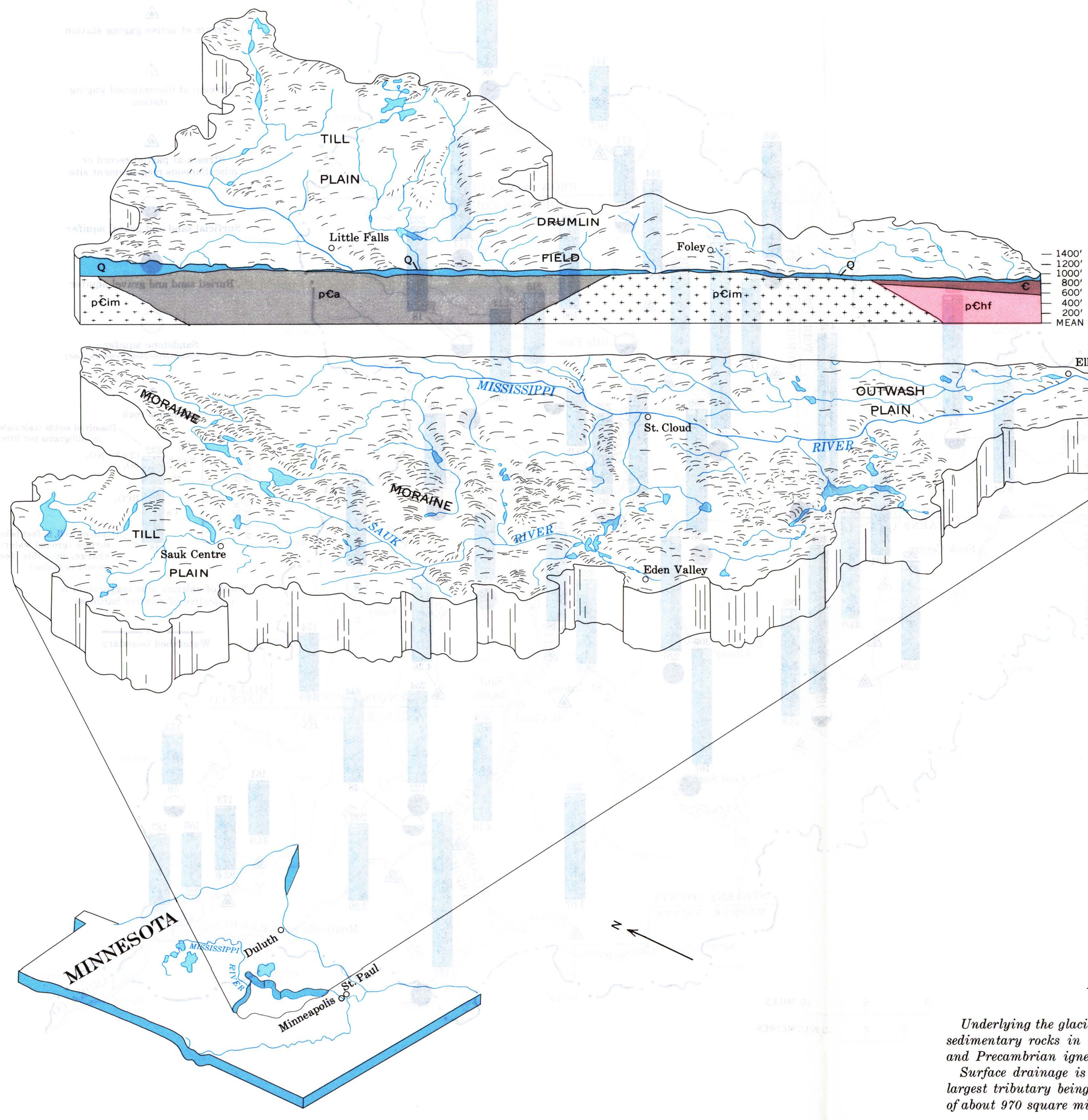
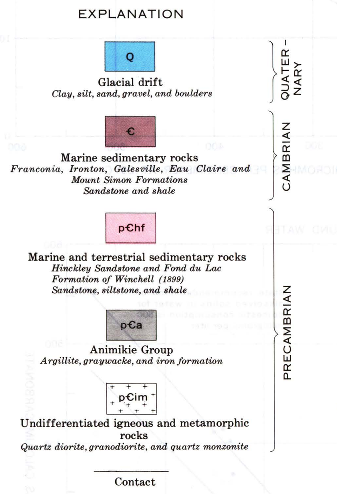
