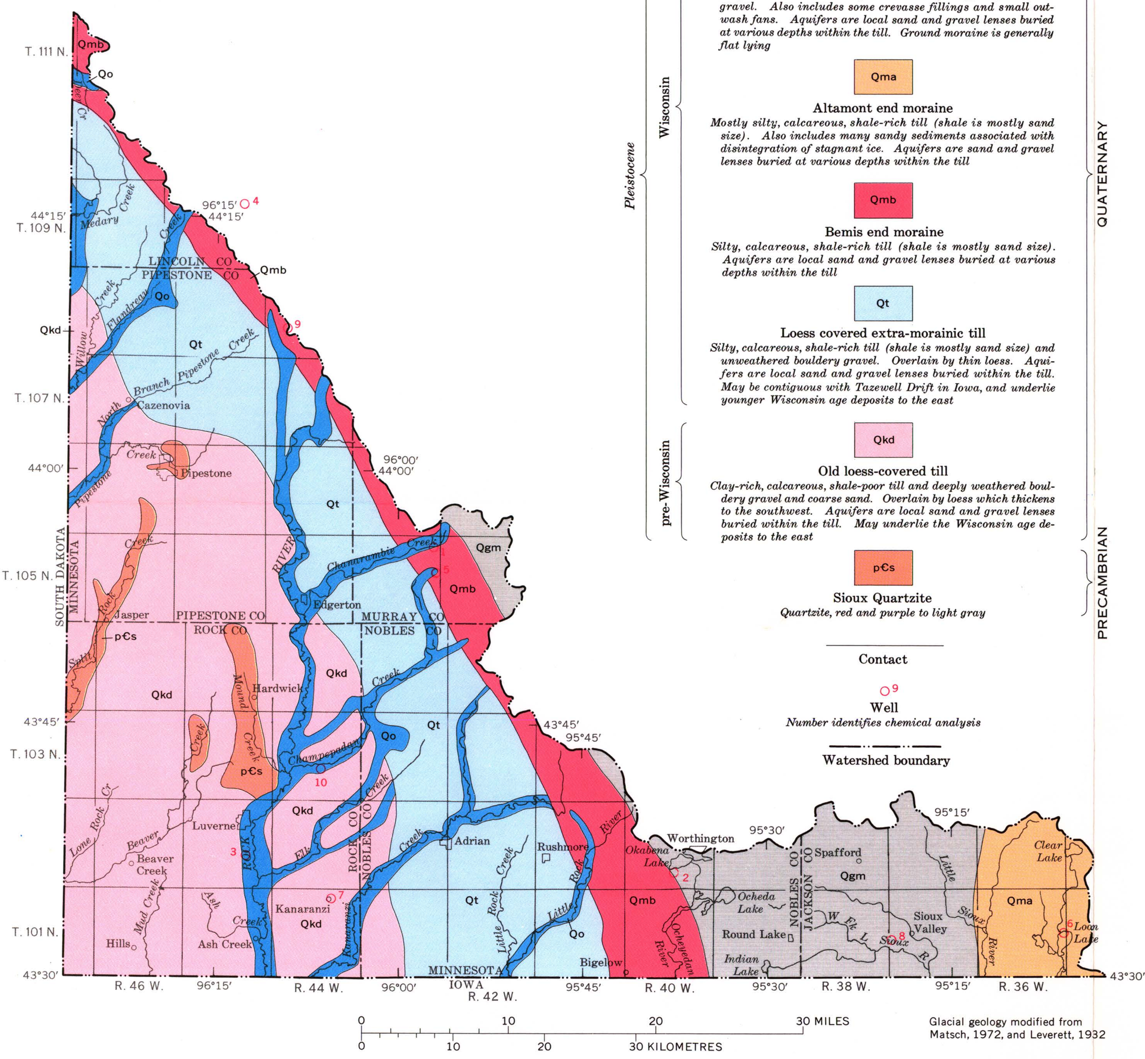
GROUND WATER

The ground-water system involves the interrelationships of water with the thickness, hydrologic characteristics, and areal extent of the geologic units. The system is continuously recharged in some places and it discharges in others and is always tending to adjust, sometimes in minor degrees, to climatic variations and withdrawal from wells.

GLACIAL DEPOSITS

GLACIAL OUTWASH SAND AND GRAVEL IS AN IMPORTANT SURFICIAL AQUIFER ALONG THE ROCK RIVER AND SEVERAL MAJOR CREEKS AND GENERALLY RANGES IN THICKNESS FROM 0 TO 40 FEET (12 METRES).—*The Bemis moraine and the area westward are well drained having few ponds or lakes. Eastward, the Altamont moraine and the ground moraine are poorly drained, having many lakes and ponds. All the moraines contain buried outwash aquifers except on the quartzite high in Rock and Pipestone Counties. Buried aquifers can be located and delineated only by extensive test drilling.*



Glacial geology modified from Matsch, 1972, and Leverett, 1932

EXPLANATION

Qo — Glacial outwash
Mostly shallow bouldery sand and gravel in glacial meltwater channels; includes some Holocene valley fill. Aquifers are near land surface and generally located along main drainages

Qgm — Ground moraine
Mostly silty, calcareous, shale-rich till (shale is mostly sand size). Till is an unstratified mixture of clay, silt, sand, and gravel. Also includes some crevasse fillings and small outwash fans. Aquifers are local sand and gravel lenses buried at various depths within the till. Ground moraine is generally flat lying

Qma — Altamont end moraine
Mostly silty, calcareous, shale-rich till (shale is mostly sand size). Also includes many sandy sediments associated with disintegration of stagnant ice. Aquifers are sand and gravel lenses buried at various depths within the till

Qmb — Bemis end moraine
Silty, calcareous, shale-rich till (shale is mostly sand size). Aquifers are local sand and gravel lenses buried at various depths within the till

Qt — Loess covered extra-morainic till
Silty, calcareous, shale-rich till (shale is mostly sand size) and unweathered bouldery gravel. Overlain by thin loess. Aquifers are local sand and gravel lenses buried within the till. May be contiguous with Tazewell Drift in Iowa, and underlie younger Wisconsin age deposits to the east

(Wisconsin) (Pleistocene) QUATERNARY

Qkd — Old loess-covered till
Clay-rich, calcareous, shale-poor till and deeply weathered bouldery gravel and coarse sand. Overlain by loess which thickens to the southwest. Aquifers are local sand and gravel lenses buried within the till. May underlie the Wisconsin age deposits to the east

