, quartzite, greenstone, and slate

PRECAMBRIAN

Contact
Dashed where approximately located

40
Line of equal thickness of unconsolidated deposits
Dashed where approximately located. Interval 20 feet

Surface-water divide

Base from State of Wisconsin Department of Resource Development, 1964

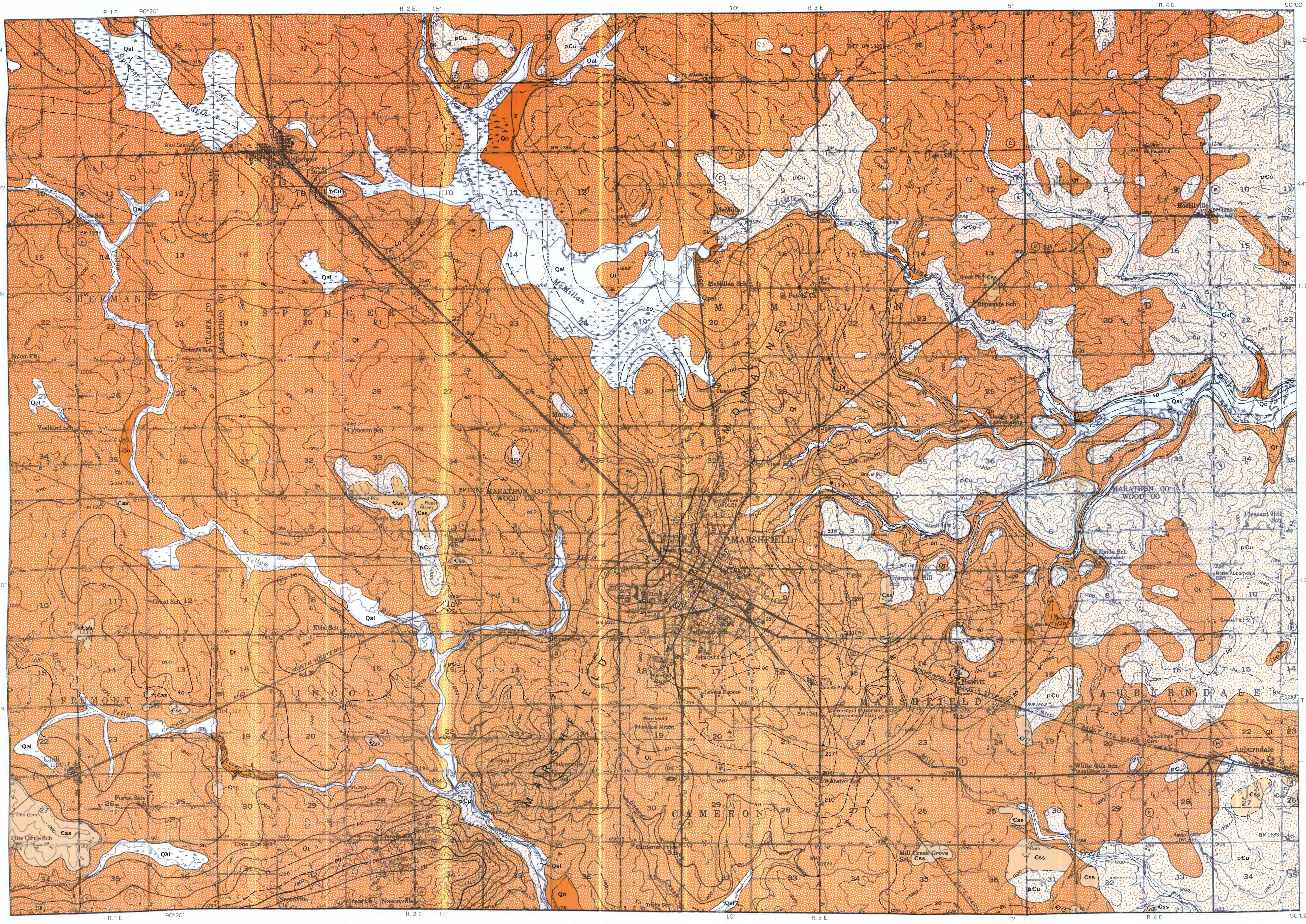
SCALE 1:125 000
2 0 2 4 6 8 10 MILES
2 0 2 4 6 8 10 KILOMETERS

