DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

HYDROLOGIC INVESTIGATIONS
ATLAS HA-490 (SHEET 2 OF 3)

GEOLOGY AND GROUND WATER

EXPLANATION

GEOLOGIC MAP AND SECTIONS

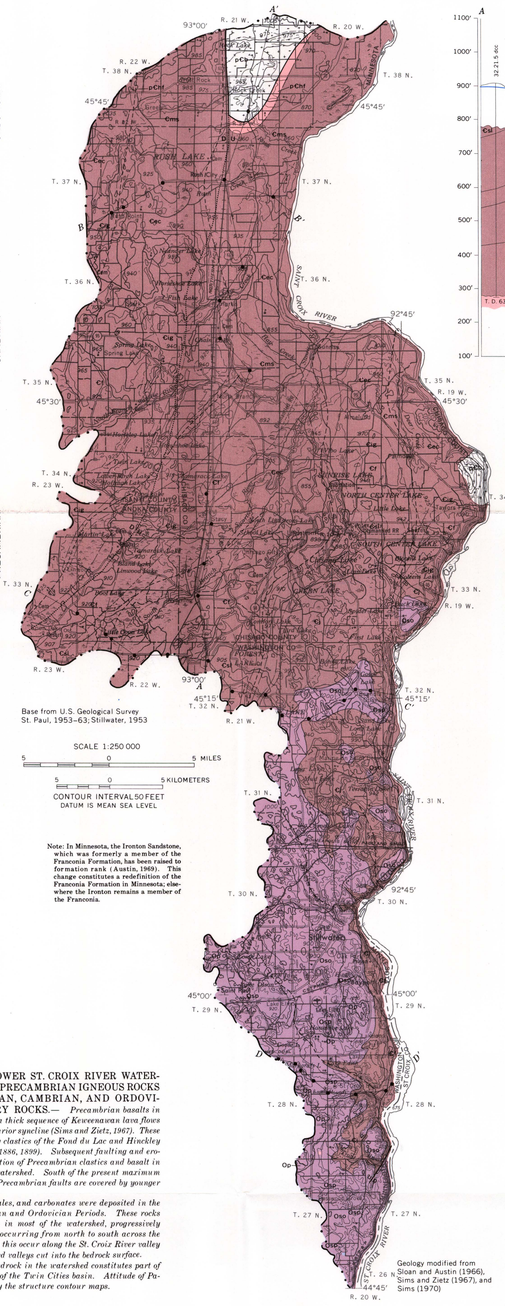
ORDOVICIAN
- Op — Platteville and Glenwood Formations — *Dolomite and shale*
- Osp — St. Peter Sandstone — *Sandstone*
- Oso — Shakopee and Oneota Formations — *Dolomite*

CAMBRIAN
- Cj — Jordan Sandstone — *Sandstone*
- Csl — St. Lawrence Formation — *Dolomite*
- Cf — Franconia Sandstone — *Sandstone*
- Ccg — Ironton and Galesville Formations — *Sandstone*
- Cec — Eau Claire Sandstone — *Shale and Sandstone*
- Cms — Mount Simon Sandstone — *Sandstone*

PRECAMBRIAN
- pChf — Hinckley and Fond du Lac Formations of Winchell (1886 and 1899) — *Sandstone, siltstone, and shale*
- pCb — Basalt

MAP
- Contact — *Dashed where inferred*
- U / D Fault — *Dotted where concealed. Letters indicate relative direction of movement*
- Inferred axis of buried bedrock valley
- Line of section
- Watershed boundary

SECTIONS
- Conformable / Unconformable Contact
- Fault — *Arrows indicate relative direction of movement*
- Water table
- 32.21.5 dcc — Well number and location
- T. D. 630' (Total depth) — Well