(pre-Wisconsin)

p€s — Sioux Quartzite
Quartzite, red and purple to light gray

PRECAMBRIAN

Contact

Well
Number identifies chemical analysis

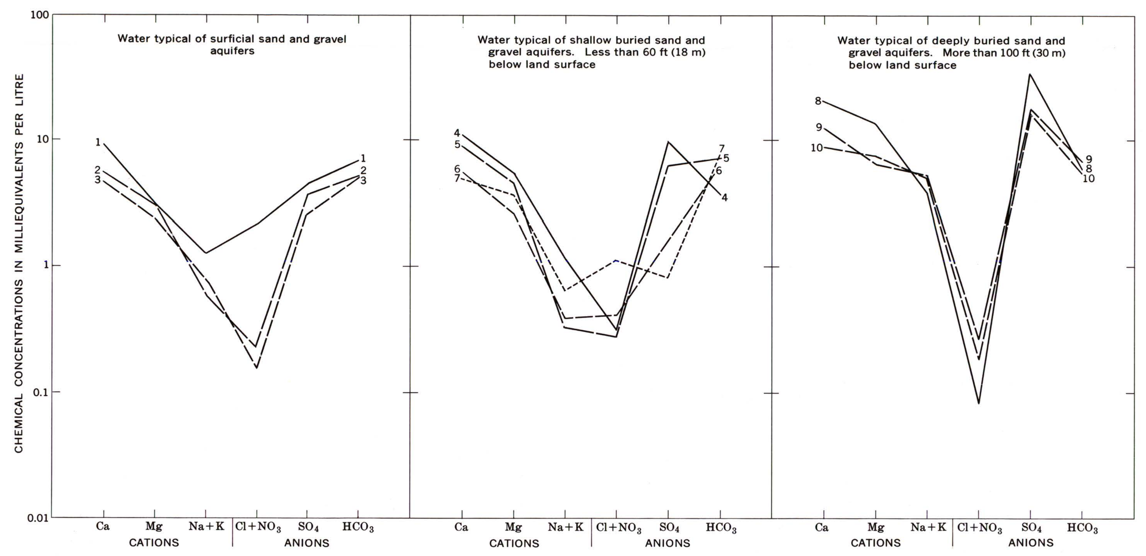
Watershed boundary

QUALITY OF WATER IN GLACIAL AQUIFERS IS AFFECTED BY TYPE OF DEPOSIT, DEPTH, SURFICIAL DRAINAGE, AND LOCATION.—*Water of relatively good quality (wells 2, 3, 6, and 7) is found in surficial sand and gravel (stream alluvium, and glacial outwash) and shallow buried sand and gravel aquifers. Wells 1, 4, 6, and 7 contain significant concentrations of nitrates and larger concentrations of sodium plus potassium (Na+K) and chloride plus nitrate ($Cl+NO_3$) than other shallow wells indicating contamination. Shallow aquifers (wells 1, 4, and 5) in the well drained Wisconsin Till contain water with more dissolved solids and more sulfates than water (wells 3 and 7) in the pre-Wisconsin loess-covered till.*

Water containing the largest concentrations of dissolved solids is found in wells 8, 9, and 10 finished in deep drift that receives recharge from overlying till. This water contains higher concentrations of sulfates and sodium than water from shallower glacial deposits.