Geology by Marvin G. Sherrill, 1969. Portage County after Holt (1965)

SURFICIAL GEOLOGIC MAP SHOWING THICKNESS OF UNCONSOLIDATED DEPOSITS IN CENTRAL WISCONSIN

523-120 O - 74 (In pocket) No. 2

PREPARED IN COOPERATION WITH THE
UNIVERSITY EXTENSION-THE UNIVERSITY OF WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY



Base from U.S. Geological Survey, 1:62,500 Marshfield and Granton, 1954; Abbotsford and Stratford, 1963

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Geology by Marvin G. Sherrill, 1969

EXPLANATION

POSTGLACIAL

Holocene

Qal

Alluvium and peat
Silt, sandy clay, and gravel, stratified; located in present drainageways. Peat and muck in marsh areas

GLACIAL

Pleistocene

Qo

Outwash
Sand and gravel, stratified; deposited as broad flood plains or in bedrock channels

Qt

Till
Clay, sand, silt, gravel, and cobbles, unstratified; forms a thin mantle (ground moraine) over bedrock, with ridges (end moraines) of uneven, thicker deposits

QUATERNARY

PREGLACIAL

Css

Sandstone
Sandstone and weathered sandstone, shaly and sandy shale, fine- to coarse-grained, brown to light-gray, generally thin

CAMBRIAN

pCu

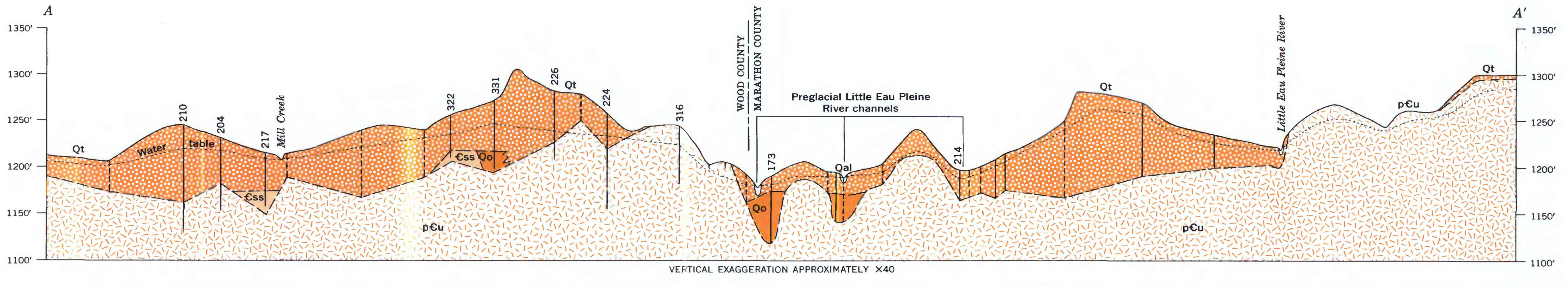
Crystalline rock and weathered crystalline rock (undifferentiated)
Granite, gneiss, schist, quartzite, greenstone, and slate

