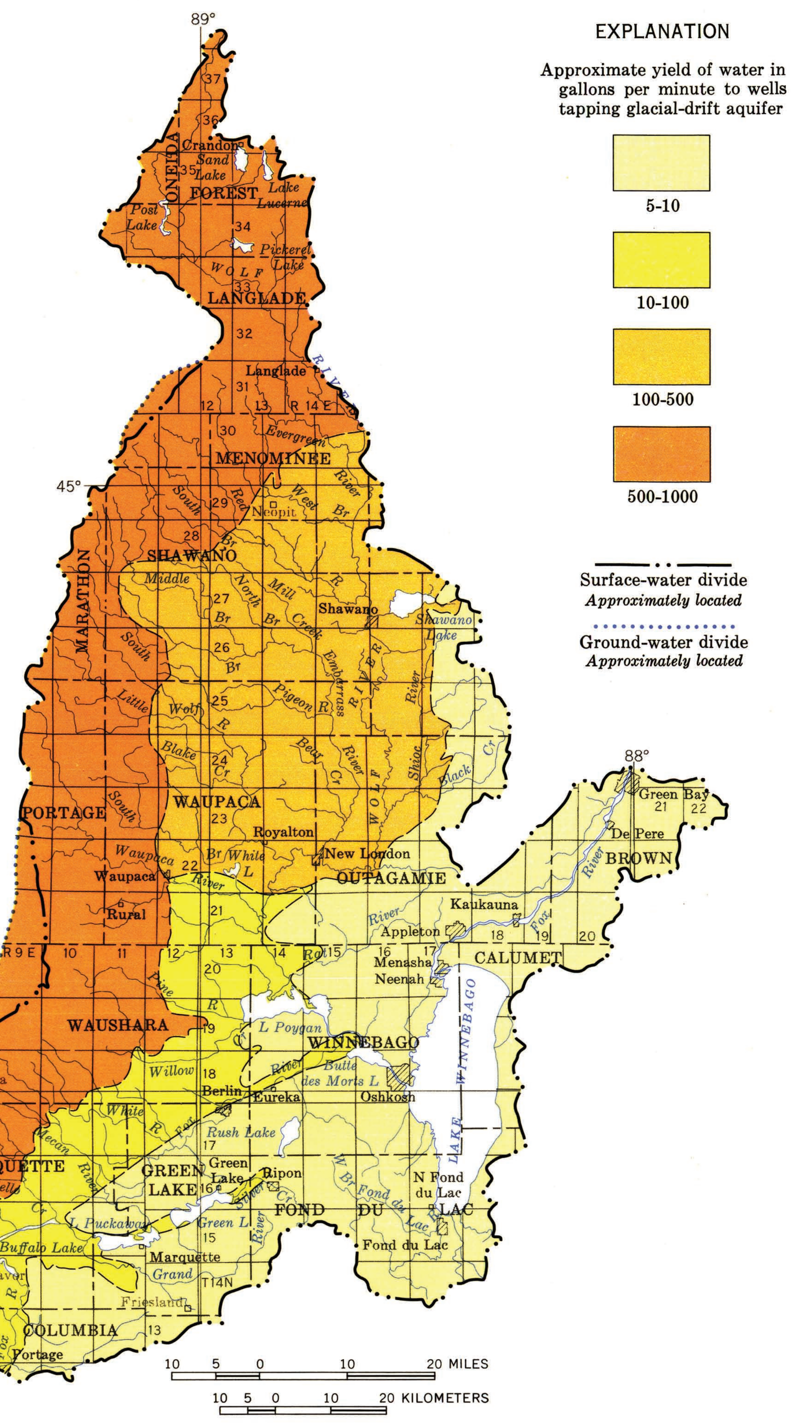
