INTRODUCTION

PURPOSE AND SCOPE

This report describes the physical environment, availability, distribution, movement, quality, and use of water in the St. Croix River basin as an aid in future planning of water management. It is based on data from several Federal, State, and local agencies, supplemented by additional information collected in areas where data were scarce. Detailed studies of individual areas may be necessary in the future as the need for specific information increases.

ACKNOWLEDGMENTS

Many persons and organizations assisted the study by providing data. Among the contributors are University Extension—the University of Wisconsin Geological and Natural History Survey, the Wisconsin Department of Natural Resources, the Public Service Commission of Wisconsin, the Wisconsin Department of Transportation, the Minnesota Pollution Control Agency, and the Minneapolis - St. Paul Sanitary District. Municipal water officials furnished water-supply information and well records. Many individuals and companies allowed access to their wells for water-level measurements and collection of water samples for chemical analysis.

GEOGRAPHY

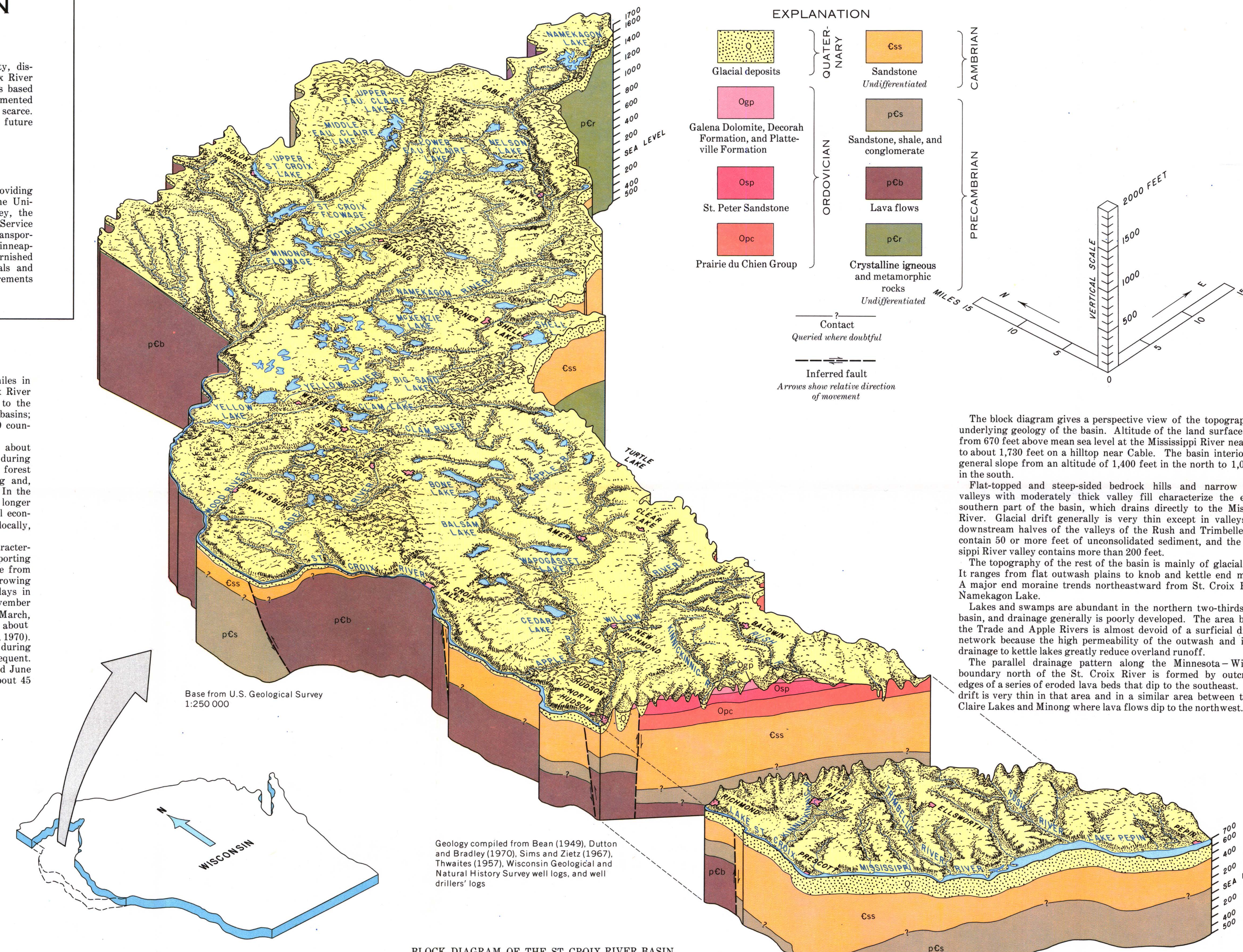
The region described comprises an area of 4,828 square miles in northwestern Wisconsin. It includes the part of the St. Croix River basin in Wisconsin, and 488 square miles of direct drainage to the Mississippi River between the St. Croix and Chippewa River basins; it comprises 8.6 percent of the State and consists of parts of 10 counties.