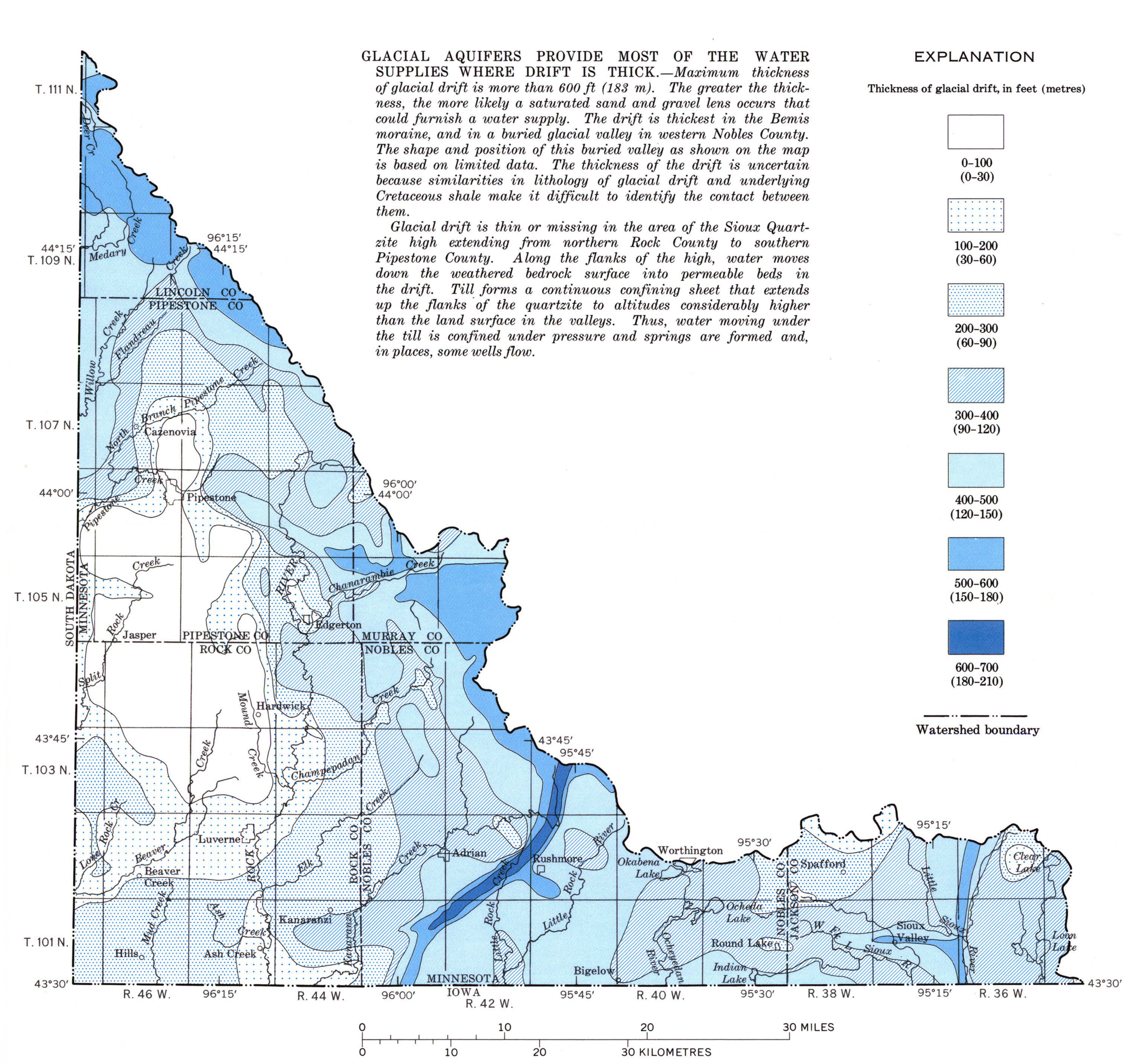
QUALITY OF WATER DATA FROM WELLS IN GLACIAL AQUIFERS

Well	Aquifer	Depth (ft)	Dissolved solids (mg/l)	Hardness as calcium carbonate (mg/l) Total	Non-carbonate	Iron (mg/l)	Manganese (mg/l)	Nitrate (mg/l)
1	Surficial sand and gravel	30	830	630	280	0.58	<0.02	62
2		30	552	450	180	1.2	1.2	.7
3		55	467	360	100	1.7	.31	.1
4	Shallow buried sand and gravel	40	1,070	820	640	.11	.00	57
5		50	748	670	310	3.4	--	.9
6		48	467	410	86	.06	.00	13
7		55	502	430	54	.02	.00	13
8	Deeply buried sand and gravel	205	2,500	1,700	1,400	6.0	5.1	1.9
9		362	1,520	960	610	10	.27	.2
10		138	1,370	830	550	2.5	.18	2.8



GLACIAL AQUIFERS PROVIDE MOST OF THE WATER SUPPLIES WHERE DRIFT IS THICK.—*Maximum thickness of glacial drift is more than 600 ft (183 m). The greater the thickness, the more likely a saturated sand and gravel lens occurs that could furnish a water supply. The drift is thickest in the Bemis moraine, and in a buried glacial valley in western Nobles County. The shape and position of this buried valley as shown on the map is based on limited data. The thickness of the drift is uncertain because similarities in lithology of glacial drift and underlying Cretaceous shale make it difficult to identify the contact between them.*

Glacial drift is thin or missing in the area of the Sioux Quartzite high extending from northern Rock County to southern Pipestone County. Along the flanks of the high, water moves down the weathered bedrock surface into permeable beds in the drift. Till forms a continuous confining sheet that extends up the flanks of the quartzite to altitudes considerably higher than the land surface in the valleys. Thus, water moving under the till is confined under pressure and springs are formed and, in places, some wells flow.



EXPLANATION

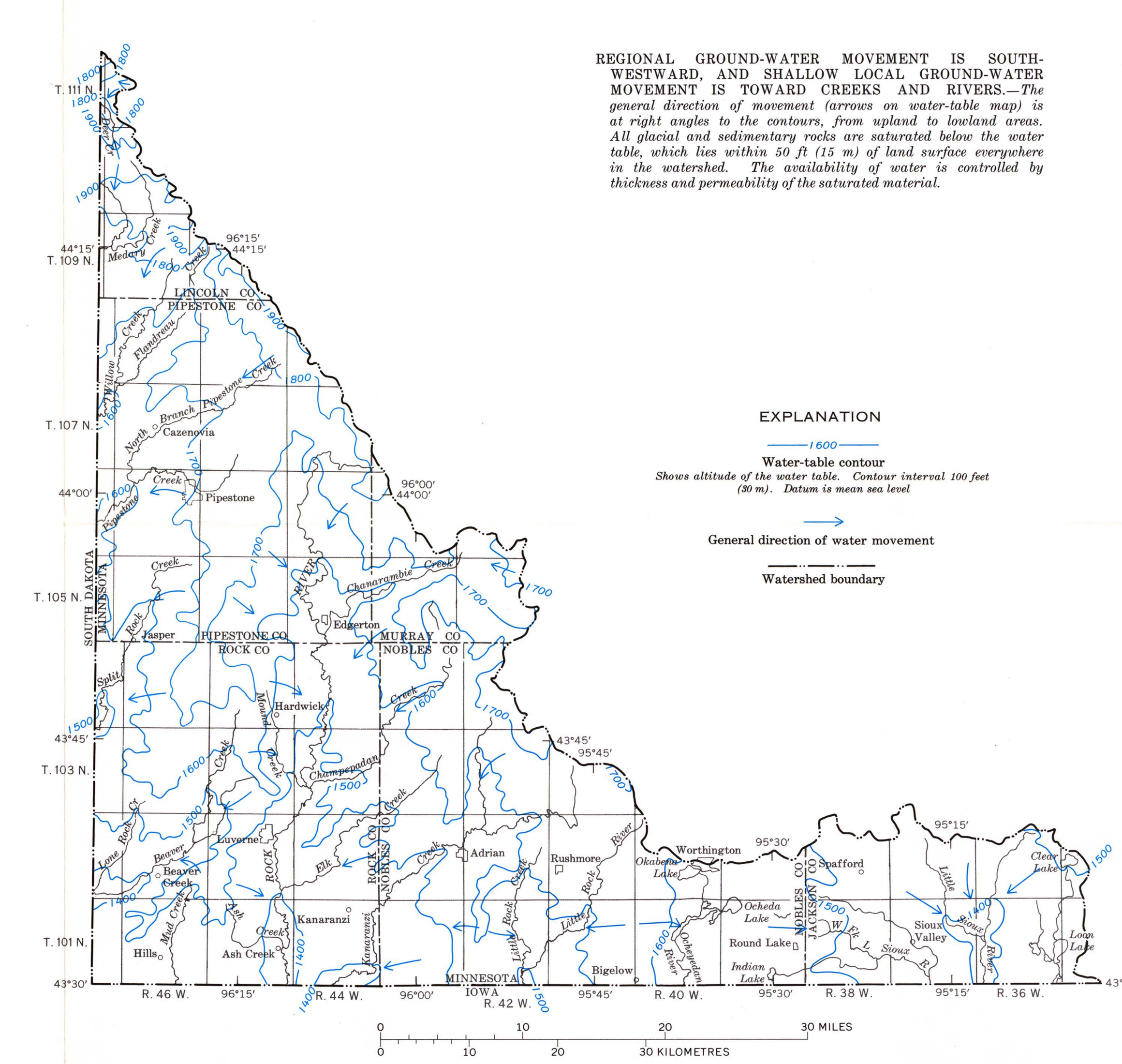
Thickness of glacial drift, in feet (metres)