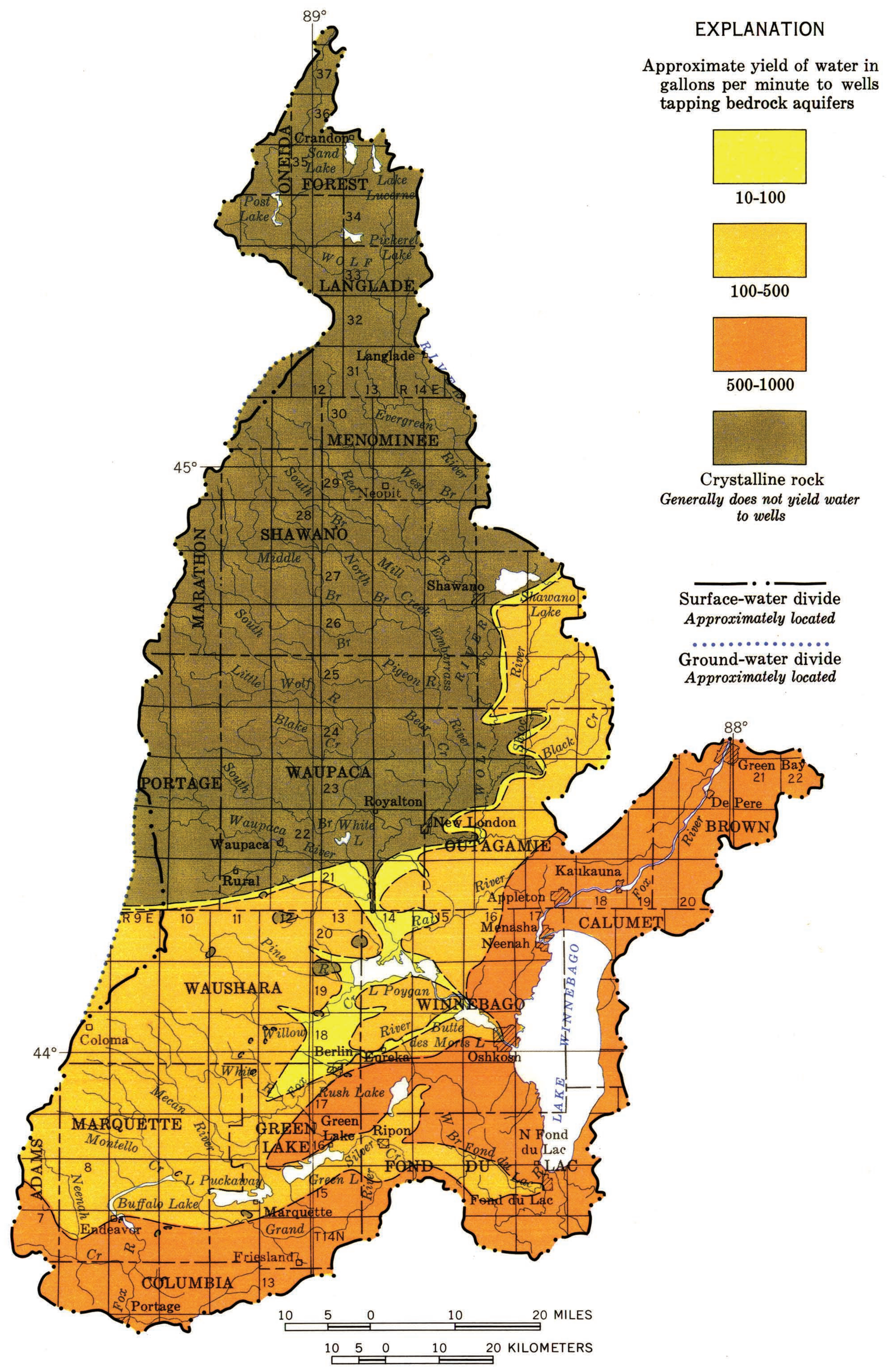
GROUND WATER