Base from U.S. Geological Survey
St. Paul, 1953–63; Stillwater, 1953

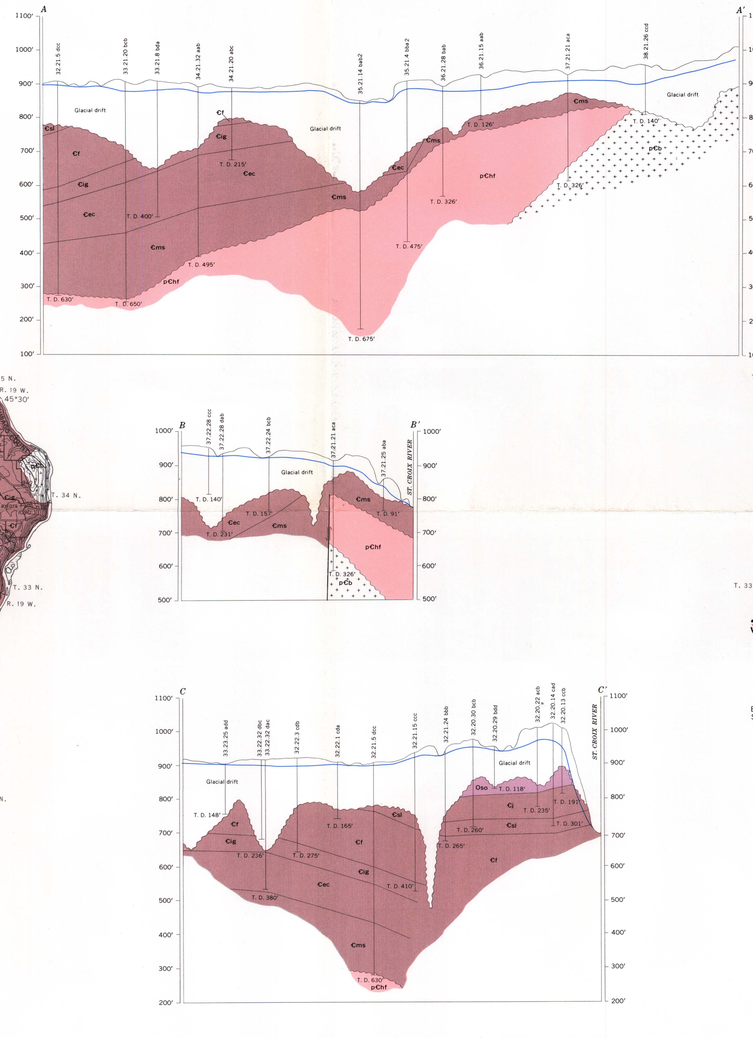
SCALE 1:250 000

5 0 5 MILES
5 0 5 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

Note: In Minnesota, the Ironton Sandstone, which was formerly a member of the Franconia Formation, has been raised to formation rank (Austin, 1969). This change constitutes a redefinition of the Franconia Formation in Minnesota; elsewhere the Ironton remains a member of the Franconia.

Geology modified from Sloan and Austin (1966), Sims and Zietz (1967), and Sims (1970)



VERTICAL EXAGGERATION X 104

BEDROCK IN THE LOWER ST. CROIX RIVER WATERSHED CONSISTS OF PRECAMBRIAN IGNEOUS ROCKS AND PRECAMBRIAN, CAMBRIAN, AND ORDOVICIAN SEDIMENTARY ROCKS.—