- 0-100 (0-30)
- 100-200 (30-60)
- 200-300 (60-90)
- 300-400 (90-120)
- 400-500 (120-150)
- 500-600 (150-180)
- 600-700 (180-210)

Watershed boundary

HYDROLOGY

REGIONAL GROUND-WATER MOVEMENT IS SOUTHWESTWARD, AND SHALLOW LOCAL GROUND-WATER MOVEMENT IS TOWARD CREEKS AND RIVERS.—*The general direction of movement (arrows on water-table map) is at right angles to the contours, from upland to lowland areas. All glacial and sedimentary rocks are saturated below the water table, which lies within 50 ft (15 m) of land surface everywhere in the watershed. The availability of water is controlled by thickness and permeability of the saturated material.*



EXPLANATION

—1600— Water-table contour
Shows altitude of the water table. Contour interval 100 feet (30 m). Datum is mean sea level

→ General direction of water movement

Watershed boundary

BEDROCK

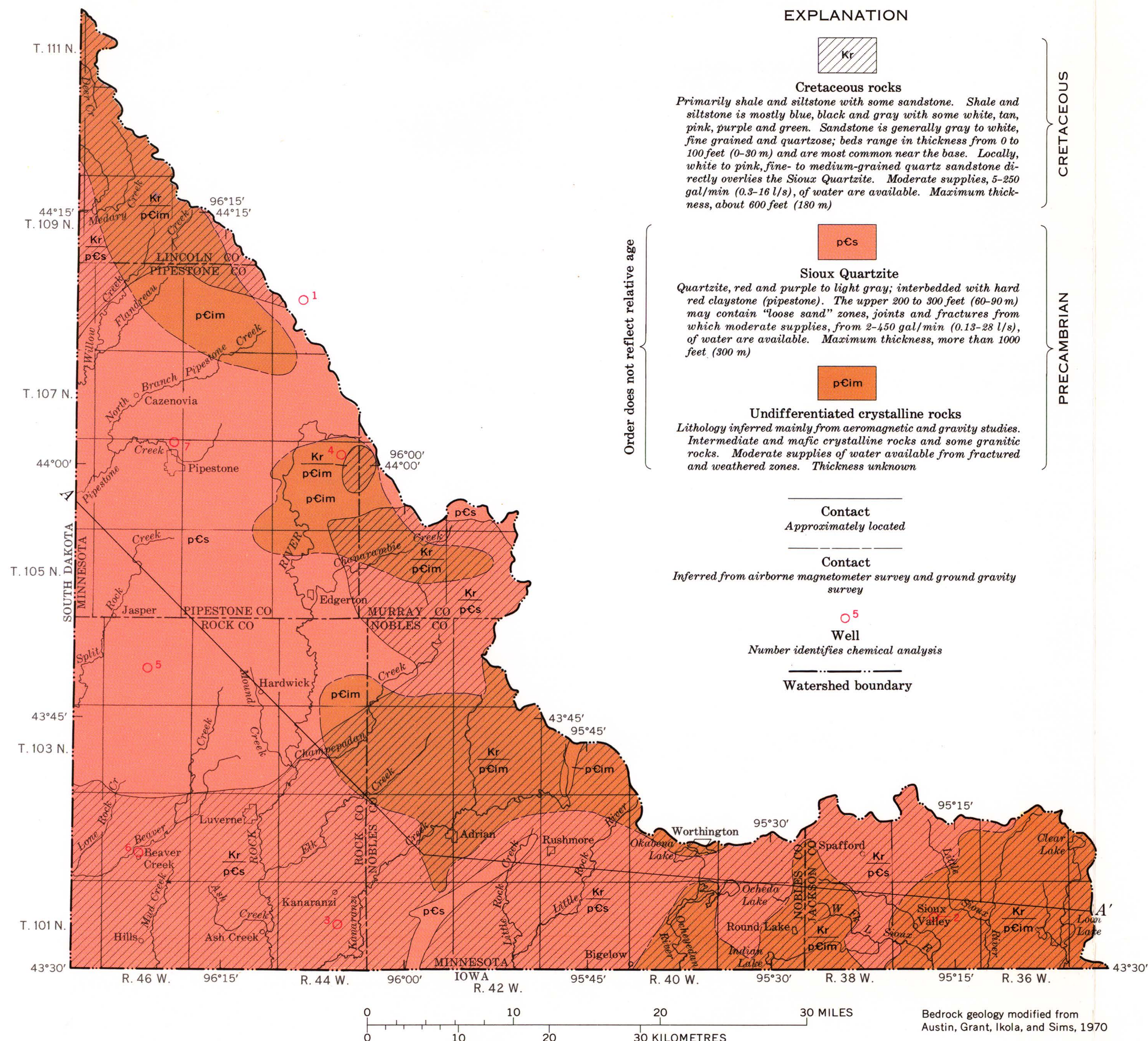
SIOUX QUARTZITE IS THE MAIN AQUIFER ON THE QUARTZITE HIGH IN THE WEST-CENTRAL PART OF THE WATERSHED, BUT FEW WELLS TAP BEDROCK ELSEWHERE IN THE WATERSHED.—*The weathered zone at the quartzite surface is generally permeable and provides a fairly reliable source of water. Some loose sandstone zones as much as 25 ft (8 m) thick, below as much as 200 ft (60 m) of quartzite have permeability that may have resulted from fracturing and subsequent solution of cementing material by percolating water. Some differences in amount or kind of original cementing material was probably a factor in formation of these deep, loose sandstones. The hydrologic characteristics of Precambrian rocks at low altitudes, away from the quartzite high, are poorly known because drill-hole data are lacking.*

The average depth to quartzite in wells in Rock and Pipestone Counties is about 110 ft (34 m) and the maximum reported is 496 ft (151 m). The average thickness of quartzite penetrated is 150 ft (46 m), and the maximum is 500 ft (152 m). Well yields from the quartzite range from zero to 450gal/min (28 l/s).

Sioux Quartzite underlies about 68 percent of the watershed. In about half of this area, it lies directly below glacial drift; in the other half, it lies directly below Cretaceous rocks.

Few wells are known to obtain water from Precambrian mafic and intermediate crystalline or granitic rocks. These rocks have low primary permeability, but fracturing and weathering create secondary permeability. In some areas, a weathered zone at the rock surface yields water. Contacts between Precambrian rock types were determined principally by geophysical methods.