GLACIAL-DRIFT AQUIFERS



BEDROCK AQUIFERS

AVAILABILITY OF GROUND WATER

Water availability from glacial deposits differs greatly within small areas. The best glacial-drift aquifers are thick sands and gravels laid down by melt water from glaciers (outwash). Clay and silt that were deposited in glacial lakes restrict water movement and are not good aquifers.

The extensive outwash deposits in the western and northern parts of the Fox-Wolf basin generally are thick permeable sands and gravels that form excellent aquifers. Outwash deposits are thin but permeable in the central part of the basin in parts of Waupaca, Shawano, and Menominee Counties. Yields of 500 to 1,000 gpm (gallons per minute) are common throughout the outwash area, except in the thin-drift area where yields generally range from 100 to 500 gpm. Terminal and recessional moraines in this outwash area also are permeable because they contain large amounts of sand and gravel.

Thick glacial deposits fill preglacial river channels in the central part of the basin between Portage and Shawano (sheet 1). Although these deposits are predominantly lake clays, buried beds of sand and gravel may occur in the base. In Outagamie and Shawano Counties these sand and gravel beds may yield from 100 to 500 gpm to properly constructed wells. In other areas, notably Winnebago and Waushara Counties, yields may be much lower, ranging from 10 to 100 gpm.

Glacial-drift deposits generally are thin and are poorly permeable in the eastern and southern parts of the basin and yield only about 5 to 10 gpm to wells. Ground water in these areas generally is obtained from wells penetrating bedrock aquifers.

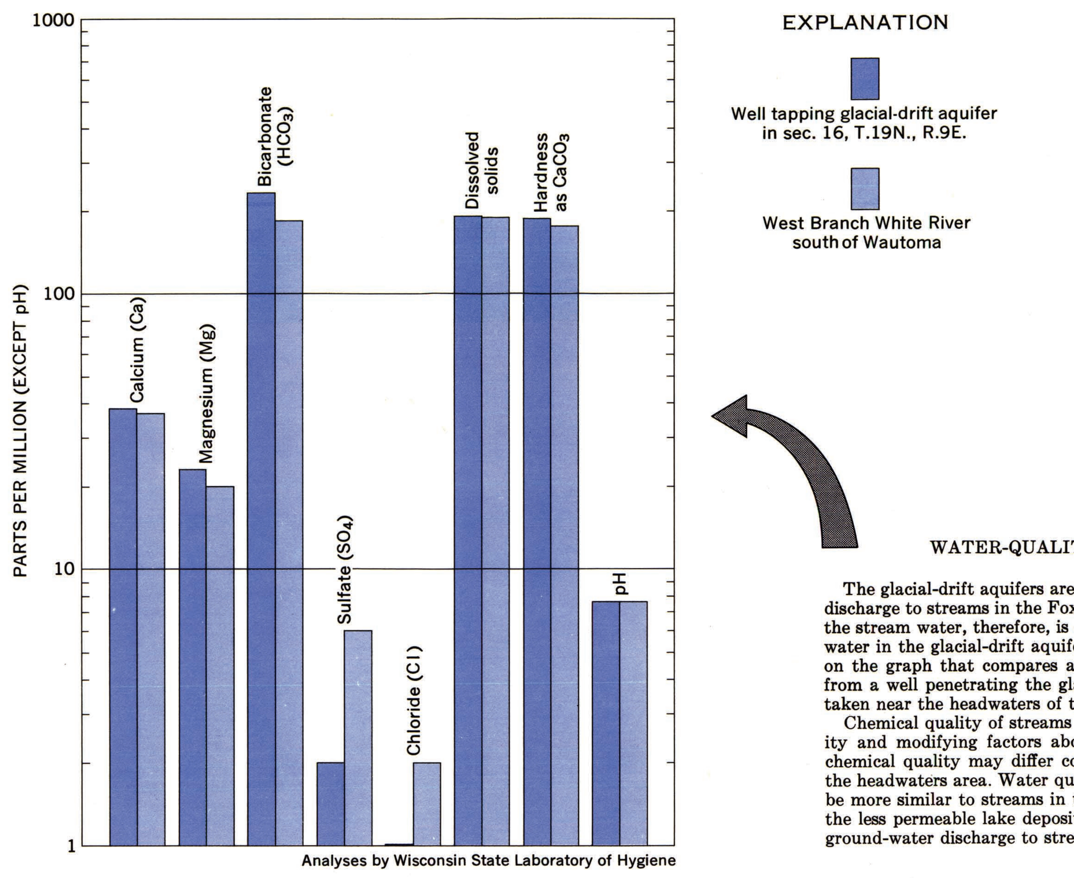
Bedrock aquifers, formed by consolidated sedimentary rocks, are present only in the southern half of the Fox-Wolf basin and overlie impermeable crystalline rocks.

The sandstones of Cambrian age, the Prairie du Chien Group, and the St. Peter Sandstone form the principal bedrock aquifer in the basin. In general, these rock units are hydraulically connected and act as one aquifer. Yields to properly constructed wells commonly range from 500 to 1,000 gpm in the southern and eastern parts of the basin. As the aquifer thins toward the northwest, well yields diminish, ranging from 100 to 500 gpm. Where the aquifer is very thin, such as in the preglacial river valley and along the margins of the sandstone, well yields range from 10 to 100 gpm.