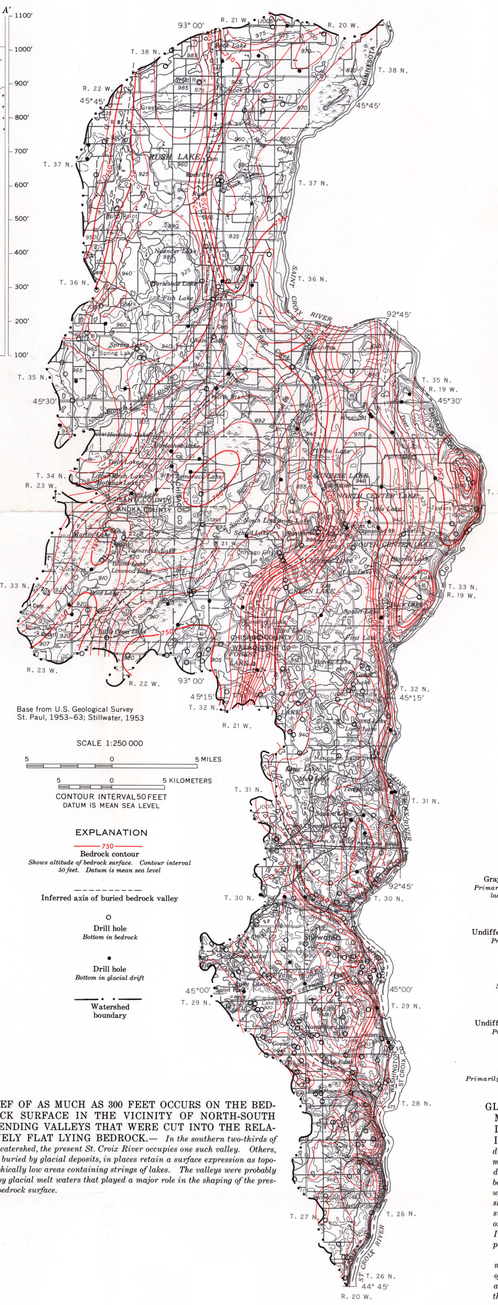
Precambrian basalts in the watershed are part of a thick sequence of Keweenawan lava flows deposited in the Lake Superior syncline (Sims and Zietz, 1967). These lava flows were covered by clastics of the Fond du Lac and Hinckley Formations of Winchell (1886, 1899). Subsequent faulting and erosion resulted in juxtaposition of Precambrian clastics and basalt in the northern part of the watershed. South of the present maximum extent of Paleozoic rocks, Precambrian faults are covered by younger rocks.

Marine sandstones, shales, and carbonates were deposited in the area during the Cambrian and Ordovician Periods. These rocks form the bedrock surface in most of the watershed, progressively younger rocks generally occurring from north to south across the watershed. Exceptions to this occur along the St. Croix River valley and along other now-buried valleys cut into the bedrock surface.

Regionally, Paleozoic bedrock in the watershed constitutes part of the north and east flanks of the Twin Cities basin. Attitude of Paleozoic bedrock is shown by the structure contour maps.

RELIEF OF AS MUCH AS 200 FEET OCCURS ON THE BEDROCK SURFACE IN THE VICINITY OF NORTH-SOUTH TRENDING VALLEYS THAT WERE CUT INTO THE RELATIVELY FLAT LYING BEDROCK.—

In the southern two-thirds of the watershed, the present St. Croix River occupies one such valley. Others, now buried by glacial deposits, in places retain a surface expression as topographically low areas containing strings of lakes. The valleys were probably cut by glacial melt waters that played a major role in the shaping of the present bedrock surface.



Base from U.S. Geological Survey
St. Paul, 1953–63; Stillwater, 1953

SCALE 1:250 000

5 0 5 MILES
5 0 5 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

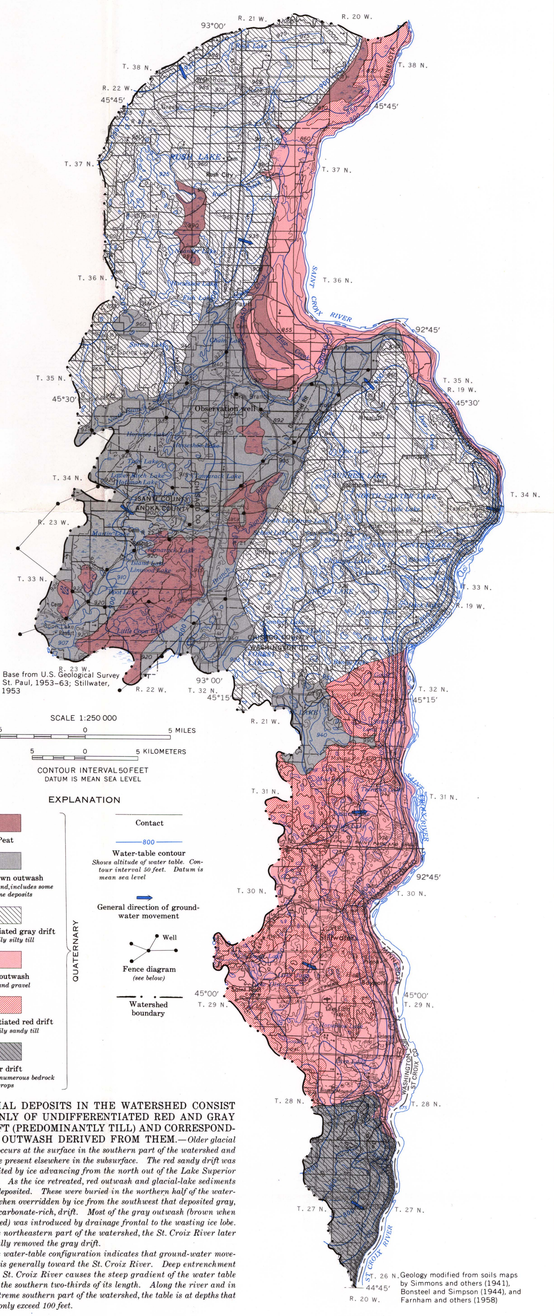
750 — Bedrock contour — *Shows altitude of bedrock surface. Contour interval 50 feet. Datum is mean sea level*

