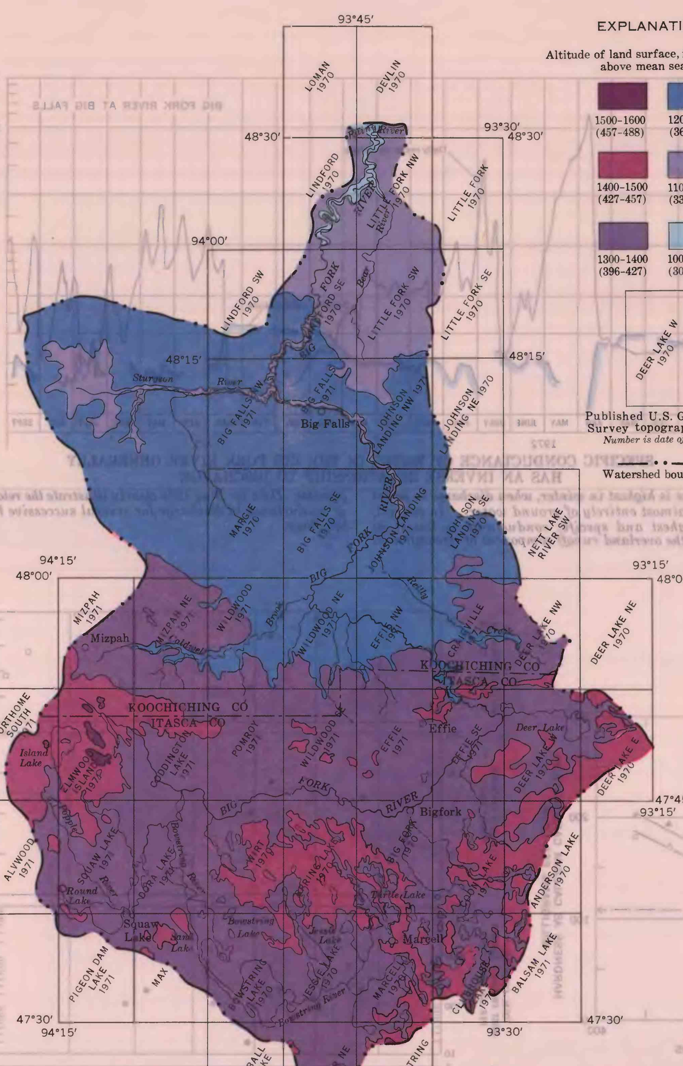
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

INTRODUCTION

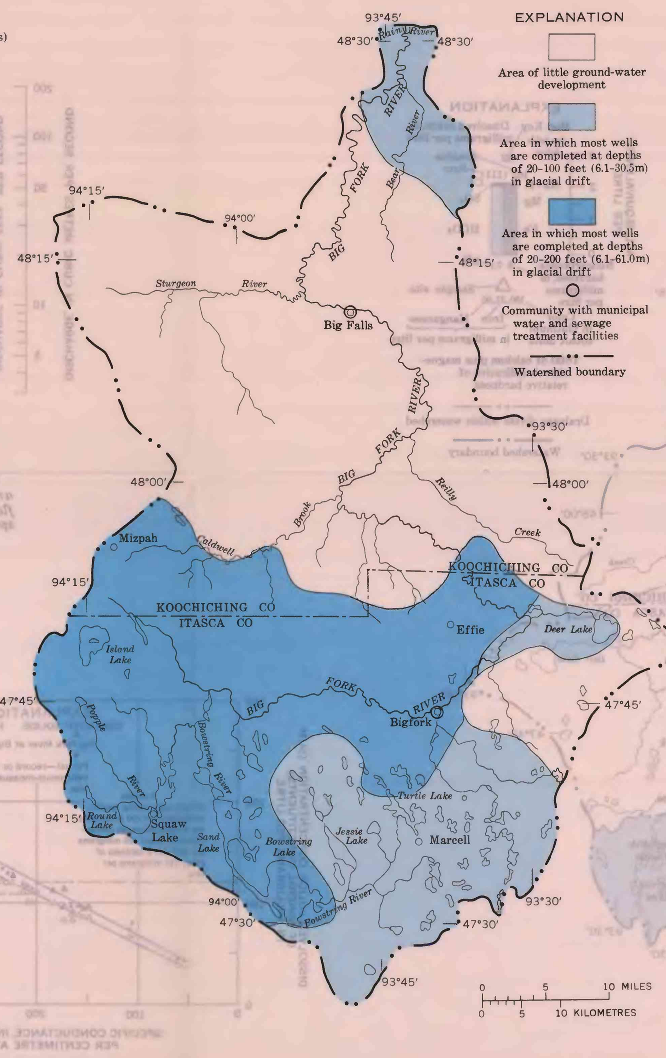


THE NORTHWARD-FLOWING BIG FORK RIVER DRAINS AN AREA OF ABOUT 2,060 SQUARE MILES (5,335 SQUARE KILOMETRES) AND IS TRIBUTARY TO THE RAINY RIVER

The northern two-thirds of the Big Fork River watershed is part of the glacial Lake Agassiz plain and slopes gently northward, generally less than 10 ft/mi (2 m/km). This part is characterized by extensive peat-covered wetlands. Relief in the northern two-thirds is greatest near incised streams, approaching 90 feet (27 m) along some reaches of the Big Fork River. The southern third is morainic and is characterized by irregular topography, local relief of as much as 100 feet (30 m), and many lakes, some of which occupy closed basins.