The Platteville-Galena unit generally yields less than 50 gpm to wells, but is important as an aquifer for domestic and farm wells. This unit tends to prevent the vertical movement of water, causing artesian pressures in the underlying sandstone aquifer.

The Maquoketa Shale generally does not yield water. The shale retards vertical movement of water, causing artesian pressures in the underlying units.

The Niagara Dolomite is an important aquifer east of the Fox-Wolf basin, but it is unimportant within the basin because of its small areal extent. Small yields, possibly 50 to 100 gpm, can be obtained locally.



WATER-QUALITY RELATIONSHIPS

WATER-QUALITY RELATIONSHIPS

The glacial-drift aquifers are the principal source of ground-water discharge to streams in the Fox-Wolf basin. The chemical quality of the stream water, therefore, is closely associated with the quality of water in the glacial-drift aquifers. Chemical similarity is illustrated on the graph that compares analyses of water from a stream and from a well penetrating the glacial-drift aquifers. All samples were taken near the headwaters of the stream.

Chemical quality of streams is a composite of ground-water quality and modifying factors above the sampling site. Downstream, chemical quality may differ considerably from chemical quality in the headwaters area. Water quality in the glacial-drift aquifers may be more similar to streams in the permeable outwash areas than in the less permeable lake deposits because of the greater quantity of ground-water discharge to streams in the outwash areas.

WATER MOVEMENT

Ground water moves through aquifers from areas of recharge to areas of discharge, or, down the hydraulic gradient from areas of high head to areas of low head. Differences in water head within an aquifer are defined and measured as differences in altitude of the piezometric surface. This surface is the height to which water will rise in a well tapping a confined aquifer and it is the water table in an unconfined aquifer. Piezometric maps of parts of the area appeared in several publications (Berkstresser, 1964; Harder and Drescher, 1954; Holt, 1965; Knowles, 1964; LeRoux, 1957; Newport, 1962; Olcott, 1966; and Summers, 1965) and additional data were collected in the field. These maps and information were the basis for the piezometric map below. Ground-water movement is perpendicular to the contours shown on the map.

The contours on the western side of the upper Fox and Wolf Rivers and in the northern part of the basin generally define water-table conditions in the glacial-drift aquifers. Ground-water movement in the glacial-drift aquifers in the western and northern parts of the basin generally is southeastward toward the Wolf and upper Fox Rivers. Locally, ground water moves toward nearby rivers and streams. The contours also define the ground-water divide on the western side of the basin. The ground-water divide is considerably west of the surface water divide (formed by the terminal moraine) along much of the western side of the basin, especially in Portage County (Holt, 1965). The ground-water and surface-water divides nearly coincide on the eastern side of the basin north of Shawano.