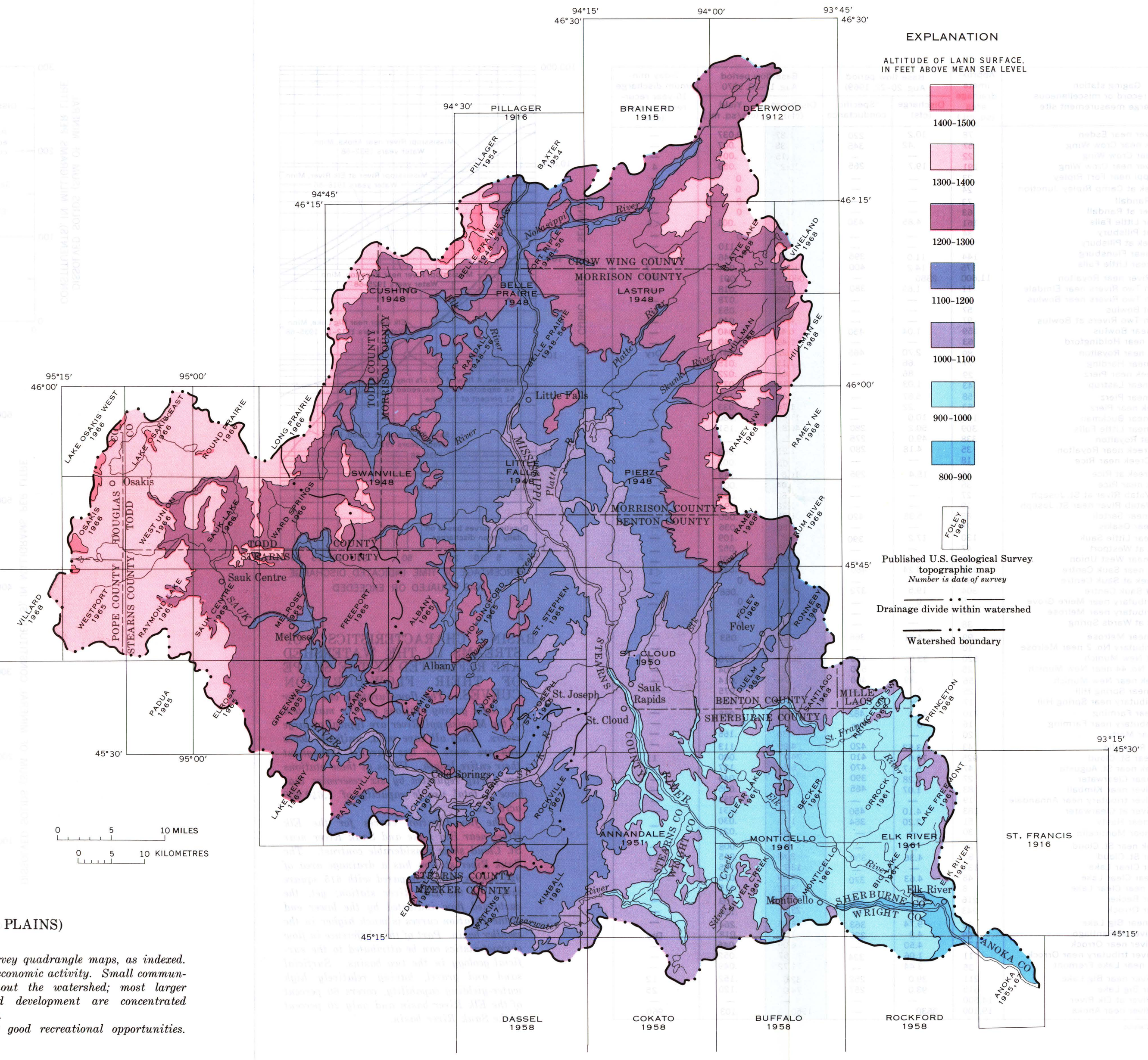
INTRODUCTION