The population of the basin in both 1950 and 1960 was about 109,900, although the State population increased 15 percent during that period. Major land uses are agriculture, recreation, and forest management. In the north, forests provide wood harvesting and, along with lakes and streams, offer recreation opportunities. In the south, agriculture is dominant because the growing season is longer and soils are more suitable than in the north. The agricultural economy is increased by manufacturing of dairy products and, locally, by irrigation.

The basin has a temperate, continental climate that is characterized by marked seasonal changes (Wisconsin Statistical Reporting Service, 1967, p. 5). Average monthly air temperatures range from 10° to 15°F in January to 68° to 72°F in July. The average growing season is about 100 days in the north and greater than 120 days in the south. The ground is frozen generally from late November through early April. Maximum depth of frost occurs in early March, ranging from an average of 26 inches in the south to about 34 inches in the north (Wisconsin Statistical Reporting Service, 1970).

Average annual precipitation on the basin was 29.3 inches during 1931–60 (see Hydrologic Budget); periods of drought are infrequent. February is normally the driest month (less than 0.8 inch), and June is the wettest month (about 4.8 inches). Snowfall averages about 45 inches annually.

PHYSICAL SETTING



BLOCK DIAGRAM OF THE ST. CROIX RIVER BASIN

The block diagram gives a perspective view of the topography and underlying geology of the basin. Altitude of the land surface ranges from 670 feet above mean sea level at the Mississippi River near Pepin to about 1,730 feet on a hilltop near Cable. The basin interior has a general slope from an altitude of 1,400 feet in the north to 1,000 feet in the south.

Flat-topped and steep-sided bedrock hills and narrow stream valleys with moderately thick valley fill characterize the extreme southern part of the basin, which drains directly to the Mississippi River. Glacial drift generally is very thin except in valleys. The downstream halves of the valleys of the Rush and Trimbelle Rivers contain 50 or more feet of unconsolidated sediment, and the Mississippi River valley contains more than 200 feet.