Cretaceous rocks are present in about 60 percent of the watershed; however, few wells tap them. Most Cretaceous aquifers are sandstones that are local in extent and secondary in importance to drift aquifers. Locating Cretaceous aquifers requires test drilling because sandstone beds may be absent or of low permeability. A basal sandstone derived from weathered Sioux Quartzite is widespread but thin and patchy. A tabulation of wells in Jackson County showed less than 5 percent of the wells tapped Cretaceous rocks and the rest tapped drift.



Bedrock geology modified from Austin, Grant, Ikola, and Sims, 1970

EXPLANATION

(Order does not reflect relative age)

Kr — Cretaceous rocks
Primarily shale and siltstone with some sandstone. Shale and siltstone is mostly blue, black and gray with some white, tan, pink, purple and green. Sandstone is generally gray to white, fine grained and quartzose; beds range in thickness from 0 to 100 feet (0-30 m) and are most common near the base. Locally, white to pink, fine- to medium-grained quartz sandstone directly overlies the Sioux Quartzite. Moderate supplies, 5-250 gal/min (0.3-16 l/s), of water are available. Maximum thickness, about 600 feet (180 m)

CRETACEOUS

p€s — Sioux Quartzite
Quartzite, red and purple to light gray; interbedded with hard red claystone (pipestone). The upper 200 to 300 feet (60-90 m) may contain "loose sand" zones, joints and fractures from which moderate supplies, from 2-450 gal/min (0.13-28 l/s), of water are available. Maximum thickness, more than 1000 feet (300 m)

p€im — Undifferentiated crystalline rocks
Lithology inferred mainly from aeromagnetic and gravity studies. Intermediate and mafic crystalline rocks and some granitic rocks. Moderate supplies of water available from fractured and weathered zones. Thickness unknown

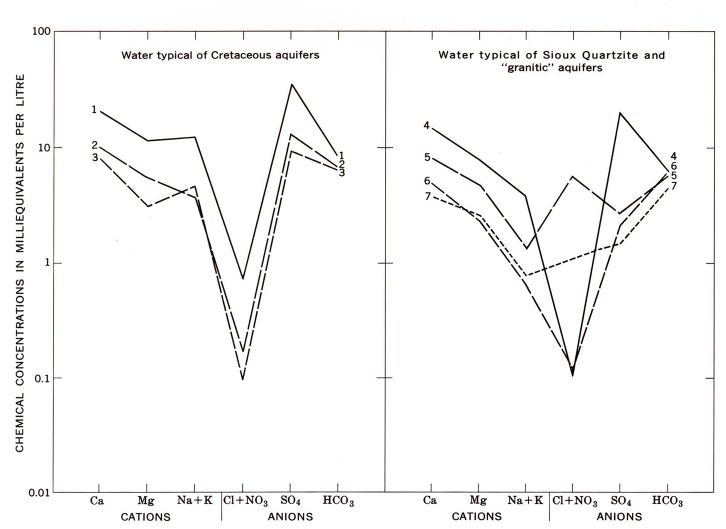
PRECAMBRIAN

Contact
Approximately located

Contact
Inferred from airborne magnetometer survey and ground gravity survey

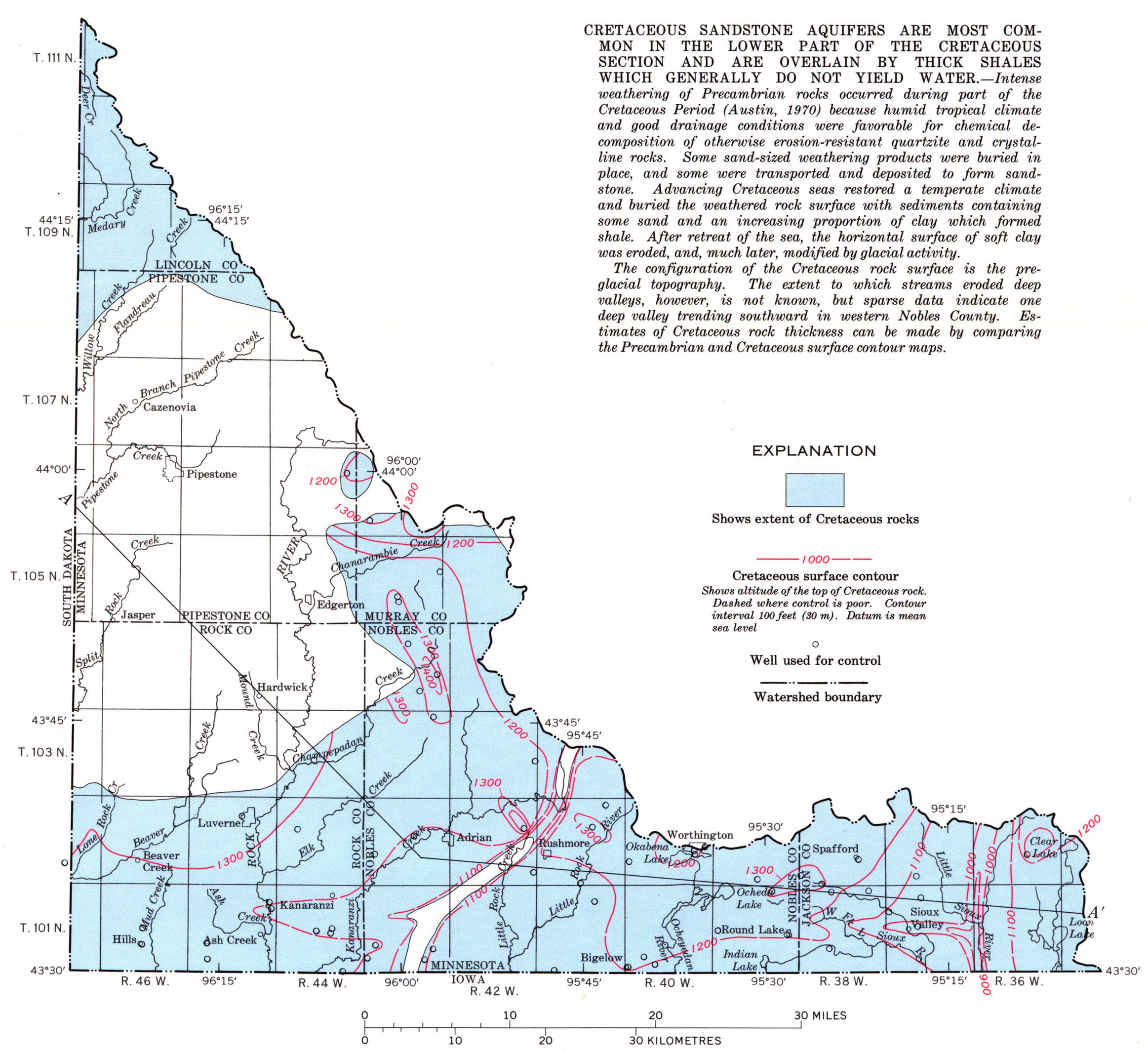
Well
Number identifies chemical analysis