Inferred axis of buried bedrock valley

Drill hole — *Bottom in bedrock*

Drill hole — *Bottom in glacial drift*

Watershed boundary



Base from U.S. Geological Survey
St. Paul, 1953–63; Stillwater, 1953

SCALE 1:250 000

5 0 5 MILES
5 0 5 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

- Peat
- Gray-brown outwash — *Primarily sand, includes some lacustrine deposits*
- Undifferentiated gray drift — *Primarily silty till*
- Red outwash — *Sand and gravel*
- Undifferentiated red drift — *Primarily sandy till*
- Older drift — *Primarily till, numerous bedrock outcrops*

QUATERNARY

- Contact
- 800 — Water-table contour — *Shows altitude of water table. Contour interval 50 feet. Datum is mean sea level*
- General direction of ground-water movement
- Well
- Fence diagram — *(see below)*
- Watershed boundary

GLACIAL DEPOSITS IN THE WATERSHED CONSIST MAINLY OF UNDIFFERENTIATED RED AND GRAY DRIFT (PREDOMINANTLY TILL) AND CORRESPONDING OUTWASH DERIVED FROM THEM.—

Older glacial drift occurs at the surface in the southern part of the watershed and may be present elsewhere in the subsurface. The red sandy drift was deposited by ice advancing from the north out of the Lake Superior basin. As the ice retreated, red outwash and glacial-lake sediments were deposited. These were buried in the northern half of the watershed when overridden by ice from the southwest that deposited gray, silty, carbonate-rich, drift. Most of the gray outwash (brown when oxidized) was introduced by drainage frontal to the wasting ice lobe. In the northeastern part of the watershed, the St. Croix River later partially removed the gray drift.

The water-table configuration indicates that ground-water movement is generally toward the St. Croix River. Deep entrenchment of the St. Croix River causes the steep gradient of the water table along the southern two-thirds of its length. Along the river and in the extreme southern part of the watershed, the table is at depths that commonly exceed 100 feet.

Geology modified from soils maps by Simmons and others (1941), Bonsteel and Simpson (1944), and Farnham and others (1958)