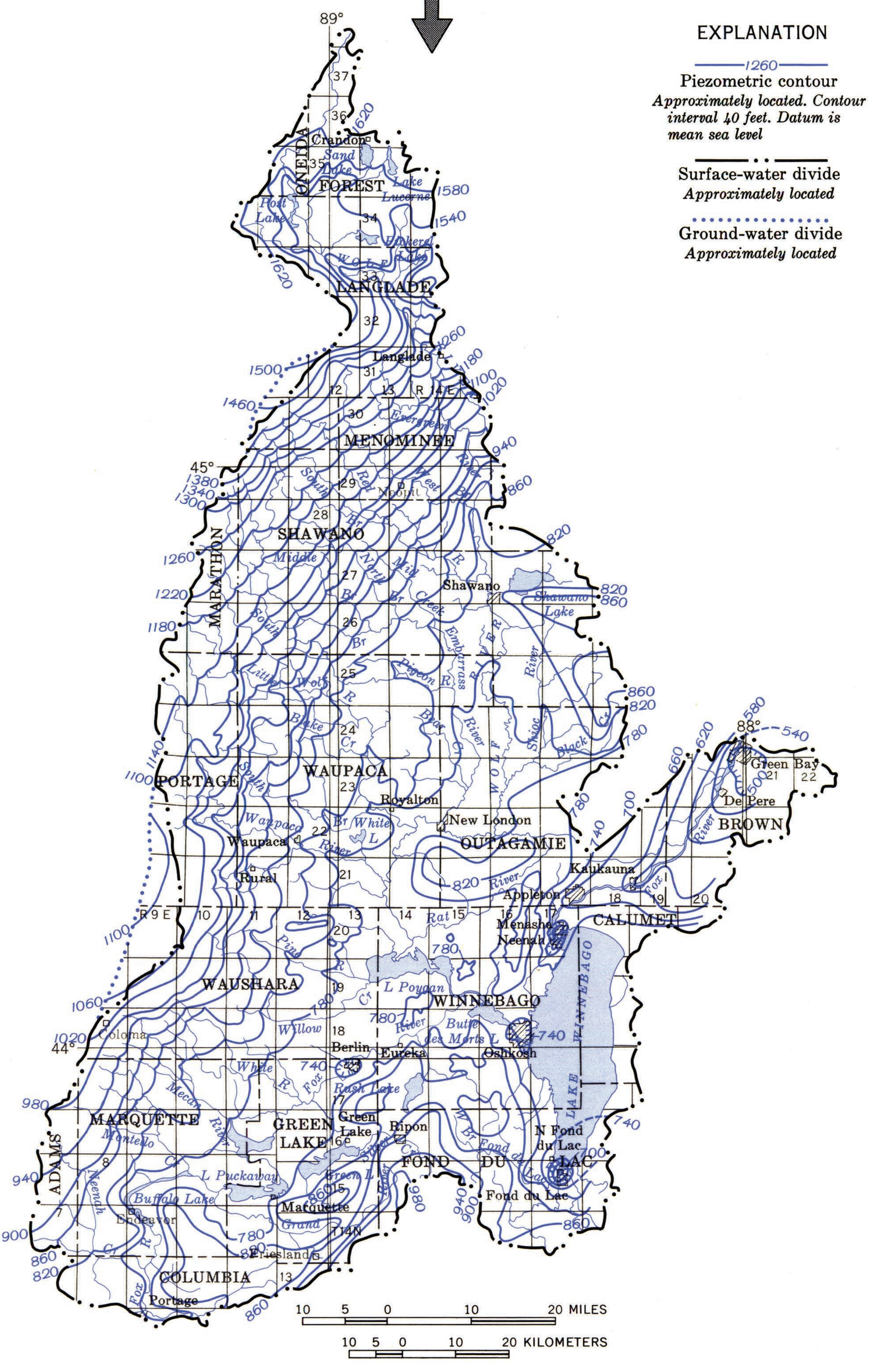
The hydraulic gradient of the glacial-drift aquifers, indicated by the spacing of the contours on the piezometric map, generally is steep from the basin divide eastward to about the 860-foot contour. The gradient flattens between the 860-foot contour and the Wolf and Fox Rivers because ground water is discharging to the rivers and wetlands. The aquifer also thickens in this area, the site of the preglacial river valley, thus increasing ground-water storage and the aquifers transmissibility. The flat gradient in parts of the lake area in the northern Wolf basin probably reflects a relatively flat topography and may partially be caused by ground-water discharge to lakes and wetlands.

The piezometric surface of the sandstones in the southwestern part of the basin probably is similar to that shown for the glacial-drift aquifers. Ground water moves through the sandstones from the divide to the Wolf and upper Fox Rivers.