A VARIETY OF GLACIAL LANDFORMS (MORAINES, TILL PLAINS, DRUMLIN FIELDS AND OUTWASH PLAINS) CHARACTERIZE THE 3,890-SQUARE-MILE MISSISSIPPI AND SAUK RIVERS WATERSHED

Underlying the glacial drift are Cambrian and Precambrian sedimentary rocks in the southeastern part of the watershed and Precambrian igneous and metamorphic rocks elsewhere. Surface drainage is entirely to the Mississippi River, the largest tributary being the Sauk River, which drains an area of about 970 square miles. The Mississippi follows a regional topographic low and transects the watershed from north to south. Greatest relief is in the morainal area in the west-central part of the watershed. The outwash plain in the southeastern part of the watershed and associated terrace deposits along the Mississippi River form a large area of relatively low relief. Details of topography are shown on 7½ and 15' U.S. Geological Survey quadrangle maps, as indexed.

Agriculture is the major economic activity. Small communities are scattered throughout the watershed; most larger municipalities and related development are concentrated along the Mississippi River.

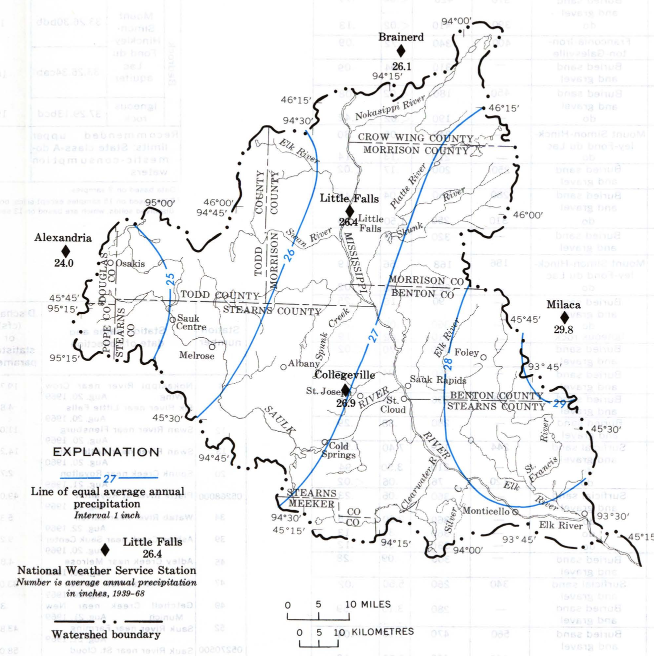
Lakes and streams offer good recreational opportunities.

WATER BUDGET

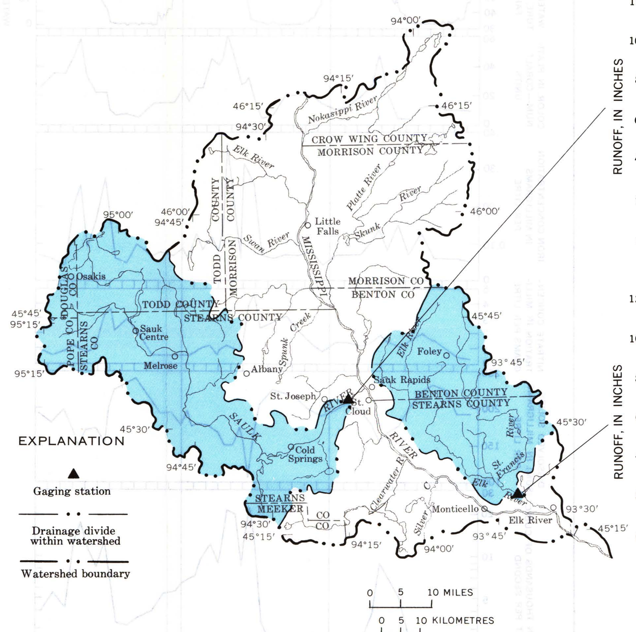
PRECIPITATION	=	RUNOFF	+	EVAPOTRANSPIRATION	±	CHANGE IN STORAGE AND UNDERFLOW
26.6 inches		4.4 inches		22.2 inches		0

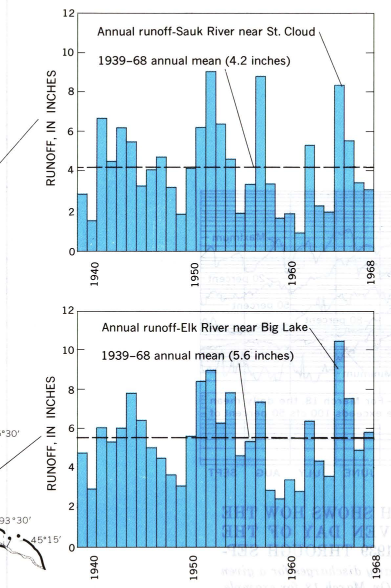
The average annual water budget for the watershed is approximated for 1939–68. It includes all inflow and outflow items, the totals of which balance over a long period of time. Contributing items in the budget equation are considered individually at right.

Although ground-water levels fluctuate both seasonally and annually, over a long period, water gains are cancelled by water losses. Change in storage is, therefore, assumed to be zero in the long-term budget. A small amount of underflow occurs through sedimentary bedrock in the southeastern part of the watershed. Calculated amounts are negligible, and underflow is, therefore, considered to be zero in the budget equation.