PRE-CAMBRIAN

Contact
Dashed where approximately located

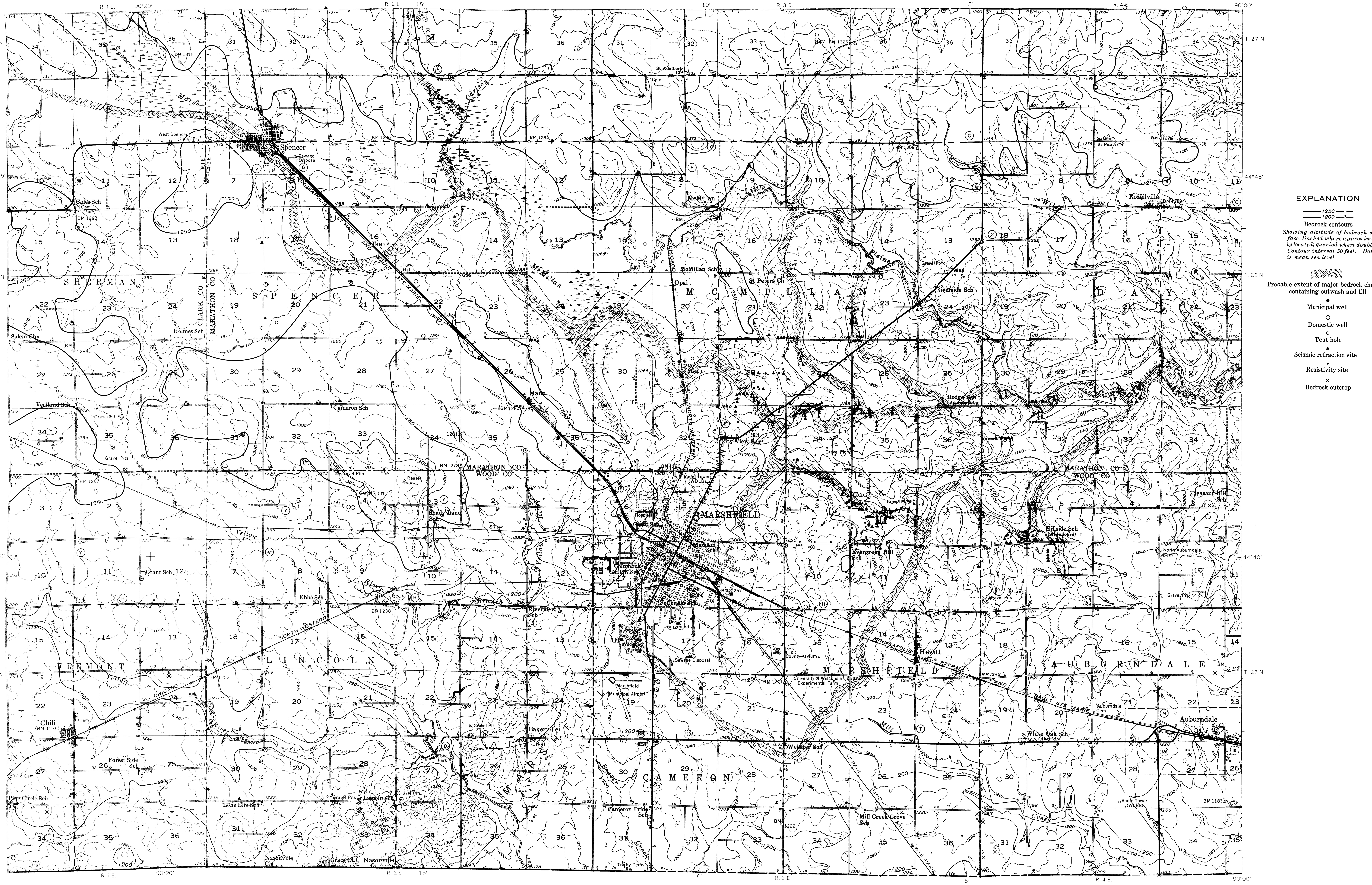
100
80
Line of equal thickness of unconsolidated deposits
Dashed where approximately located. Interval 20 feet

Municipal well and number
Domestic well and number
Seismic refraction site
Test hole
Resistivity site
A 173 210 A′
Line of geologic section
Showing control points



SURFICIAL GEOLOGIC MAP SHOWING THICKNESS OF UNCONSOLIDATED DEPOSITS NEAR MARSHFIELD, WISCONSIN

PREPARED IN COOPERATION WITH THE
UNIVERSITY EXTENSION-THE UNIVERSITY OF WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY



EXPLANATION

1250 — 1200 — ?
Bedrock contours
Showing altitude of bedrock surface. Dashed where approximately located; queried where doubtful. Contour interval 50 feet. Datum is mean sea level

Probable extent of major bedrock channels containing outwash and till

● Municipal well

○ Domestic well

○ Test hole

▲ Seismic refraction site

• Resistivity site

× Bedrock outcrop

Base from U.S. Geological Survey, 1:62,500 Marshfield and Granton, 1954; Abbotsford and Stratford, 1963