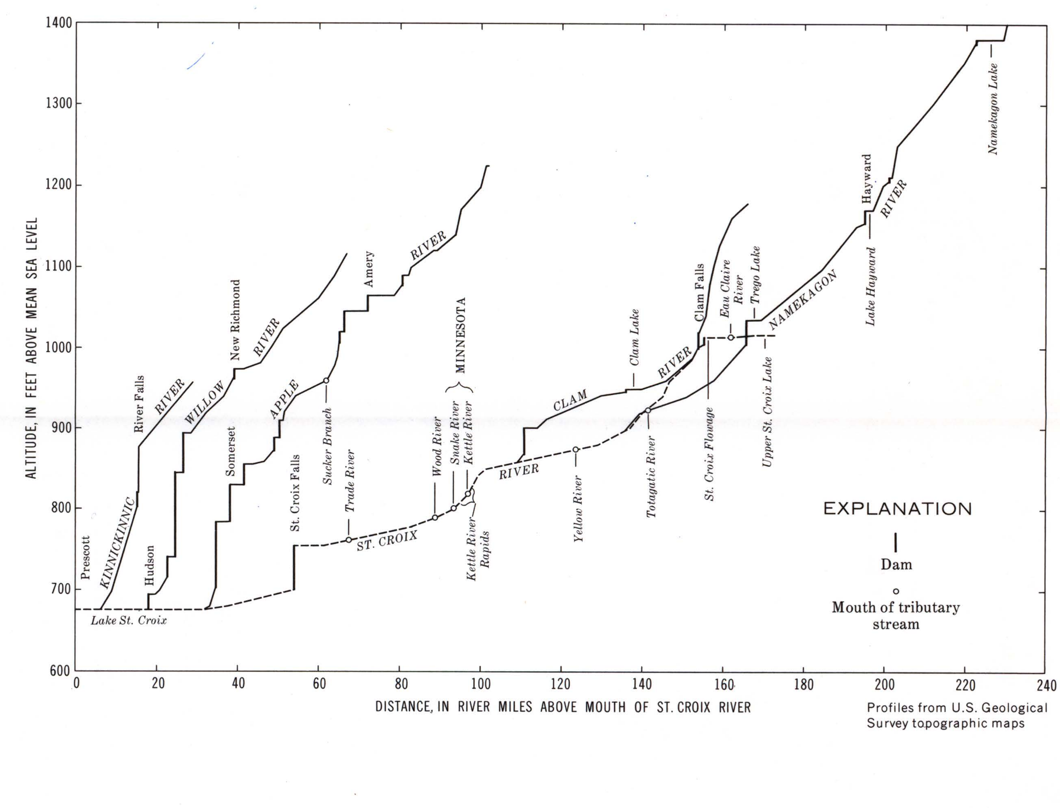
The topography of the rest of the basin is mainly of glacial origin. It ranges from flat outwash plains to knob and kettle end moraine. A major end moraine trends northeastward from St. Croix Falls to Namekagon Lake.

Lakes and swamps are abundant in the northern two-thirds of the basin, and drainage generally is poorly developed. The area between the Trade and Apple Rivers is almost devoid of a surficial drainage network because the high permeability of the outwash and internal drainage to kettle lakes greatly reduce overland runoff.

The parallel drainage pattern along the Minnesota–Wisconsin boundary north of the St. Croix River is formed by outcropping edges of a series of eroded lava beds that dip to the southeast. Glacial drift is very thin in that area and in a similar area between the Eau Claire Lakes and Minong where lava flows dip to the southwest.

DRAINAGE

The St. Croix River adjusted to large-scale changes in its drainage basin during the glacial period. Its preglacial course was to the west in Minnesota, while the present lower course contained the Apple River (Martin, 1932, p. 202). During the glacial period the St. Croix River was a main drainageway. In addition to melt water from ice in the basin, it carried overflow from large glacial lakes that occupied the Lake Superior basin. One outlet was the valley at Solon Springs, which is now occupied by Upper St. Croix Lake, the present head of the river. Another outlet to the St. Croix River was via the Kettle River in Minnesota. Lake St. Croix, which forms the lower 26 miles of the river, is caused by ponding behind a bar of Mississippi River sediment.