Details of topography can be obtained from U.S. Geological Survey 7½-minute quadrangle maps, as indexed above.

Population of the watershed in 1970 was about 7,200 persons. Eighty-five percent of the population is concentrated in Itasca County (southern half of watershed), generally near lakes. As most of the watershed is forested, forest products provide an economic base for many people. Tourism is also economically important. Agriculture is largely limited to the production of livestock.



MOST WATER USED IN THE BIG FORK RIVER WATERSHED IS OBTAINED FROM GROUND-WATER SOURCES.

—Ground-water development, though not intensive anywhere in the watershed, is chiefly in the southern half. The area of little ground-water development contains extensive wetlands and is sparsely inhabited. Most wells are completed in glacial drift, and most water is used for domestic and livestock purposes. Largest withdrawals are for municipal supplies at Big Falls and Bigfork (table above). Both municipalities have secondary sewage-treatment facilities and discharge their effluent into the Big Fork River.

MUNICIPAL WELL DATA

Municipality	1970 Population	Well number	Year completed	Well diameter (inches)	Well depth (feet)	Aquifer	Finish	Static water level (feet below land surface)	Pumping rate (gal/min)	Draw-down (feet)	Specific capacity [(gal/min)/ft of drawdown]	1970 withdrawal (millions of gallons)	Total hardness as $CaCO_3$	Iron	Manganese	Dissolved solids (sum)	Analyst[1] and date sampled
Big Falls	534	1	1916	6	199	Precam-brian bedrock	—	—	25	—	—	0.25 (est.)	290	5.7	1.6	—	MDH July 1958
		2	1938	6	79	—	—	21	25	40	0.6	4.1	400	1.0	.1	—	MDH July 1958
		3	1965	8	80	—	—	18	50	32	1.6	8.4	390	.55	.14	467	USGS August 1972
Bigfork	399	1	1949	6	173	Gravel	Screened 155–173'	20	100	88	1.1	15 (est.)	190	.02	.01	236	USGS August 1972
		2	1966	8	173	Gravel	Screened 167–173'	30	30	—	—		330	1.6	.10	—	MDH April 1966

Columns "Total hardness" through "Dissolved solids" are Selected water-quality properties (milligrams per litre).

[1] MDH, Minnesota Department of Health; USGS, U.S. Geological Survey

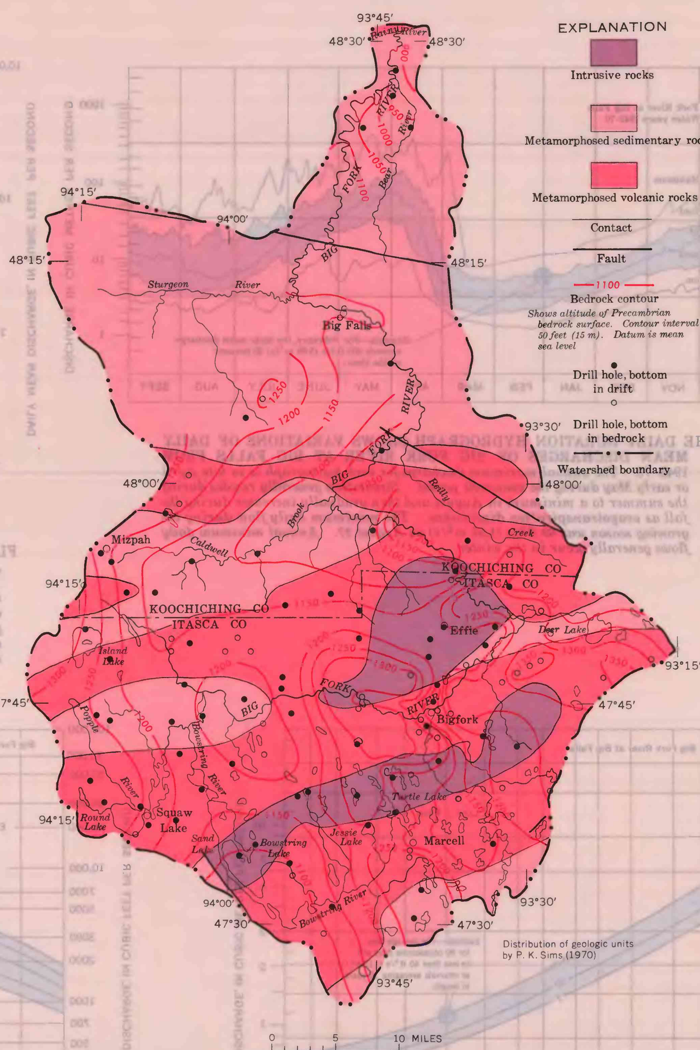
WATER USE IN 1970 (Millions of gallons)

TYPE OF USE	GROUND WATER	SURFACE WATER
Municipal	28	0
Rural domestic	129 (est.)	0
Livestock	64 (est.)	
TOTAL	221	