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

MAP SHOWING CONFIGURATION OF BEDROCK SURFACE AND DATA POINTS NEAR MARSHFIELD, WISCONSIN

522-120 O - 74 (In pocket) No. 4

PREPARED IN COOPERATION WITH THE
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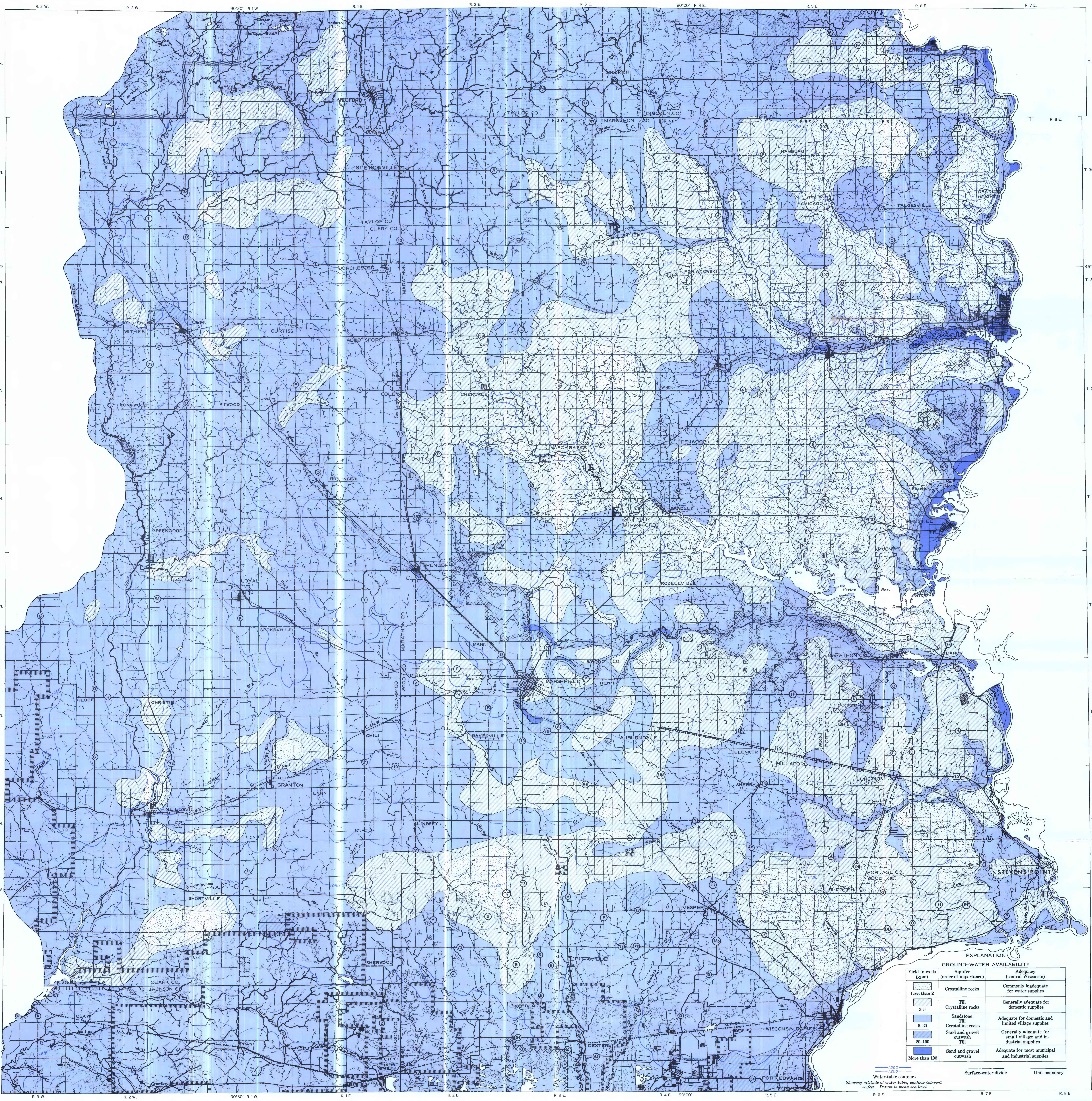
GEOLOGICAL AND NATURAL HISTORY SURVEY