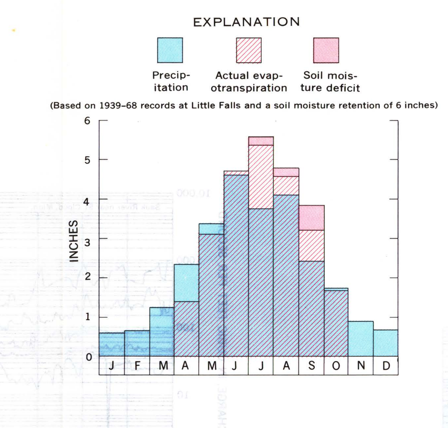


AVERAGE ANNUAL PRECIPITATION ON THE WATERSHED IS 26.6 INCHES, AS DETERMINED BY THE ISOHYETAL METHOD.—*Annual precipitation varies greatly with time; for example, the range at the Little Falls station is 17.5 to 36.5 inches over the 30-year period considered. Average monthly precipitation varies as shown on the bar graph to the right.*





AVERAGE ANNUAL RUNOFF FROM THE WATERSHED DURING 1939–68 WAS ABOUT 4.4 INCHES.—*This is an area-weighted average based on streamflow records for the Sauk River near St. Cloud and the Elk River near Big Lake. Data for the Sauk River is assumed to be representative of the entire watershed except the Elk River basin. Runoff variations between the two basins are principally due to differences in precipitation and geology.*



ANNUAL EVAPOTRANSPIRATION AVERAGES 22.2 INCHES, AS DETERMINED FROM THE WATER-BUDGET EQUATION.—*This compares favorably with the 23.8 inches of evapotranspiration, as determined by the Thornthwaite and Mather (1957) method (graph above). The relationship of evapotranspiration to precipitation shows that soil moisture is commonly inadequate for optimum plant growth during the summer. Like other items of the water budget, evapotranspiration may vary considerably from year to year.*