CONVERSION TABLE

1 in (inch)	=25.4 mm (millimetres)
1 ft (foot)	=0.3048 m (metre)
1 mi (mile)	=1.609 km (kilometres)
1 mi² (square mile)	=2.590 km² (square kilometres)
1 acre	=0.4047 hm² (square hectometre)
1 gal (gallon)	=3.785 l (litres) 0.003785 m³ (cubic metre)
1 gal/min (gallon per minute)	=0.06309 l/s (litre per second)
1 ft³/s (cubic foot per second)	=0.02832 m³/s (cubic metre per second)

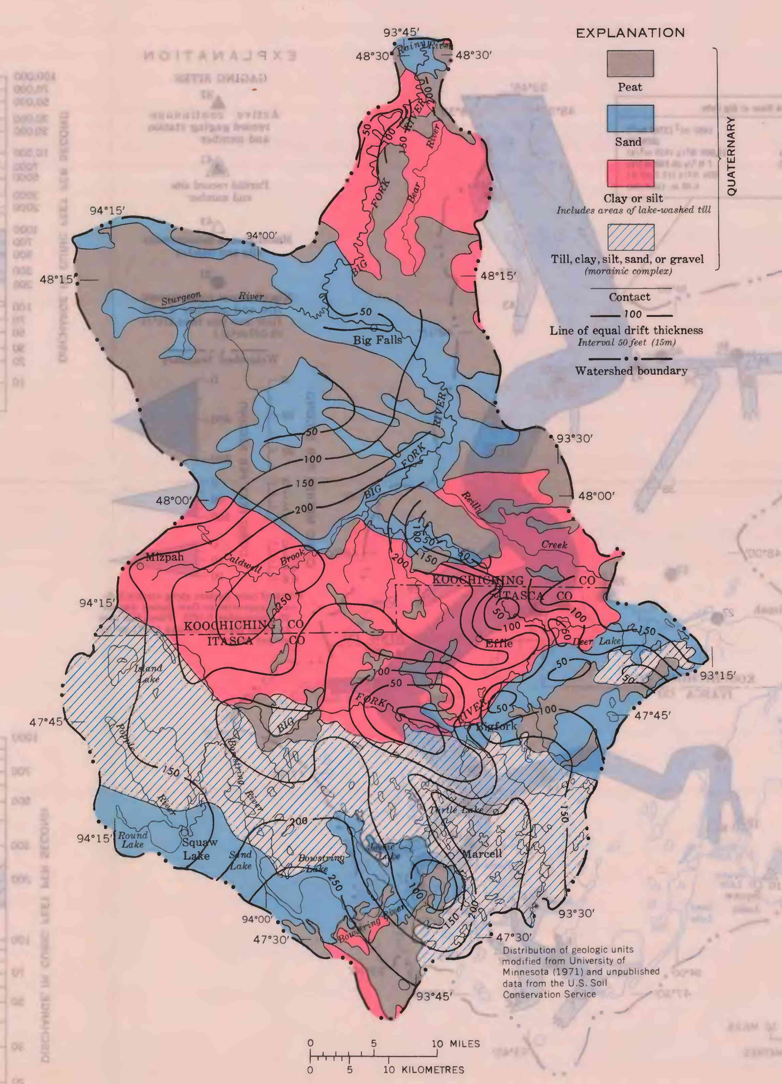
GROUND WATER



PRECAMBRIAN IGNEOUS AND METAMORPHIC BEDROCK UNDERLIES GLACIAL DRIFT IN THE WATERSHED.

—Bedrock altitude is generally highest in the southern half of the watershed. Local relief is as much as 150 feet (45 m) along a bedrock valley near Bigfork.

Cretaceous sedimentary rocks have been reported at scattered locations, though they are often difficult to distinguish from glacial drift. Although data are insufficient for delineation, Cretaceous rocks are most likely to occur in depressions on the Precambrian bedrock surface.