SUMMARY OF HYDROGEOLOGY OF BEDROCK

Age	Formation(s)	Thickness, in feet (where not truncated by erosion)	Lithologic characteristics	Water-yielding capability	Present development (reported data for single aquifer units)*	
					Common specific capacity (gpm per foot of drawdown)	Common yield (gpm)
PALEOZOIC — ORDOVICIAN	Platteville and Glenwood	(mostly eroded)	Platteville—dolomite and dolomitic limestone, gray to brown; interbedded shale. Glenwood—shale, gray to green; basal argillaceous sandstone.	Small quantities of water available to wells; very small areal extent; low hydraulic conductivity; occurs as caprock commonly above water table; relatively poor source of water.	Insufficient data	
	St. Peter	140-180	Sandstone, white to light yellow, fine to medium-grained, generally well-sorted, quartzose, friable; minor amounts of shale, particularly near base.	Small to moderate quantities of water available to wells; high porosity and hydraulic conductivity throughout most of unit; partially above water table in parts of watershed thereby limiting saturated thickness.	3–7 (4) Number in parentheses is number of wells for which data are available.	15–20 (100) Number in parentheses is maximum reported yield, in gpm.
	Shakopee and Oneota	130-170	Shakopee—dolomite, light-brown to buff, often sandy, fractured; some interbedded sandstone and shale. Oneota—dolomite, light-brownish-gray to buff, fractured, vuggy; shaly siltstone and sandstone present locally at base.	Small to moderate quantities of water available to wells; largest yields possible from Oneota Fm. where fractures and solution cavities are common; partially above water table in extreme southern part of watershed, thereby limiting saturated thickness.	1–5 (3)	15–30 (50)
PALEOZOIC — CAMBRIAN	Jordan	70-110	Sandstone, yellow to white, medium- to coarse-grained, friable, quartzose, commonly cross-bedded; locally silty at top; locally argillaceous and dolomitic at base.	Large quantities of water available to wells; high porosity and hydraulic conductivity throughout most of unit; may be capable of yielding several thousand gallons per minute.	10–30 (18)	15–1000 (1500)
	St. Lawrence	30-80	Dolomite, buff to gray, silty and argillaceous; commonly glauconitic; minor siltstone.	Small quantities of water available to wells; yields limited by low hydraulic conductivity; acts as confining bed; relatively poor source of water.	Insufficient data	
	Franconia	110-170	Sandstone, very fine- to coarse-grained, predominantly fine; commonly silty and glauconitic; some shale and dolomite.	Small to large quantities of water available to wells; hydraulic conductivity variable, generally highest in Galesville Fm.; may be capable of yielding several hundred gallons per minute.	2–10 (16)	15–50 (500)
	Ironton and Galesville	50-90	Ironton—sandstone, white to gray, medium-grained, moderately well to poorly sorted; commonly silty. Galesville—sandstone, white to gray, predominantly medium-grained and well-sorted; fine-grained near base.			
	Eau Claire	80-180	Shale and sandstone interbedded, gray to green, fossiliferous; glauconitic in part.	Small quantities of water available to wells; acts as confining bed; relatively poor source of water.	Insufficient data	
	Mount Simon	80-180	Sandstone, white to pink, fine- to coarse-grained, predominantly medium, quartzose; occasional shale, particularly near top; very coarse to conglomeratic near base.	Moderate to large quantities of water available to wells; hydraulic conductivity moderate to high in Mount Simon and Hinckley Fms., low in Fond du Lac Fm.; generally capable of yielding several hundred gallons per minute; highest yields possible where sandstones of Hinckley Fm. occur to supplement yield from Mount Simon Fm.; Fond du Lac Fm. a poorer source of water.	3–10 (7)	15–600 (1300)
PRECAMBRIAN	Hinckley and Fond du Lac of Winchell (1886 and 1899)	0–several thousand (partly eroded)	Hinckley—sandstone, yellow to red, medium- to coarse-grained, poorly sorted, quartzose; interbedded shale. Fond du Lac ("red clastics")—siltstone, sandstone, and shale, poorly sorted; arkosic in part.			
	Basalt	?	Lava flows; interbedded volcanic sediments.	Small quantities of water available to wells; porosity and hydraulic conductivity limited by size and interconnection of fractures and joints; relatively poor source of water.	Insufficient data	

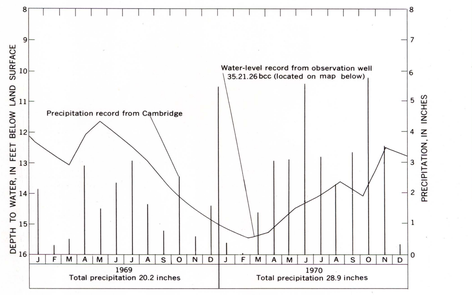
MAJOR BEDROCK AQUIFERS MAPPED BELOW

* Common completion practice is casing through glacial drift and leaving open hole in bedrock below. Many wells are open to more than one bedrock aquifer, resulting in yields larger than the single-aquifer yields stated above.