SUMMARY AND CONCLUSIONS

RELATIVE ADEQUACY OF WATER SOURCES

PURPOSE	CONSIDERATIONS	SURFACE WATER: Mississippi River	SURFACE WATER: Platte, Sauk, and Elk Rivers	SURFACE WATER: Other tributaries	SURFACE WATER: Lakes	GROUND WATER[1]: Surficial outwash	GROUND WATER[1]: Undifferentiated drift	GROUND WATER[1]: Ice contact-pitted outwash deposits	GROUND WATER[1]: Franconia, Ironton, and Galesville Formations	GROUND WATER[1]: Mount Simon, Hinckley, and Fond du Lac Formations	GROUND WATER[1]: Undifferentiated igneous and metamorphic and Animikie Group
Municipal or industrial supply	For a moderate supply principal needs are: Quantity Minimum available surface water supply of 1 cubic foot per second or wells yielding 250 gallons per minute Quality Dissolved solids content less than 500 milligrams per liter Hardness less than 180 milligrams per liter	Adequate flow ——— Manganese content may be high Disinfection and clarification necessary for municipal use Color removal may be necessary	Adequate for most uses Additional storage possible ——— Intermittant flow in headwaters Water is hard at low flow Disinfection and clarification necessary for municipal use Color removal may be necessary	Wide areal distribution ——— Supply generally inadequate on smaller tributaries No flow during parts of most years Water is hard in most streams at low flow Disinfection and clarification necessary for domestic use Color removal may be necessary	Larger lakes adequate for most uses Ground-water inflow helps maintain lake levels ——— Limited areal distribution Disinfection necessary for municipal use	May yield adequate quantity Rapid recharge from precipitation Generally good quality Relatively inexpensive to develop ——— Easily polluted Treatment for hardness and iron may be necessary Dewatering factor precludes obtaining adequate yield where aquifer is thin	Buried sand or gravel may yield adequate supply Wells may be open to more than one aquifer Generally good quality ——— Aquifer extent may be small Recharge may be slow Treatment for hardness and iron may be necessary May be costly to develop	May yield adequate quantity Generally good quality ——— May be easily polluted Dewatering factor may preclude obtaining adequate yield	Adequate quantity, most probably from Ironton and Galesville Formations Good quality ———	Adequate quantity, most probably from Mount Simon Sandstone Generally good quality High hydraulic potential aids withdrawal ——— Requires wells several hundred feet deep	Adequate quality ——— Supply inadequate
Rural domestic or stock supply	For an adequate farm supply needs are: Quantity Minimum of 5 gallons per minute Quality Dissolved-solids content less than 1,000 milligrams per liter	Adequate flow Suitable quality for stock ——— Available only to riparian lands Disinfection and clarification necessary for domestic use	Adequate flow Suitable quality for stock ——— Available only to riparian lands Disinfection and clarification necessary for domestic use	Suitable quality for stock ——— Smaller tributaries have no flow during parts of most years Available only to riparian lands Disinfection and clarification necessary for domestic use	Adequate supply Suitable quality for stock ——— Available only to riparian lands Disinfection necessary for domestic use	Generally adequate quantity and quality Relatively inexpensive to develop ——— Easily polluted Treatment for hardness and iron may be necessary for domestic use	Generally adequate quantity and quality ——— Treatment for hardness and iron may be necessary for domestic use	Commonly adequate quantity and quality ——— May be easily polluted	Adequate quantity and quality ——— Depth of well required may be economically prohibitive	Adequate quantity and quality High hydraulic potential aids withdrawal ——— Depth of well required may be economically prohibitive	Adequate quality ——— Supply may be inadequate
Irrigation supply	For an average farm needs are: Quantity Minimum available surface water supply of 2 cubic feet per second during growing season or wells yielding 250 gallons per minute Quality Suitability of water quality for irrigation as indicated by classification of Wilcox (1955)	Adequate flow Suitable quality ——— Restricted to riparian lands	Adequate supply in lower reaches Suitable quality ——— Restricted to riparian lands May require storage facilites	Suitable quality ——— Restricted to riparian lands Intermittent flow; supply generally inadequate	Larger lakes have adequate supply Suitable quality ——— Restricted to riparian lands	May yield adequate quantity Rapid recharge from precipitation Good quality Relatively inexpensive to develop ——— Dewatering factor precludes obtaining adequate yield where aquifer is thin	Buried sand or gravel may yield adequate supply Wells may be open to more than one aquifer Good quality ——— Aquifer extent may be small Recharge may be slow May be costly to develop	May yield adequate quantity Good quality ——— Dewatering factor may preclude obtaining adequate yield	Adequate quantity, most probably from Ironton and Galesville Formations Good quality ———	Adequate quantity, most probably from Mount Simon Sandstone Good quality High hydraulic potential aids withdrawal ——— Requires wells several hundred feet deep	Adequate quality ——— Supply inadequate
Fish and wildlife habitat	Adequate depth and quality of water for fish in lakes and streams Adequate cover needed for wildlife habitat is provided by: Wetlands—lakes or potholes surrounded by marsh areas Streams—marsh and woodland along banks	Adequate depth Adequate flow Suitable quality Excellent wildlife habitat along banks Excellent migratory water-fowl resting and feeding areas ——— Occasional flooding	Generally adequate depths in lower reaches Suitable quality Excellent wildlife habitat along banks Excellent migratory water-fowl resting and feeding areas ——— Occasional flooding Intermittent flow in headwaters	Excellent wildlife habitat along banks Wide areal distribution ——— Shallow Intermittent flow	Adequate depths in larger lakes Suitable quality Good wildlife habitat along shores of most lakes Good wetlands around smaller lakes ——— Considerable lakeshore development on larger lakes						
Recreation	Adequate access to lakes and streams Availability of areas suitable for hunting, fishing, and other water sports Available resorts, lake cottages and campgrounds Esthetic values and absence of pollution	Public access at many sites Suitable for hunting, fishing, and other water sports Excellent asthetic values Suitable quality ——— Occasional flooding	Public access at many sites Suitable for hunting and fishing Excellent esthetic values ——— Occasional flooding Intermittent flow in headwaters	Public access at many sites Many suitable for hunting and fishing Wide areal distribution ——— Intermittent flow Easily polluted	Public access at many sites Suitable for hunting, fishing, and other water sports Lakeshore resorts and residences Suitable quality Esthetic values generally good ——— Easily polluted						

[1] The Cretaceous rocks and Eau Claire Sandstone are relatively poor and underdeveloped sources of water and are not evaluated

EXPLANATION

Buried sand and gravel may yield adequate supply; Wells may be open to more than one aquifer; Good quality — Desirable features above line

Aquifer extent may be small; Recharge may be slow; May be costly to develop — Undesirable features below line

Good — Fair — Poor: Color indicates overall adequacy of water source as evaluated for specific purposes