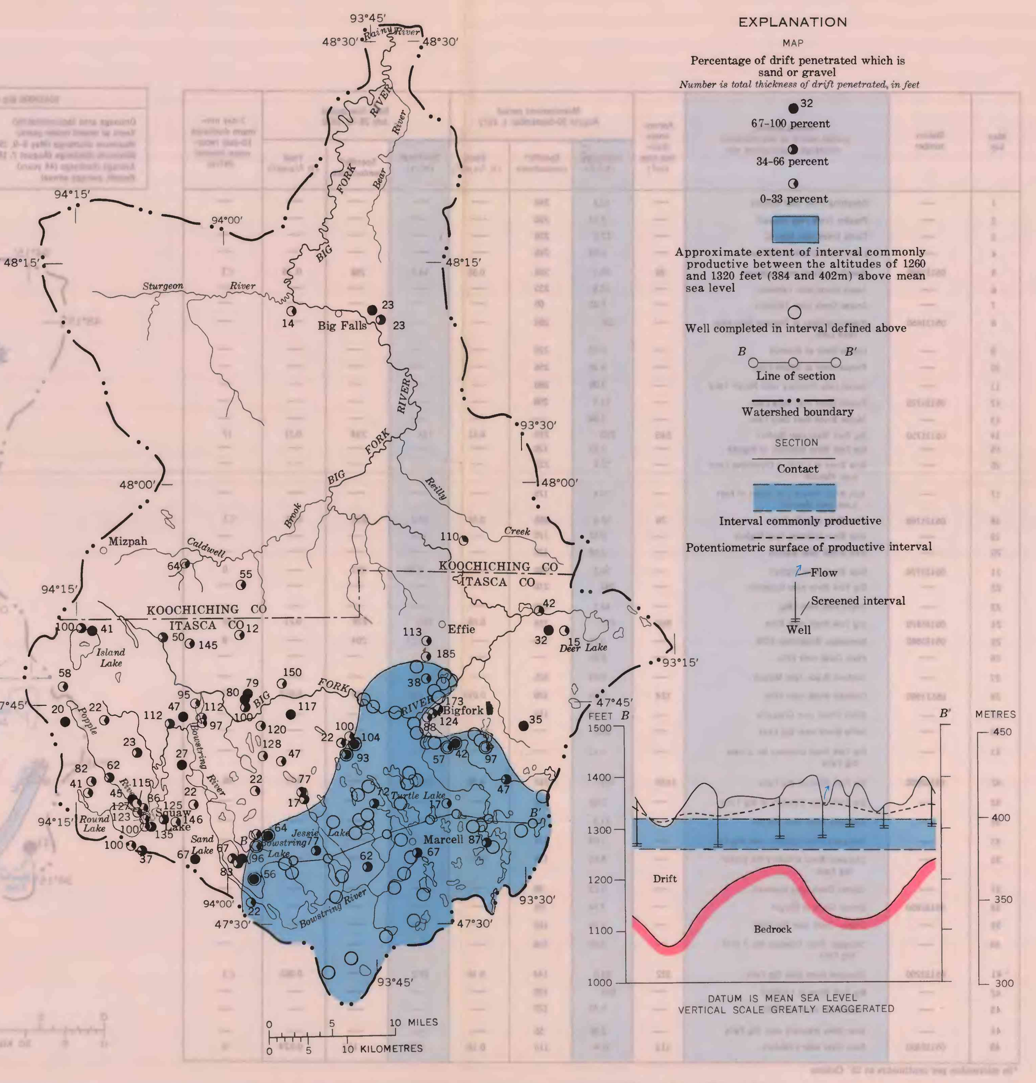


SURFICIAL MATERIALS IN MOST OF THE WATERSHED CONSIST OF GLACIAL LAKE DEPOSITS, PEAT, TILL, OR OUTWASH.

—Lacustrine clay or silt, which predominates in the northern two-thirds of the watershed, is generally less than 5 feet (1.5 m) thick. Sand in that area is mostly fine beach-bar deposits of glacial Lake Agassiz. The sand commonly occurs as elongate ridges less than 10 feet (3 m) high on an otherwise nearly level surface. In some areas the sand is as thick as 30 feet (9 m), though much of it is less than 5 feet (1.5 m) thick. Peat is generally a few feet thick, but in places it is as thick as 25 feet (8 m). Lake-washed, clay-rich till containing numerous carbonate rock fragments underlies all the materials described above and is in places exposed.

Morainic deposition was at least partly controlled by the east-west trending bedrock high in the southern part of the watershed. Outwash sand and gravel associated with morainic deposition occurs adjacent to and within the morainic complex. The outwash is composed mostly of fine to coarse sand of highly variable thickness. Although as much as 117 feet (36 m) of surficial sand was penetrated in test augering, 10 to 40 feet (3 to 12 m) is most common.

Glacial drift is generally thickest on bedrock lows, and thinnest on bedrock highs. Bedrock outcrops are numerous where drift thickness is less than 50 feet (15 m). Because data do not permit differentiation between Cretaceous rocks and glacial drift, drift thickness in places may be less than shown on the map, particularly where the drift is thick.



SAND AND GRAVEL ZONES WITHIN GLACIAL DRIFT ARE THE MOST FAVORABLE GROUND-WATER SOURCES

Adequate water supplies for domestic or stock use, generally less than 10 gal/min (0.63 l/s), can be obtained from drift at most places in the watershed. Availability of larger ground-water supplies is undefined. Drillers' logs show that the extent of sand and gravel deposits varies considerably in short distances. The data suggest that locally in the southern half of the watershed sand and gravel zones are sufficiently thick and permeable to supply short-term well yields of several hundred gallons per minute.

Correlation of well-bottom altitudes identifies an area in the southern part of the watershed in which many water supplies are obtained between altitudes of 1,260 and 1,320 feet (384 and 402 m) above mean sea level. This interval probably does not consist of a single aquifer but several, most of which are confined. Seventy-two percent of the wells on record in the mapped area are completed in that interval, 19 percent above it, and 9 percent below it. Characteristics common for wells completed within the interval are as follows: depth, 40 to 100 feet (12 to 30 m); yield, 3 to 10 gal/min (0.69 to 2.4 l/s); static water level, 5 to 45 feet (2 to 14 m) below land surface; and available drawdown, 20 to 70 feet (6 to 21 m).

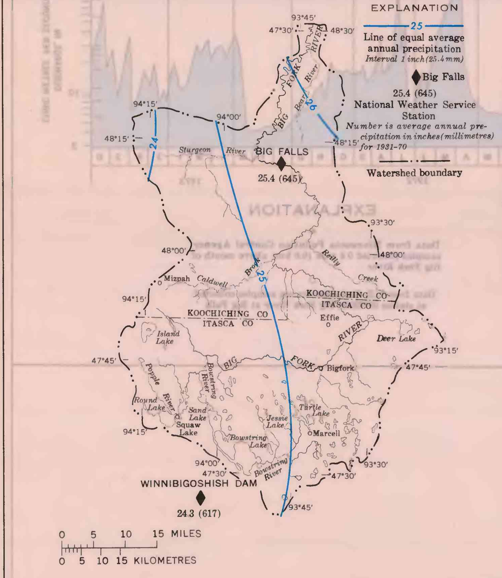
Present and potential development of ground water is described in the table below. Because pumping rates reflect user need, they are not indicative of ultimate yield capacities of the designated water sources.