Watershed boundary



CRETACEOUS SANDSTONE AQUIFERS ARE MOST COMMON IN THE LOWER PART OF THE CRETACEOUS SECTION AND ARE OVERLAIN BY THICK SHALES WHICH GENERALLY DO NOT YIELD WATER.—*Intense weathering of Precambrian rocks occurred during part of the Cretaceous Period (Austin, 1970) because humid tropical climate and good drainage conditions were favorable for chemical decomposition of otherwise erosion-resistant quartzite and crystalline rocks. Some sand-sized weathering products were buried in place, and some were transported and deposited to form sandstone. Advancing Cretaceous seas restored a temperate climate and buried the weathered rock surface with sediments containing some sand and an increasing proportion of clay which formed shale. After retreat of the sea, the horizontal surface of soft clay was eroded, and, much later, modified by glacial activity.*

The configuration of the Cretaceous rock surface is the preglacial topography. The extent to which streams eroded deep valleys, however, is not known, but sparse data indicate one deep valley trending southward in western Nobles County. Estimates of Cretaceous rock thickness can be made by comparing the Precambrian and Cretaceous surface contour maps.



EXPLANATION

Shows extent of Cretaceous rocks

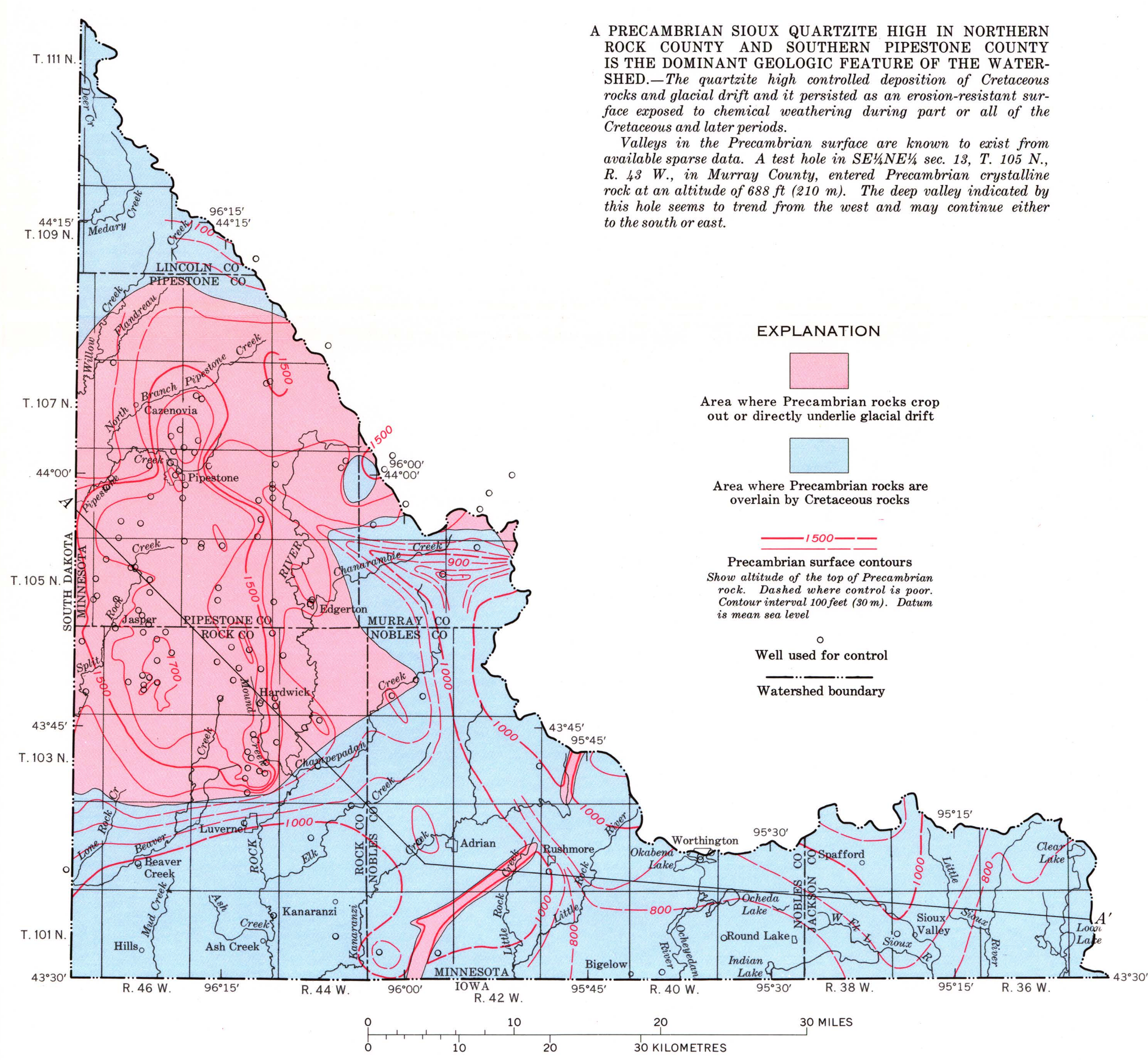
—1000— Cretaceous surface contour
Shows altitude of the top of Cretaceous rock. Dashed where control is poor. Contour interval 100 feet (30 m). Datum is mean sea level

Well used for control

Watershed boundary

A PRECAMBRIAN SIOUX QUARTZITE HIGH IN NORTHERN ROCK COUNTY AND SOUTHERN PIPESTONE COUNTY IS THE DOMINANT GEOLOGIC FEATURE OF THE WATERSHED.—*The quartzite high controlled deposition of Cretaceous rocks and glacial drift and it persisted as an erosion-resistant surface exposed to chemical weathering during part or all of the Cretaceous and later periods.*

Valleys in the Precambrian surface are known to exist from available sparse data. A test hole in SE¼NE¼ sec. 13, T. 105 N., R. 43 W., in Murray County, entered Precambrian crystalline rock at an altitude of 688 ft (210 m). The deep valley indicated by this hole seems to trend from the west and may continue either to the south or east.