CONCLUSIONS

1. Average annual inflow to the watershed, as precipitation, was 26.6 inches during 1939–68. Average annual outflow during the same period was 4.4 inches as runoff and 22.2 inches as evapotranspiration.
2. All municipalities except St. Cloud use ground water as a source of supply. St. Cloud, the largest city, obtains its water from the Mississippi River. Nearly all the 1,890 million gallons of ground water withdrawn by municipalities in 1968 was from glacial-drift aquifers.
3. Water usage for irrigation, primarily on sandy soils derived from surficial outwash, totaled 1,090 million gallons in 1968. Two-thirds of this amount was withdrawn from sandstones of the Mount Simon-Hinckley-Fond du Lac aquifer in the southeastern part of the watershed.
4. Thickness of glacial drift ranges from 0 to 300 feet over most of the watershed. Water-bearing zones in the drift vary widely in thickness and areal extent; well yields of several hundred gallons per minute or more are commonly obtainable.
5. Surficial outwash, covering about one-third of the watershed, is in some areas a potential source of large ground-water supplies. Where saturated thickness is sufficient, well yields in excess of 1,000 gpm (gallons per minute) are, theoretically, possible. Much of the greatest potential is in a narrow band of channel-fill deposits paralleling the Mississippi River.
6. In most of the watershed, drift is directly underlain by igneous and metamorphic rocks of low water-yielding capability. Large amounts of water are supplied by Cambrian and Precambrian sandstones (Mount Simon-Hinckley-Fond du Lac aquifer) in the southeastern part. Maximum possible well yields from this aquifer are estimated to be several thousand gallons per minute.
7. Ground-water movement in glacial drift is generally toward the Mississippi and Sauk Rivers. Water movement through the Mount Simon-Hinckley-Fond du Lac aquifer is generally southeastward and has a component toward the Mississippi River.
8. Basin yields determined from base-flow measurements made August 17–20, 1970, generally ranged from 0 to 0.15 cubic foot per second per square mile. Greatest yields were from basins having extensive deposits of surficial sand and gravel.
9. Flow characteristics of the Mississippi River are affected by regulation of six reservoirs upstream from the watershed. During periods of high flow, flood runoff is stored in the reservoirs for release later to augment base flows during prolonged dry spells and in the winter when there is little or no surface runoff.
10. The quality of Mississippi River water does not change significantly as it moves through the watershed. Dissolved-solids content, iron content, and color vary significantly with discharge.
11. Ground water and surface water are of the calcium magnesium bicarbonate type and chemically suitable for most purposes. Iron and manganese concentrations and hardness in ground water are troublesome in some areas.

ACKNOWLEDGMENTS

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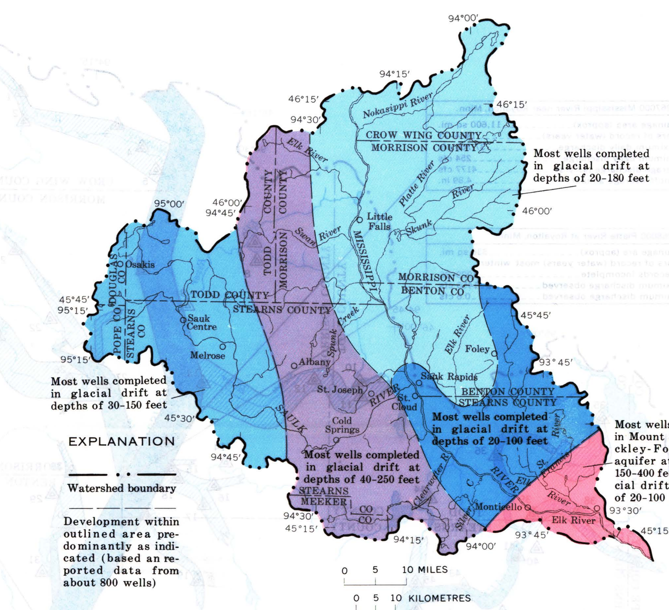
WATER USE