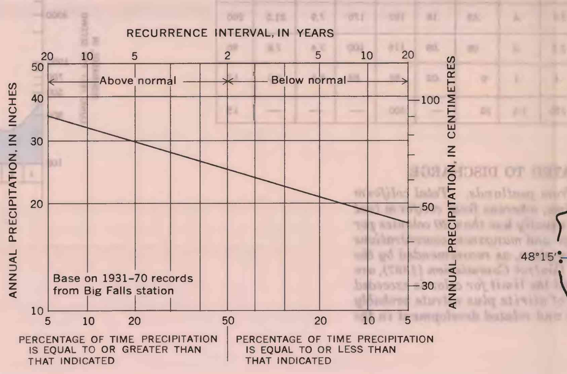
WATER BUDGET

PRECIPITATION	=	RUNOFF	+	UNDERFLOW	±	CHANGE IN STORAGE	+	EVAPOTRANSPIRATION
25.1 inches (638mm)		6.5 inches (165mm)		0.1 inch (3mm)		0		18.5 inches (470 mm)
(measured)		(measured)		(calculated)		(assumed)		(remainder)

THE AVERAGE ANNUAL WATER BUDGET IS BASED ON 1931-70 DATA

Water entering and leaving is part of a dynamic system, as illustrated below (blue arrows—inflow; red arrows—outflow). For a given year, components of the budget equation will vary from the values given above. On the average, about 900 billion gal (3.4 billion m³) of water move through the hydrologic system annually.



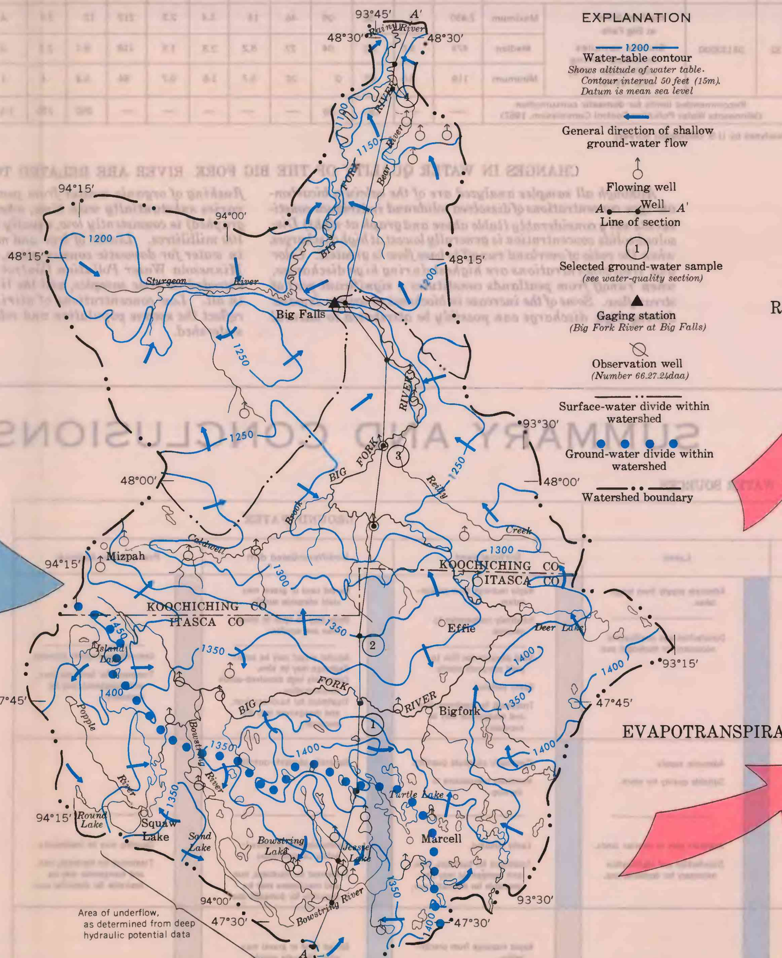


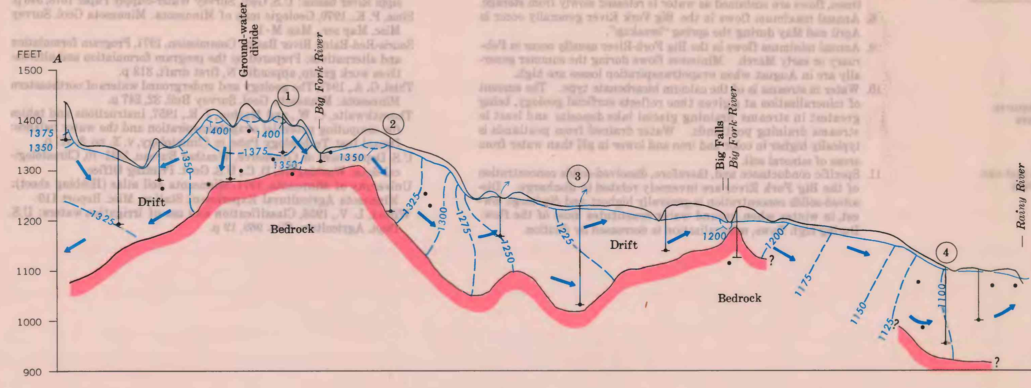
AVERAGE ANNUAL PRECIPITATION INCREASES FROM WEST TO EAST ACROSS THE WATERSHED.