EXPLANATION

Area where Precambrian rocks crop out or directly underlie glacial drift

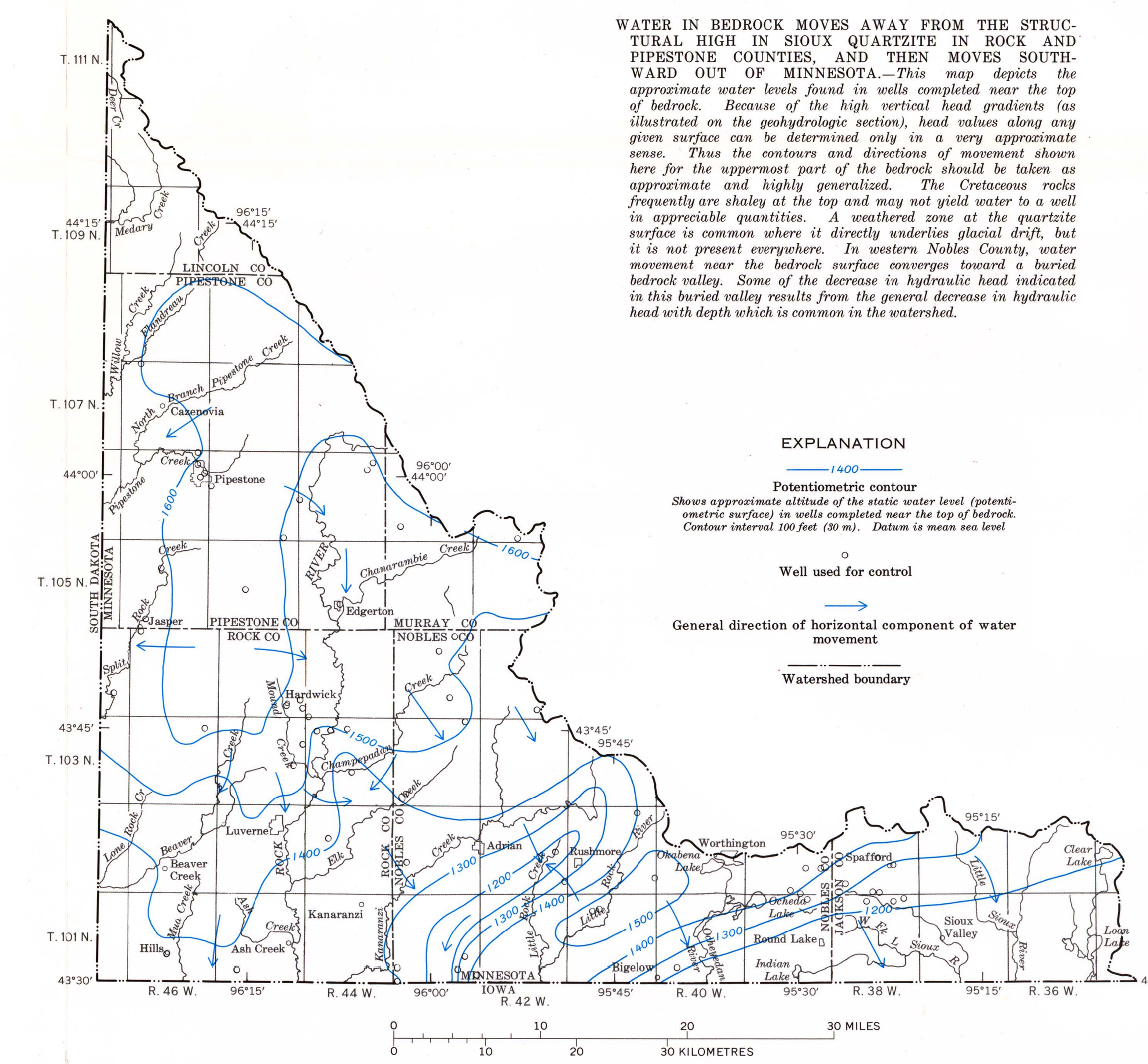
Area where Precambrian rocks are overlain by Cretaceous rocks

—1500— Precambrian surface contours
Show altitude of the top of Precambrian rock. Dashed where control is poor. Contour interval 100 feet (30 m). Datum is mean sea level

Well used for control

Watershed boundary

WATER IN BEDROCK MOVES AWAY FROM THE STRUCTURAL HIGH IN SIOUX QUARTZITE IN ROCK AND PIPESTONE COUNTIES, AND THEN MOVES SOUTHWARD OUT OF MINNESOTA.—*This map depicts the approximate water levels found in wells completed near the top of bedrock. Because of the high vertical head gradients (as illustrated on the geohydrologic section), head values along any given surface can be determined only in a very approximate sense. Thus the contours and directions of movement shown here for the uppermost part of the bedrock should be taken as approximate and highly generalized. The Cretaceous rocks frequently are shaley at the top and may not yield water to a well in appreciable quantities. A weathered zone at the quartzite surface is common where it directly underlies glacial drift, but it is not present everywhere. In western Nobles County, water movement near the bedrock surface converges toward a buried bedrock valley. Some of the decrease in hydraulic head indicated in this buried valley results from the general decrease in hydraulic head with depth which is common in the watershed.*



EXPLANATION

—1400— Potentiometric contour
Shows approximate altitude of the static water level (potentiometric surface) in wells completed near the top of bedrock. Contour interval 100 feet (30 m). Datum is mean sea level

Well used for control

→ General direction of horizontal component of water movement

Watershed boundary

WATER IN BEDROCK AQUIFERS CONTAINS CHEMICAL PROPERTIES SIMILAR TO THOSE IN WATER FROM OVERLYING GLACIAL AQUIFERS AND IS AFFECTED BY DRAINAGE FROM BEDROCK HIGHS.—*Water having the best quality (wells 6 and 7) is obtained from Sioux Quartzite underlying pre-Wisconsin drift. However, where the drift is thin, this aquifer is susceptible to contamination (well 5) from the land surface. Dominant ions in the noncontaminated water are calcium and bicarbonate.*