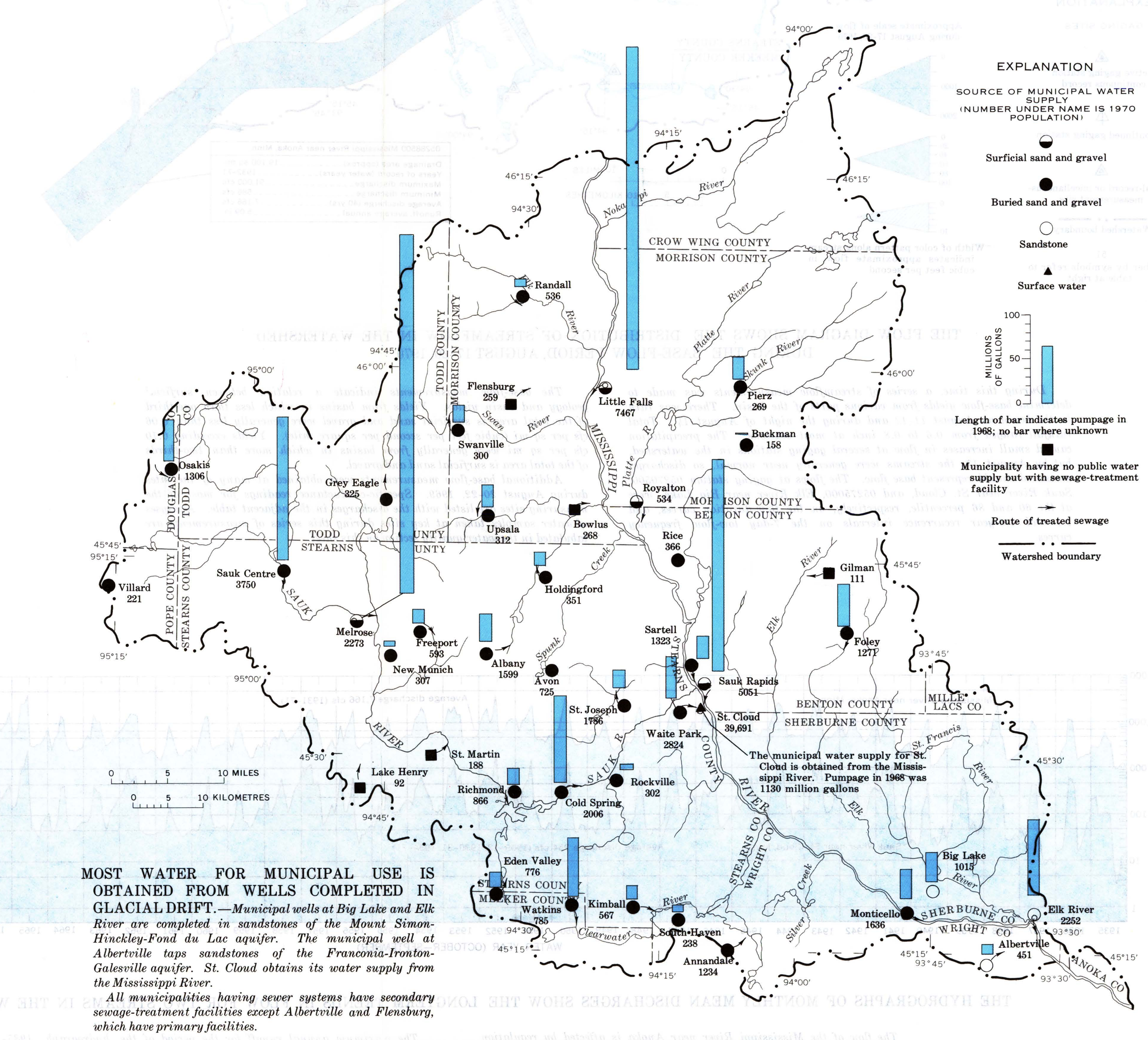
MORE THAN 27 BILLION GALLONS OF WATER IS USED ANNUALLY IN THE WATERSHED.—*Of this amount, two-thirds is Mississippi River water that is withdrawn and in large part returned after being used in the production of paper and electricity. The remainder is largely ground water, most of which is used by people and livestock. Figures shown are based on reported data, except as indicated, and are considered to be minimal.*

WATER USE IN 1968 (MILLIONS OF GALLONS)

TYPE OF USE	GROUND WATER	SURFACE WATER	SURFACE WATER (Used and returned)
Municipal	1890	1130	—
Industrial (private supply)	60	less than 1	18,300
Military and institutional	120	—	—
Irrigation	930	160	—
Rural domestic	2500 (estimated)	—	—
Livestock	2500 (estimated)		—
TOTAL	9290		18,300