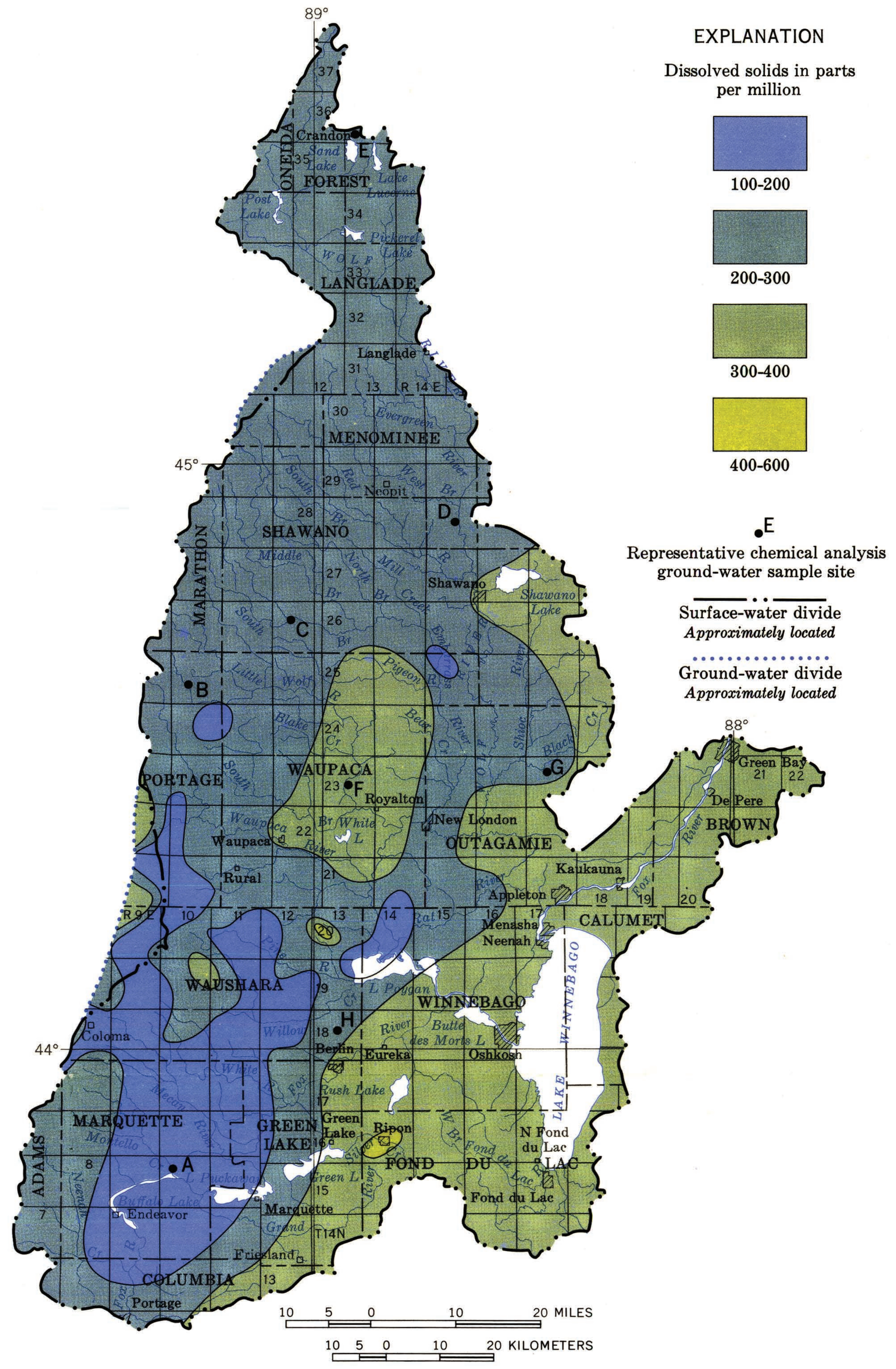
Contours on the eastern side of the rivers show the piezometric surface of the confined sandstone aquifer. Water in the sandstone aquifer east and south of the Wolf and upper Fox Rivers moves toward these rivers, Lake Winnebago, and the lower Fox River. Divides separate water movement to these principal surface-water bodies. For example, in the area west of Neenah-Menasha, water moves westward and southward toward the Wolf River and Butte des Morts Lake and eastward toward Lake Winnebago. Some water in the sandstone aquifer probably moves under Lake Winnebago and the Niagara escarpment toward Lake Michigan, although data are lacking to prove this.

The effects of large-scale municipal and industrial pumpage from the sandstone aquifer can be seen at Fond du Lac, Oshkosh, Neenah-Menasha, Green Bay, and Berlin. Pumpage increases the hydraulic gradient locally, creating a cone of depression in the piezometric surface that causes water to move through the aquifer toward the center of pumpage.