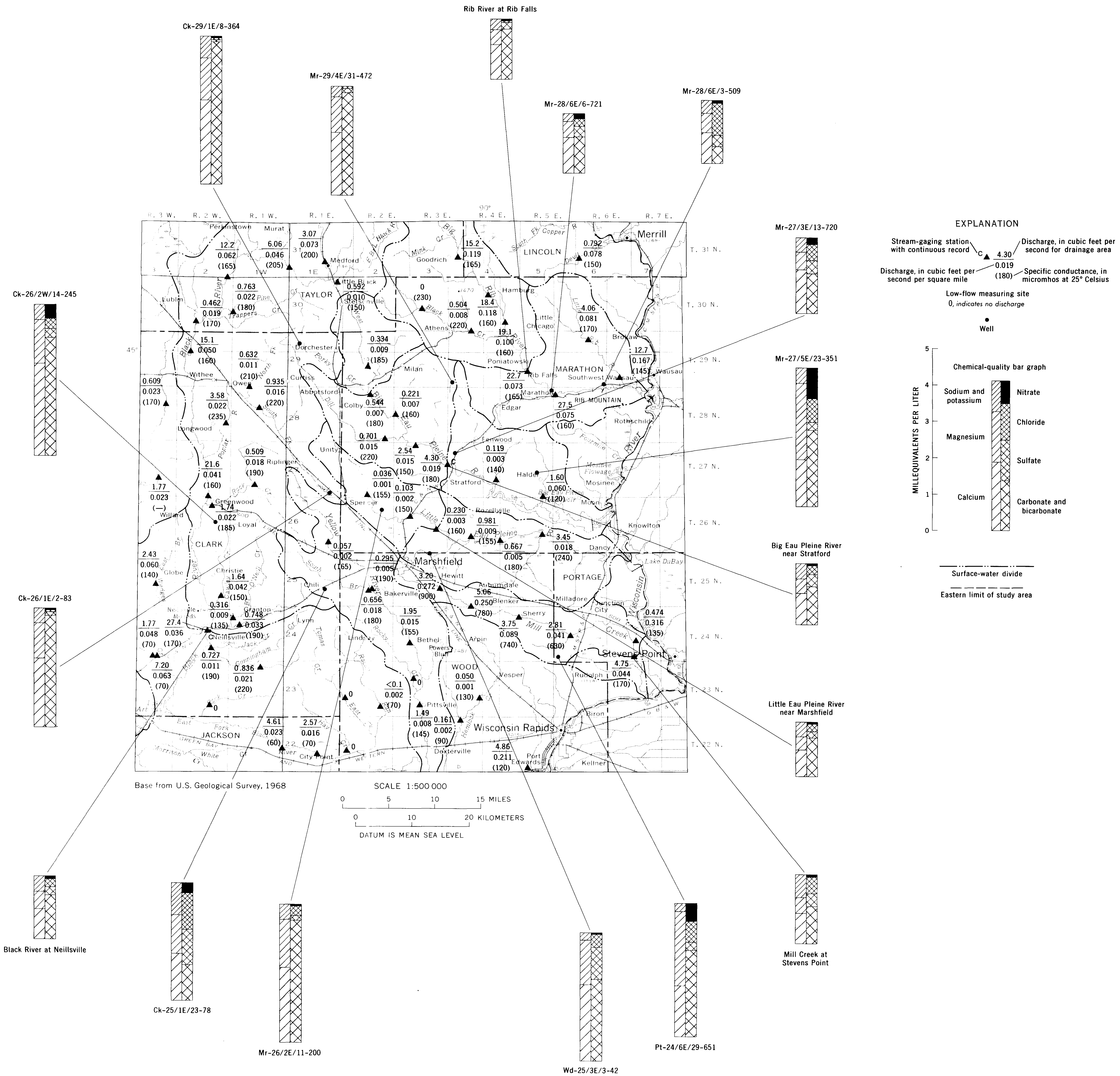


Base from State of Wisconsin Department of Resource Development, 1964

SCALE 1:125 000

Hydrology by Marvin G. Sherrill, 1970

MAP SHOWING CONFIGURATION OF WATER TABLE, 1968-69, AND AVAILABILITY OF GROUND WATER IN CENTRAL WISCONSIN



MAP SHOWING DATA ON LOW-FLOW CHARACTERISTICS OF STREAMS AND CHEMICAL QUALITY OF WATER FROM SELECTED STREAMS AND WELLS

522-120 O - 74 (In pocket) No. 6