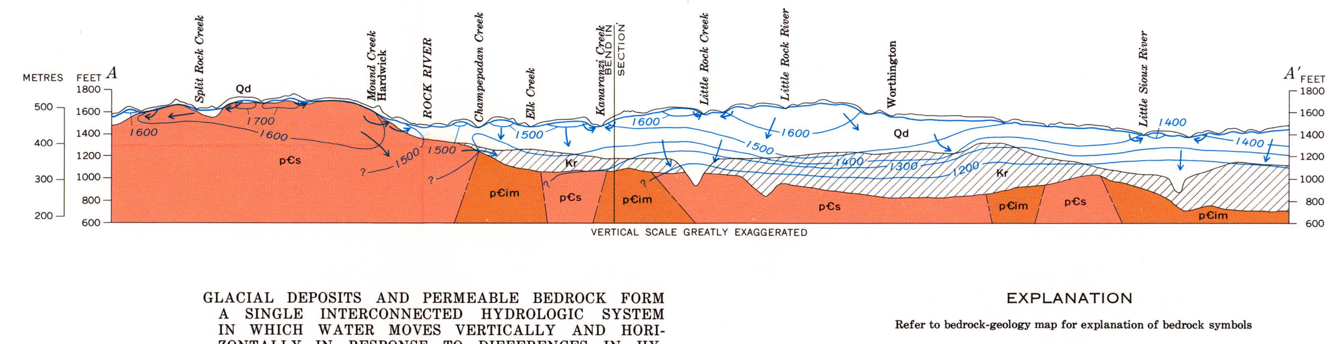
Water from the Cretaceous aquifer (well 1) and the "granitic" crystalline aquifer (well 4) contains dissolved-solids concentrations and dominant ions (calcium and sulfate) characteristic of water from deeply buried glacial sand and gravel. Locally the Cretaceous aquifer (wells 2 and 3) receives water of relatively low dissolved-solids concentration from areas of quartzite highs. The resulting mixture contains a larger percentage of bicarbonates and lower dissolved-solids concentrations than found in wells 1 and 4.

Non-carbonate hardness is dominant in water that contains sulfate as the major anion and requires special treatment for removal.

Dissolved iron and manganese are common in water in the bedrock because most glacial deposits through which this water percolates contain iron sediments and decaying organic material.

QUALITY OF WATER DATA FROM WELLS IN BEDROCK AQUIFERS

Well	Aquifer	Depth (ft)	Dissolved solids (mg/l)	Hardness as calcium carbonate (mg/l) Total	Non-carbonate	Iron (mg/l)	Manganese (mg/l)	Nitrate (mg/l)
1	Cretaceous	595	2,820	1,600	1,200	4.7	0.45	16
2		540	1,210	770	440	3.0	.25	.4
3		540	986	560	240	5.5	.02	.5
4	"Granitic"	522	1,640	1,100	790	13	1.5	.4
5	Sioux Quartzite	335	853	640	340	.12	.04	200
6		505	435	360	50	2.7	.18	.1
7		416	389	320	98	.00	.00	7.2



GLACIAL DEPOSITS AND PERMEABLE BEDROCK FORM A SINGLE INTERCONNECTED HYDROLOGIC SYSTEM IN WHICH WATER MOVES VERTICALLY AND HORIZONTALLY IN RESPONSE TO DIFFERENCES IN HYDRAULIC POTENTIAL.—*Geohydrologic section A-A′ illustrates generalized ground-water movement in a vertical plane along the line of section. The location of the section is shown on the bedrock geology map and on the bedrock surface map. The potentiometric contours indicate the altitude to which water will rise in a well completed at the depth at which a contour is drawn. Water moves from areas of high hydraulic potential to areas of low potential as indicated by the arrows.*

In the quartzite at the west end of the section, movement of water is away from the topographic high. This movement is concentrated in the weathered upper part of the quartzite and causes a local upward discharge through the drift into the Rock River. Throughout most of the section, however, the hydraulic potential in the drift decreases with depth, indicating downward movement. A part of this downward movement is discharged by flow away from the line of section through buried valleys in the bedrock surface, such as the one near Little Rock Creek. The balance enters the bedrock and is discharged laterally as shown in the bedrock potential map.

EXPLANATION

Refer to bedrock-geology map for explanation of bedrock symbols

Qd — Glacial drift
Mostly till, some sand and gravel. Includes Holocene deposits

Contact
Approximately located. Dashed where inferred from airborne magnetometer survey and ground gravity survey

Water table
Approximately located

—1400— Potentiometric contour
Shows altitude of the static water level (potentiometric surface). Contour interval 100 feet (30 m). Datum is mean sea level

→ Direction of ground-water movement

ALL MUNICIPAL WATER SUPPLIES ARE OBTAINED FROM AQUIFERS IN THE GLACIAL DRIFT OR IN THE SIOUX QUARTZITE.—*Towns on the quartzite high use the Sioux Quartzite aquifer, those in surficial outwash valleys use outwash sand and gravel, and those that are not near quartzite or surficial outwash use buried glacial sand and gravel. No town uses Cretaceous sandstone as a source of water supply.*

Specific capacity of wells may be defined as yield, in gallons per minute, per foot of drawndown of water level in the well caused by pumping.

AQUIFER AND WATER QUALITY DATA FROM MUNICIPAL RECORDS

Aquifer	Towns using aquifer	Municipal wells tapping aquifer	Well depth (ft) Range	Average	Thickness open to wells (feet) Range	Average	Normal pumping rate (gal/min) Range	Average	Specific capacity of wells [(gal/min)/ft] Range	Average	Iron (mg/l) Range	Median	Sulfate (mg/l) Range	Median	Chloride (mg/l) Range	Median	Dissolved solids, residue (mg/l) Range	Median	Hardness as $CaCO_3$ (mg/l) Range	Median
Surficial sand and gravel	7	39	26-89	45	5-25	12	30-350	128	7-100	30	0.03-5.1	1.1	46-770	230	<1-71	16	830-2,000	1,300	360-1,300	560
Buried sand and gravel	7	16	19-375	147	2-30	13	16-300	112	2.5-30	14	.13-7.2	3.2	47-1,800	821	.6-15	1.8	1,480	--	280-1,800	1,120
Sioux Quartzite	7	12	241-596	448	22-413	285	11-450	104	.09-1.5	0.7	.02-2.7	.08	17-180	80	1.9-58	6.1	700	--	210-490	365

Base from U.S. Geological Survey 1:250,000 series: Fairmont, Minn., 1954; Sioux Falls, 1955, and Watertown, 1953, S. Dak.

Interior—Geological Survey, Reston, Va.—1976

WATER RESOURCES OF THE ROCK RIVER WATERSHED, SOUTHWESTERN MINNESOTA

By
H. W. Anderson, Jr., W. L. Broussard, D. F. Farrell, and P. E. Felsheim

1976