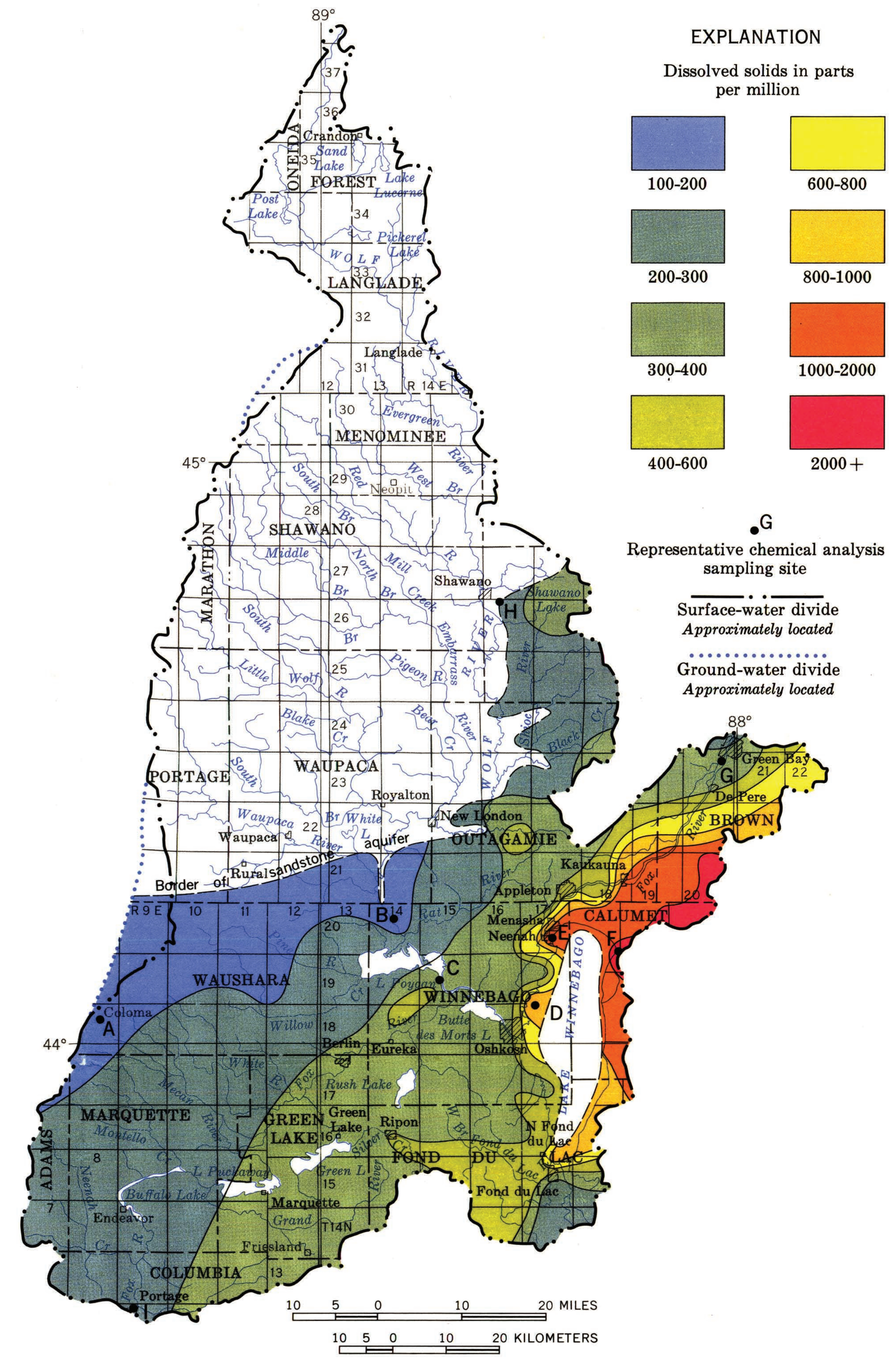
Water movement in the Niagara Dolomite adjacent to the eastern edge of Lake Winnebago is westward toward Lake Winnebago. The water moves under a steep gradient because of the high topographic relief. Many springs located along the base of the escarpment discharge water from the Niagara Dolomite.



GENERALIZED PIEZOMETRIC SURFACE



GLACIAL-DRIFT AQUIFERS



BEDROCK AQUIFERS

QUALITY OF GROUND WATER

Water in the glacial-drift aquifers generally has dissolved solids that range from 100 to 300 ppm (parts per million) over much of the basin, and as much as 400 ppm in the eastern side of the basin. Higher concentrations are found locally. The distribution of dissolved solids in the glacial-drift aquifers is shown on the map above, and selected chemical analyses are shown on the table below. The quality of water from the glacial-drift aquifers probably is controlled by the type of water, type of rocks, and the rate of water movement. The latter factor is influenced to a large degree by differences in the permeability of the aquifers. High concentrations of dissolved solids are generally in the eastern part of the basin where clayey lake deposits and ground moraine predominate. Dissolved mineral concentrations generally are least in the permeable outwash areas in the western and northern parts of the basin.