SUMMARY OF HYDROGEOLOGY OF GLACIAL DRIFT

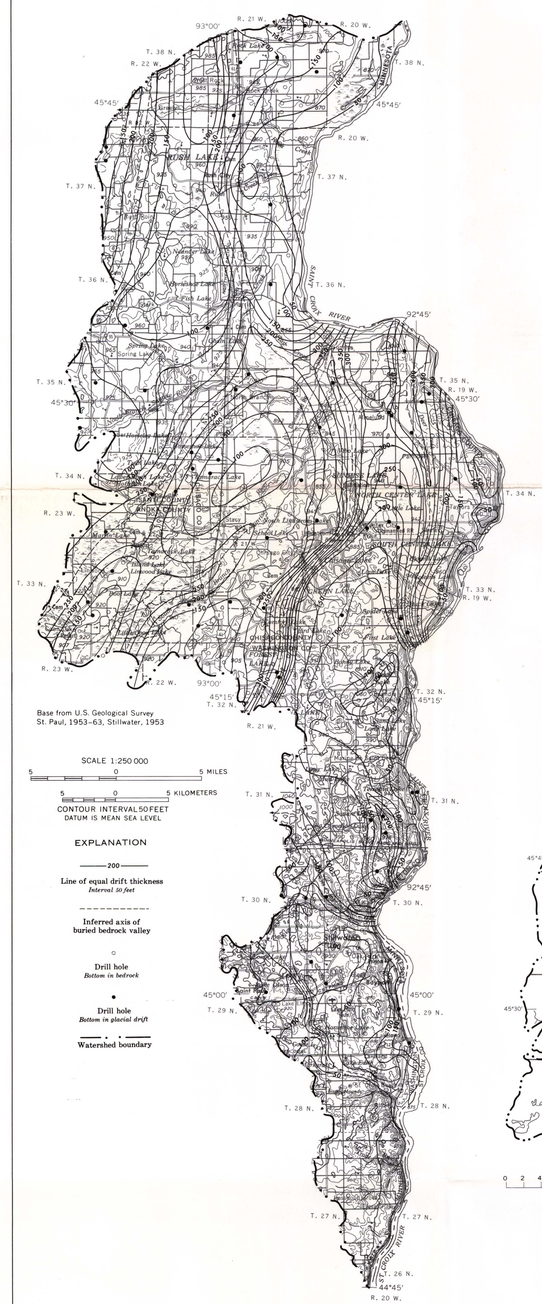
Age	Lithologic unit	Thickness, in feet	Lithologic characteristics	Water-yielding capability
QUATERNARY — HOLOCENE	Alluvium		Occurs along streams as generally thin deposits of sand, gravel, silt, and clay which have not been delineated; small areal extent; insignificant as a source of ground water.	
QUATERNARY — PLEISTOCENE	Gray-brown outwash	0-100	Sand and gravel; stratified; primarily fine to medium sand, in part coarse sand to fine gravel; generally well sorted.	Small to large quantities of water available to wells; yields of several hundred gallons per minute possible where saturated thickness is sufficient.
	Undifferentiated gray drift	0-100	Primarily silty, carbonate-rich till (unstratified clay, silt, sand, gravel, and boulders); contains stratified sand and gravel bodies of relatively small extent.	Small to moderate quantities of water available to wells; till is of low hydraulic conductivity; yields from wells completed in stratified zones are highly variable, being limited by lateral extent and thickness; greater drift thickness enhances possibility of penetrating stratified zones.
	Red outwash	0-200	Sand and gravel; stratified; in northern part of watershed, fine sand to fine gravel, commonly well-sorted; in southern part of watershed, considerable gravel, poorly to well sorted.	Small to large quantities of water available to wells; yields of several hundred gallons per minute theoretically possible where saturated thickness is sufficient; significant portion is above water table near St. Croix River in southern half of watershed.
	Glacial lake deposits	0-100	Primarily clay; may be silty or sandy; red, may be interlaminated with gray.	Very little water available to wells; very low hydraulic conductivity throughout unit; (occurs in subsurface in some areas, total extent unknown).
	Undifferentiated red drift	0-300	Primarily sandy till (unstratified clay, silt, sand, gravel, and boulders); contains stratified sand and gravel bodies of relatively small extent.	Small to moderate quantities of water available to wells; till is of low to moderate hydraulic conductivity; yields from wells completed in stratified zones are highly variable, being limited by lateral extent and thickness; greater drift thickness enhances possibility of penetrating stratified zones.