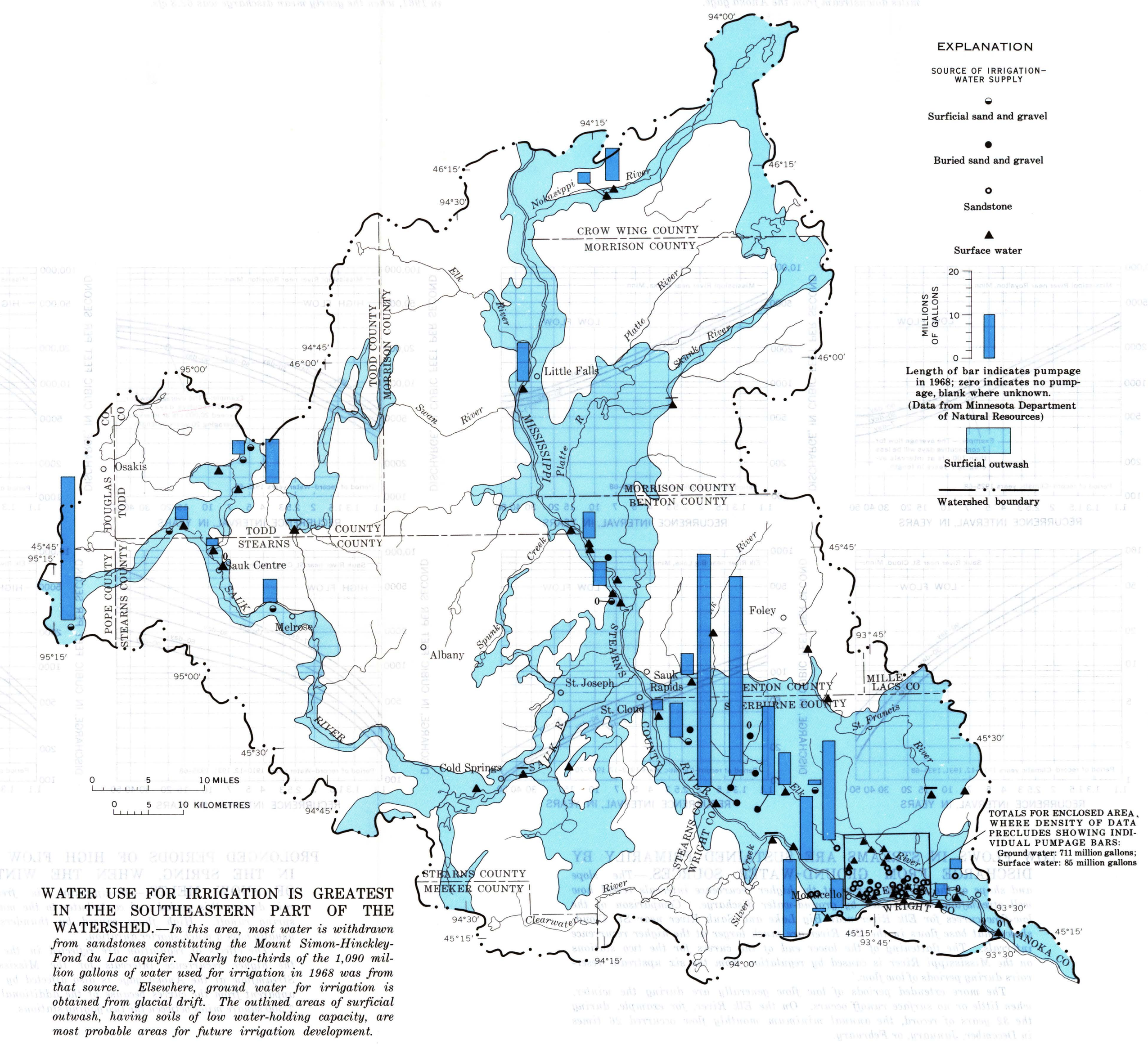


MOST WELLS ARE COMPLETED IN GLACIAL DRIFT AT DEPTHS OF LESS THAN 150 FEET.—*Deeper wells are common along a north-south band in the west-central part of the watershed that generally corresponds with an area of morainal highs. Though not indicated on the map, some water is obtained from igneous or metamorphic bedrock, where the drift is thin or unproductive. In the southeastern part, many wells, used chiefly for irrigation, are completed in sandstone bedrock.*



MOST WATER FOR MUNICIPAL USE IS OBTAINED FROM WELLS COMPLETED IN GLACIAL DRIFT.—*Municipal wells at Big Lake and Elk River are completed in sandstones of the Mount Simon-Hinckley-Fond du Lac aquifer. The municipal well at Albertville taps sandstones of the Franconia-Ironton-Galesville aquifer. St. Cloud obtains its water supply from the Mississippi River.*

All municipalities having sewer systems have secondary sewage-treatment facilities except Albertville and Flensburg, which have primary facilities.



WATER USE FOR IRRIGATION IS GREATEST IN THE SOUTHEASTERN PART OF THE WATERSHED.—*In this area, most water is withdrawn from sandstones constituting the Mount Simon-Hinckley-Fond du Lac aquifer. Nearly two-thirds of the 1,090 million gallons of water used for irrigation in 1968 was from that source. Elsewhere, ground water for irrigation is obtained from glacial drift. The outlined areas of surficial outwash, having soils of low water-holding capacity, are most probable areas for future irrigation development.*

WATER RESOURCES OF THE MISSISSIPPI AND SAUK RIVERS WATERSHED, CENTRAL MINNESOTA

By
J. O. Helgesen, D. W. Ericson, and G. F. Lindholm
1975