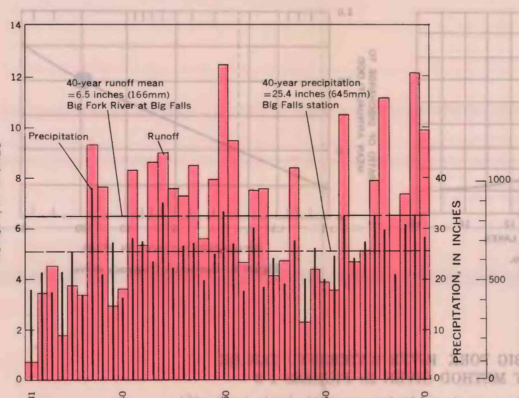
—An areal average obtained from lines of equal precipitation was used in the budget equation. Annual precipitation variations and frequency of recurrence are illustrated using data from the Big Falls station.

ABOUT 0.1 INCH (3 MILLIMETRES) OF WATER LEAVES THE WATERSHED ANNUALLY AS UNDERFLOW.

—Most ground water moves relatively short distances within local flow systems to lakes or streams at right angles to water-table contours. (See water-table map.) Some water moves deeper as part of a regional flow system, as shown on the section. South of the ground-water divide in the southern part of the watershed, some ground water leaves the watershed as underflow. North of the divide, virtually all ground water is discharged within the watershed. As shown on the section, the regional flow system is recharged (downward flow component) mainly in the morainic area and just north of Big Falls. It is discharged (upward flow component) mainly in the vicinity of the Rainy River. Water in confined aquifers is commonly under sufficient pressure to flow at the land surface when tapped by wells in regional discharge areas. Locally, wells tapping shallower confined aquifers in the morainic area also may flow.

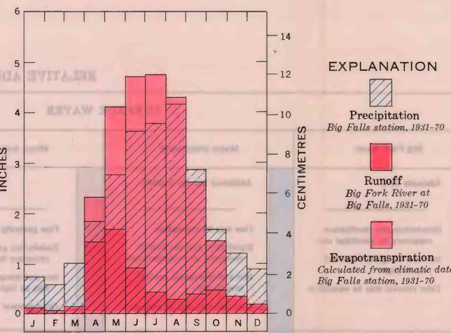






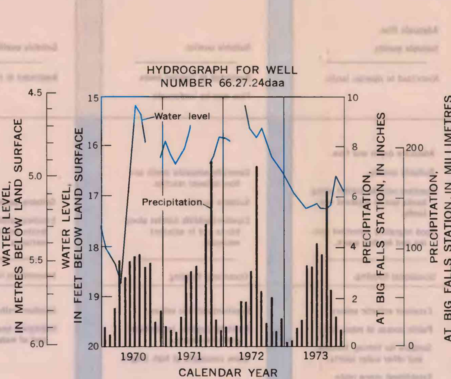
THE GAGING STATION ON BIG FORK RIVER AT BIG FALLS PROVIDES RUNOFF DATA FOR ABOUT 70 PERCENT OF THE WATERSHED.

—For purposes of the budget equation, runoff below the station is assumed to be comparable to that above it. A wide range in annual runoff, largely due to variations in precipitation, is shown by the graph.



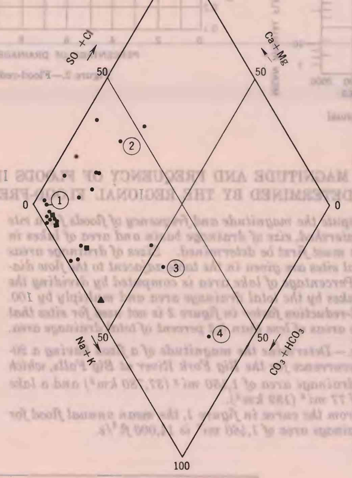
MOST WATER LEAVES THE WATERSHED BY EVAPORATION AND TRANSPIRATION DURING THE SUMMER.

—Average annual evapotranspiration was for purposes of this study, assumed to be equal to the remainder required to balance the water-budget equation. Monthly evapotranspiration was determined by the method of Thornthwaite and Mather (1957) and adjusted slightly to correspond with the total value obtained from the budget equation.



LONG-TERM NET CHANGES IN STORAGE IN THE WATERSHED ARE ASSUMED TO BE ZERO.

—During individual years, net storage may change in the ground-water reservoir, in surface-water bodies, and to a lesser extent in the unsaturated zone. As shown by the example well hydrograph, net ground-water storage near Big Falls increased in 1970–71 and decreased in 1972–73.