RIVER PROFILES

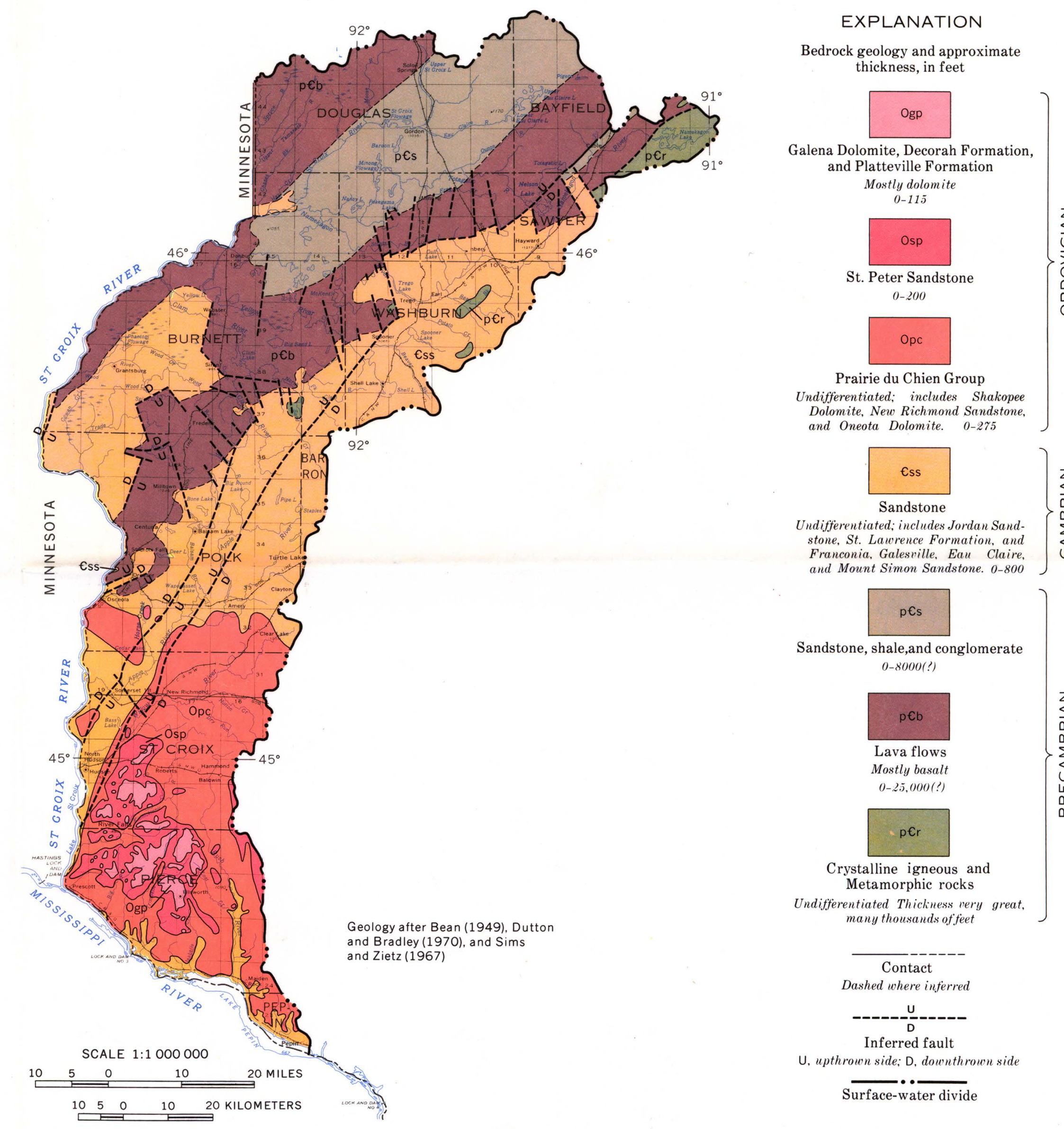
The gradient of the St. Croix River averages about 2 feet per mile but ranges from almost zero on Lake St. Croix to 8.5 feet per mile in the Kettle River Rapids. In the upper reach through St. Croix Flowage the gradient is also very flat. Below St. Croix Flowage to the mouth of the Namekagon the river flows on Precambrian sedimentary rocks and has a uniform gradient of about 6 feet per mile.

The Namekagon River, the major tributary of the St. Croix, extends almost 60 miles farther than does the St. Croix above their confluence. It has a rather uniform gradient of about 6 to 8 feet per mile except for an 11-mile reach of low gradient, about 1.0 foot per mile, near the mouth. This reach of the river is underlain by easily eroded Cambrian sandstones, whereas St. Croix Falls and Kettle River Rapids are formed by Precambrian lava flows, which are more resistant to erosion.

The Clam River has an average gradient of about 15 feet per mile in the end moraine area northeast of St. Croix Falls. Clam Falls is formed by resistant Precambrian lava flows. Below the falls the river flows on outwash and has a general gradient of about 2 feet per mile until it nears the St. Croix River.

The major southern tributaries of the St. Croix River, the Apple, Willow, and Kinnickinnic Rivers, are relatively steep and cross sandstone of Cambrian age and dolomite of the Prairie du Chien Group. Upper reaches of these streams have gradients of about 6 feet per mile. Steep gradients of 15 to 40 feet per mile near the mouths are the result of faster downcutting caused by the deepening of the St. Croix River channel.