SURFICIAL OUTWASH IN WEST CENTRAL PART OF WATERSHED EVALUATED BELOW (includes gray-brown and red outwash where not separated by undifferentiated drift)



THE WATER LEVEL RISES PRIMARILY IN RESPONSE TO PRECIPITATION.—

The monthly hydrograph of a shallow observation well near North Branch indicates typical seasonal variations in depth to water table. Most recharge to surficial and shallow aquifers comes from snowmelt and spring rains. In 1969, below-normal precipitation caused a net decline in ground-water storage. In 1970, the water level rose throughout most of the year, resulting in a net gain in ground-water storage.



Base from U.S. Geological Survey
St. Paul, 1953–63, Stillwater, 1953

SCALE 1:250 000

5 0 5 MILES
5 0 5 KILOMETERS

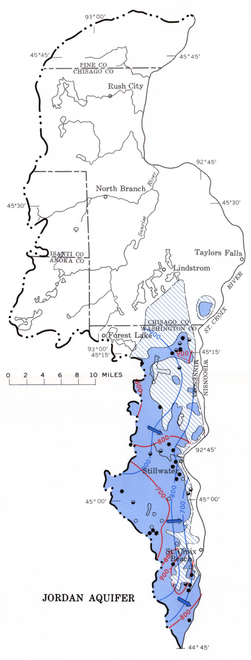
CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

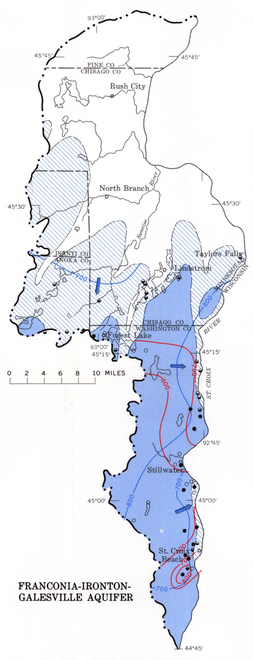
- 200 — Line of equal drift thickness — *Interval 50 feet*
- Inferred axis of buried bedrock valley
- Drill hole — *Bottom in bedrock*
- Drill hole — *Bottom in glacial drift*
- Watershed boundary

THICKNESS OF GLACIAL DRIFT COMMONLY RANGES FROM 0-200 FEET AND EXCEEDS 400 FEET IN SOME BEDROCK VALLEYS.—

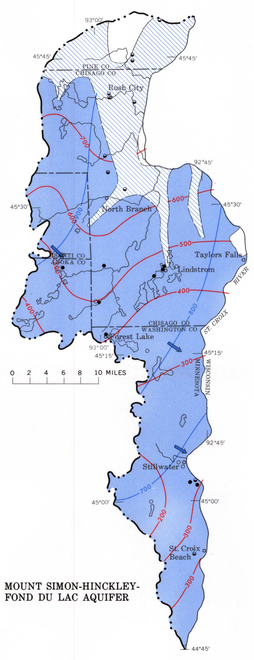
The bedrock valleys in places contain thick sections of sand and gravel, potentially capable of yielding large amounts of water to wells. Areas of thin drift, including numerous bedrock outcrops, occur in the southern part of the watershed and along the St. Croix River valley. Small amounts of water are available from the drift in these areas.