Source of ground water	Statistical parameter or well number	Dissolved silica	Iron	Manganese	Calcium	Magnesium	Dissolved sodium	Dissolved potassium	Bicarbonate	Dissolved sulfate	Dissolved chloride	Fluoride	Nitrite and nitrate as nitrogen	Boron	Dissolved solids (sum)	Total hardness as $CaCO_3$	pH	Temperature (°Celsius)
Glacial drift (23 samples)	Maximum	29	37	0.51	160	100	180	7.4	1020	310	72	1.1	19	0.59	888	700	8.2	16.0
	Median	21	.55	.14	83	25	15	3.6	390	14	4.9	.3	.02	.09	387	310	7.3	10.0
	Minimum	11	.02	0	18	5.8	3.1	1.4	110	3.5	.9	.1	0	.02	155	69	7.0	7.5
Cretaceous(?) bedrock	147.25.18aba	11	.48	.03	47	22	62	8.6	432	8.3	2.4	.8	.09	1.2	377	210	7.6	13.5
	149.25.24scb	26	.20	.08	30	8.3	3.9	2.3	150	2.7	1.3	.2	0	.04	149	110	7.6	9.0
Precambrian bedrock	149.26.26dbb	18	.04	.06	78	30	57	4.7	509	35	2.5	.4	.06	.26	477	320	7.7	8.0
	155.25.35dad	22	.34	.34	79	33	16	4.7	433	7.8	2.0	.3	.01	.10	379	330	7.5	11.0
Recommended limits for domestic consumption (Minnesota Water Pollution Control Commission, 1967)		—	.30	.05	—	—	—	—	—	250	250	1.5	10	—	500	—	—	—

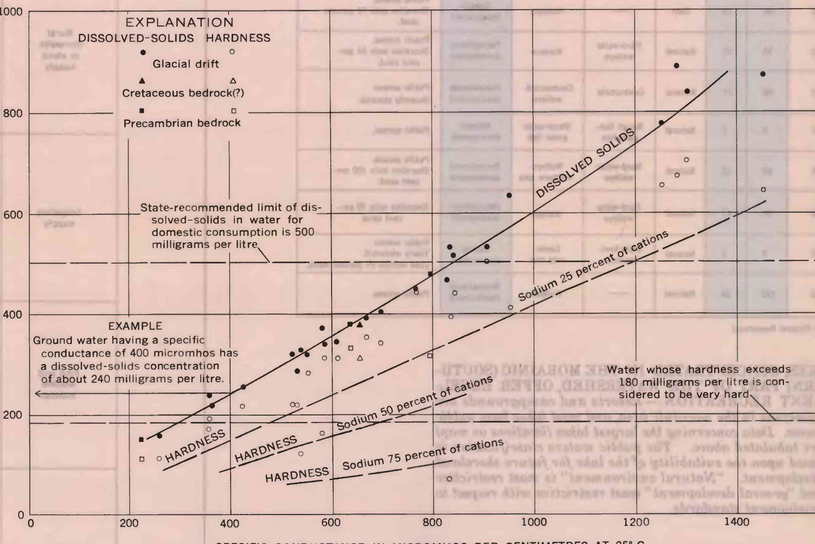
Columns Dissolved silica through Total hardness: Chemical constituents and hardness, in milligrams per litre[1].

[1] Analyses by U.S. Geological Survey

GROUND WATER IN THE WATERSHED IS MOSTLY OF THE CALCIUM OR SODIUM BICARBONATE TYPE, DERIVING ITS CHEMICAL QUALITY CHIEFLY FROM THE GLACIAL DRIFT

Calcium or calcium magnesium bicarbonate type water predominates in most local (shallow) flow systems and in the upper part of the regional flow system (sample 1). Down-gradient in parts of the regional flow system, solution of sulfate minerals changes water chemistry accordingly (sample 2). Farther downgradient in deeper parts of the regional system, sodium bicarbonate type water (samples 3 and 4) results from cation exchange. Sodium is exchanged for calcium and magnesium as the water contacts clay in the drift or Cretaceous rocks. Relatively high concentrations of sodium, chloride, and boron in water from deep wells in the central part of the watershed suggest the presence of Cretaceous rocks, though lithologic data are lacking.

Water in Precambrian bedrock does not seem to be of significantly different quality than water from the drift. A summary of ground-water quality is given in the table above.



DISSOLVED-SOLIDS CONCENTRATION SHOWS A NEARLY LINEAR RELATIONSHIP TO SPECIFIC CONDUCTANCE.

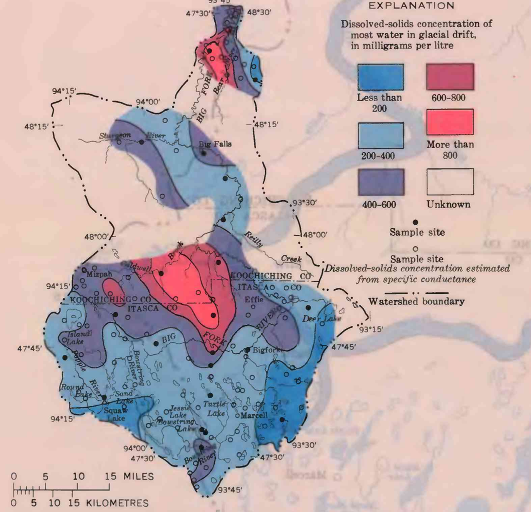
—The relationship of hardness to specific conductance depends upon sodium ion concentration. As percentage of sodium ions increases (largely because of cation exchange), the slope of the line defining the hardness-conductance relationship decreases.