Water in the glacial-drift aquifers is of the calcium magnesium bicarbonate type. It is moderately hard and excessive iron is a problem in much of the basin. Water from these aquifers generally is suitable for most domestic, municipal, and industrial uses.

The mineral content of water in bedrock aquifers generally increases to the southeast. A generalized map of the distribution of dissolved solids in water in these aquifers is shown above. Selected chemical analyses of water from the bedrock aquifers are listed in the table below and are keyed to the locations shown on the map.

On the western side of the basin mineral content of the water generally is low, but it increases slightly toward the area of discharge. Dissolved solids range from 100 to 300 ppm in this area.

East of the Fox and Wolf Rivers dissolved solids in water from bedrock aquifers generally range from 300 to 400 ppm.

Near Lake Winnebago dissolved solids in the water range from 800 to more than 2,000 ppm, increasing toward the east.

Representative chemical analyses A through F, listed on the table, show the change in chemical quality of water in the bedrock aquifers from west to east. The water is of the calcium magnesium bicarbonate type in most of the area, but high concentrations of sulfate, chloride, and sodium are present on the eastern side of the basin. The water is hard and in some places iron is a problem. Except in the highly mineralized zone on the eastern side of the basin, quality of water from the bedrock aquifers generally is suitable for most domestic, municipal, and industrial uses. However, treatment may be required for special purposes.

QUALITY OF WATER FROM SELECTED WELLS

[Results in parts per million except pH. Asterisk (*) indicates analysis by Wisconsin State Laboratory of Hygiene, remaining samples analyzed by the U.S. Geological Survey]

Map key	Well owner	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
								Bedrock aquifers										
Wells A*	Village of Coloma	9/5/45	----	0.0	----	37	19	----	----	205	0.5	4.0	T[1]	----	178	152	----	7.6
B	F. Lange	6/15/62	----	.2	----	18	5	----	----	126	16	2	----	----	130	64	----	8.0
C*	Village of Winneconne	11/14/47	----	.05	.08	81	41	----	----	444	14	8	----	----	368	355	----	7.3
D	Winnebago State Hospital	4/16/65	8.7	1.1	.08	229	23	39	4.4	224	439	64	.9	.1	940	667	1270	7.4
E	Galloway Milk Company	4/16/65	12	1.1	1.0	344	34	12	3.2	270	736	8.5	.6	.1	1400	1000	1570	7.4
F*	State of Wisconsin	5/--/65	----	.34	----	----	----	615	----	161	450	1050	----	----	----	1060	----	7.1
G	City of DePere	5/2/65	6.5	.03	.04	57	29	16	3.6	256	50	17	2.0	.0	318	261	540	7.7
H*	City of Shawano	11/15/49	----	0.0	0.0	59	28	----	----	300	3.0	6.0	T[1]	----	290	270	----	7.6
I	City of Portage	6/4/65	13	.41	.17	44	22	7	1.6	208	36	10	.2	3.2	247	201	405	7.2
								Glacial-drift aquifers										
Wells A*	Village of Montello	12/6/63	----	.04	.05	40	21	----	----	207	6.5	1.5	.05	2.6	192	188	----	7.9
B	Public School Dist. #5 at Rosholt	6/9/53	----	1.8	----	46	17	3.3	1.1	223	1.2	8.0	.3	.4	220	186	----	7.5
C*	Village of Tigerton	4/15/57	----	0.0	0.0	44	22	----	----	205	15.0	6.0	.3	----	256	206	----	7.4
D*	Village of Keshena	6/30/65	----	.8	.08	42	18	----	----	216	2.0	----	.25	.12	210	176	----	7.6
E*	Village of Crandon	5/4/65	----	1.02	.44	14.7	36	5.1	1.5	191	12	20	.05	----	222	184	----	7.3
F*	Village of Manawa	2/5/58	----	----	0.0	52	42	----	----	351	13	11	.6	----	314	280	----	7.8
G*	Village of Black Creek	9/22/60	----	.1	0.0	23.1	18	22	----	224	9.2	1.5	.2	----	208	146	----	7.8
H*	Lester Malnory	11/7/57	----	T[1]	----	14	2.4	----	----	183	20	1.5	.35	----	214	40	----	8.7

[1]Trace

Base from U.S. Geological Survey
State base map, 1911

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WATER RESOURCES OF WISCONSIN–FOX-WOLF RIVER BASIN

By
Perry G. Olcott

1968