JORDAN AQUIFER



FRANCONIA-IRONTON-GALESVILLE AQUIFER



MOUNT SIMON-HINCKLEY-FOND DU LAC AQUIFER

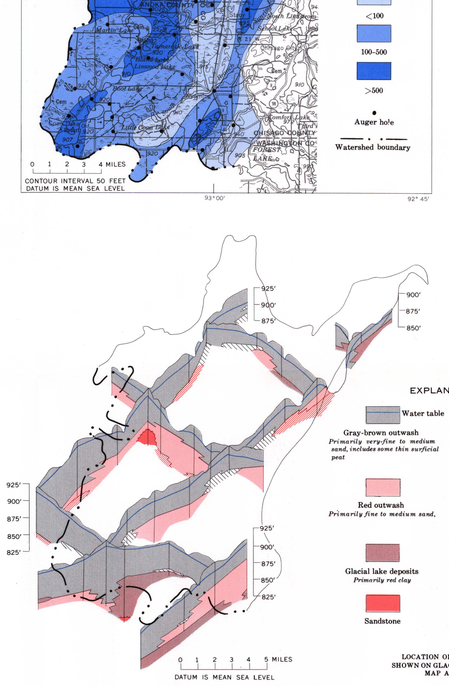
EXPLANATION

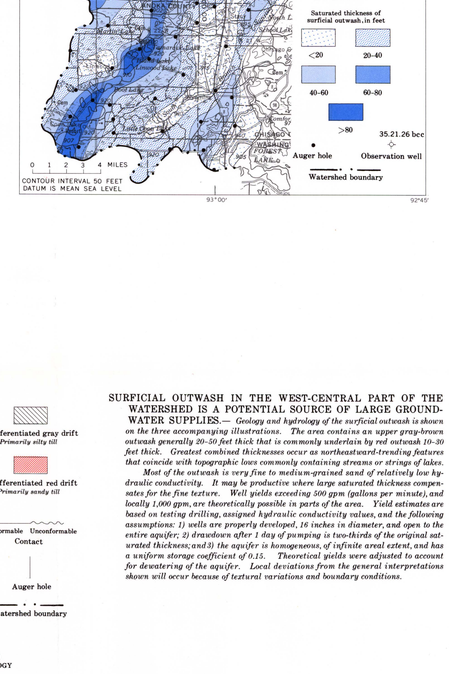
- Aquifer noneroded
- Aquifer partly eroded
- Aquifer absent
- Contact — *Dashed where inferred*
- 800 — Structure contour — *Shows altitude of noneroded top of aquifer. Contour interval 100 feet. Datum is mean sea level*
- 800 — Line of equal hydraulic potential — *Contour interval 100 feet. Datum is mean sea level*
- General direction of water movement in aquifer
- Well for which top of aquifer and hydraulic potential are known
- Well for which top of aquifer is known
- Well for which hydraulic potential is known
- Watershed boundary

THE MAJOR BEDROCK AQUIFERS DIP GENERALLY SOUTHWESTWARD.

Where the aquifer is noneroded, its maximum water-yielding capability can be realized. Where partly eroded, its capability is correspondingly less.

In the northern part of the watershed, water in bedrock generally moves in the direction of structural dip. In the southern part, the St. Croix River is entrenched to such a degree that it overshadows the effect of dip on ground-water movement. Potentiometric trends in this part of the watershed are therefore opposite the direction of dip.





SURFICIAL OUTWASH IN THE WEST-CENTRAL PART OF THE WATERSHED IS A POTENTIAL SOURCE OF LARGE GROUND-WATER SUPPLIES.—

Geology and hydrology of the surficial outwash is shown on the three accompanying illustrations. The area contains an upper gray-brown outwash generally 20–30 feet thick that is commonly underlain by red outwash 10–20 feet thick. Greatest combined thicknesses occur as northeastward-trending features that coincide with topographic lows commonly containing streams or strings of lakes.

Most of the outwash is very fine to medium-grained sand of relatively low hydraulic conductivity. It may be productive where large saturated thickness compensates for the fine texture. Well yields exceeding 500 gpm (gallons per minute), and locally 1,000 gpm, are theoretically possible in parts of the area. Yield estimates are based on testing drilling, assigned hydraulic conductivity values, and the following assumptions: 1) wells are properly developed, 16 inches in diameter, and open to the entire aquifer; 2) drawdown after 1 day of pumping is two-thirds of the original saturated thickness; and 3) the aquifer is homogeneous, of infinite areal extent, and has a uniform storage coefficient of 0.15. Theoretical yields were adjusted to account for dewatering of the aquifer. Local deviations from the general interpretations shown will occur because of textural variations and boundary conditions.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1974

WATER RESOURCES OF THE LOWER ST. CROIX RIVER WATERSHED, EAST-CENTRAL MINNESOTA

By

G. F. Lindholm, J. O. Helgesen, W. L. Broussard, and D. F. Farrell

1974