PRESENT AND POTENTIAL DEVELOPMENT OF GROUND WATER

SOURCE OF WATER	Depth range and median (feet below land surface)	Static water level range and median [feet above (+) or below (−) land surface]	Available drawdown[1] range and median (feet)	Yield range and median (gallons per minute)	Remarks	POTENTIAL FOR DEVELOPMENT
Surficial sand and gravel (morainic and non-morainic areas)	13 to 80 26 (17 wells)	−5 to −25 −10 (14 wells)	1 to 52 13 (14 wells)	3 to 20 10 (5 wells)	Slightly developed; nearly all wells for domestic or stock use; generally completed with screen or sand point.	Will support additional development; potential well yields generally less than 50 gallons per minute because of thin saturated thickness; may yield greater than 100 gallons per minute locally.
Buried sand and gravel (morainic area)	14 to 204 70 (87 wells)	+1 to −65 −18 (55 wells)	8 to 133 44 (54 wells)	1 to 40 6 (26 wells)	Slightly developed; nearly all wells for domestic or stock use; generally completed with screen.	Will support considerable additional development; data insufficient to map individual aquifers or estimate water-yielding potential; well yields of several hundred gallons per minute may be obtainable, particularly in the morainic area.
Buried sand and gravel (non-morainic area)	12 to 225 80 (153 wells)	+1 to −140 −16 (111 wells)	2 to 186 49 (103 wells)	2 to 100 7 (37 wells)		
Precambrian bedrock	100 to 400 136 (11 wells)	−4 to −30 −8 (5 wells)	28 to 121 82 (5 wells)	6 to 25 10 (4 wells)	Slightly developed; nearly all wells for domestic or stock use; generally completed as open hole.	Will support additional development; expected well yields generally less than 25 gallons per minute because of dependence on intercepting fractures in rock.

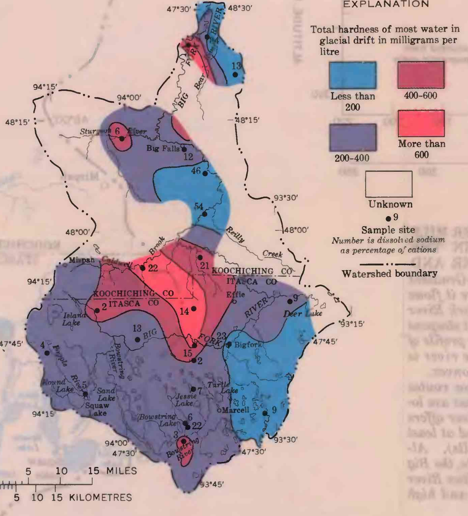
Depth, static water level, available drawdown and yield are Typical well characteristics under PRESENT DEVELOPMENT.

[1] Assumed equal to the vertical distance between the static water level and the top perforation in the well.



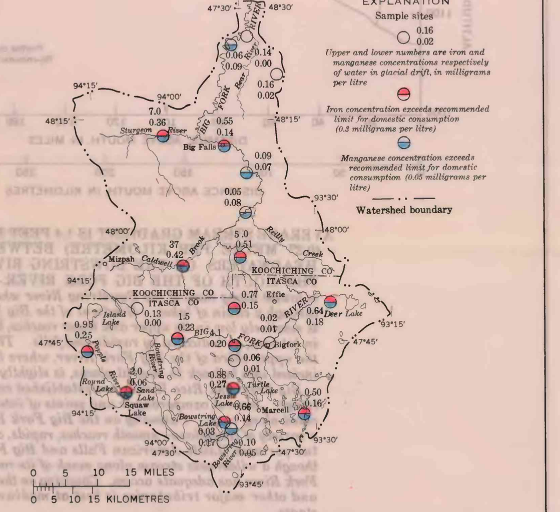
DISSOLVED-SOLIDS CONCENTRATION IN GROUND WATER IS GENERALLY LOWEST IN THE MORAINIC AREA IN THE SOUTHERN PART OF THE WATERSHED.

—More highly mineralized waters are found northward (downgradient in the regional flow system). Higher dissolved-solids concentration results from longer contact time with minerals and possibly from variations in mineralogic composition. Dissolved-solids concentration in the extreme northern part of the watershed generally increases from the watershed boundaries toward the Big Fork River, probably a reflection of ground-water movement toward the river.



MOST GROUND WATER IN THE WATERSHED IS VERY HARD (GREATER THAN 180 MILLIGRAMS PER LITRE).

—Hardness generally increases in the direction of regional ground-water movement, except where softening by cation exchange becomes predominant. Sodium, as percentage of cations, is highest and softening is greatest in the central and northern parts of the watershed.



GROUND WATER CONTAINS IRON AND MANGANESE CONCENTRATIONS THAT COMMONLY EXCEED LIMITS FOR DOMESTIC CONSUMPTION AS RECOMMENDED BY THE MINNESOTA WATER POLLUTION CONTROL COMMISSION (1967).

—At sufficiently high concentrations, iron and manganese may impart color and taste to water, encrust well screens, and stain fixtures and containers. Their concentrations may vary greatly within short lateral and vertical distances.

WATER RESOURCES OF THE BIG FORK RIVER WATERSHED, NORTH-CENTRAL MINNESOTA

By
G. F. Lindholm, J. O. Helgesen, and D. W. Ericson
1976

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