GEOLOGY AND SOILS



BEDROCK GEOLOGY

Bedrock in the northern part of the basin consists mainly of basaltic lava flows, sandstone, shale, conglomerate, and igneous and metamorphic crystalline rocks, all of Precambrian age. These rocks also underlie the younger sedimentary rocks of Cambrian and Ordovician age, which form the bedrock surface in the southern part of the basin.

In the southern one-third of the basin the Cambrian sandstones are underlain by Precambrian sandstones. Their contact is difficult to distinguish (Berg and others, 1956, p. 4), and few wells have penetrated the older formations.

The greatest thickness of Cambrian and Ordovician rocks, about 1,200 feet, occurs in the southern tip of the basin where the youngest bedrock formations cap high ridges. Cambrian rocks probably were deposited over the entire basin; however, erosion has greatly reduced their extent and thickness. Wide outcrop patterns in the central part of the basin are a result of the gentle southwestern dip of the formations and the nearly parallel slope of the land surface.

WATER SYSTEM

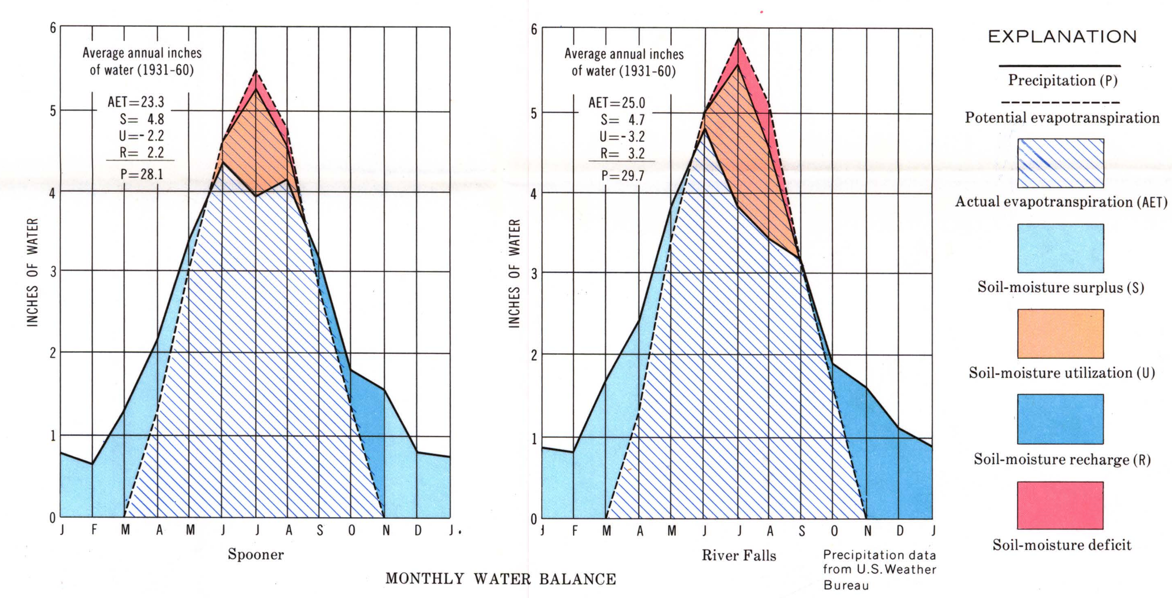
Precipitation, the source of all water in the basin, falls on the land surface, streams, and lakes and starts the cycle of circulation called the hydrologic cycle. Some water runs rapidly off the land surface to nearby streams and lakes (surface runoff); some water evaporates immediately from the surface soil and plants (evaporation); some water enters the soil but is used by plants (transpiration); and some water seeps down through the soil and eventually reaches the ground-water reservoir (recharge), which contributes base flow to streams and lakes (ground-water runoff).

The cycle is not complete within an area as small as a river basin; usually large parts of continents are involved. Within the St. Croix River basin most precipitation results from storms from the southwest and northwest, and moisture returned to the atmosphere leaves the basin on winds from the same direction (Wisconsin Statistical Reporting Service, 1967, p. 19).

HYDROLOGIC BUDGET

The hydrologic budget is a simplified equation of the basic components of the hydrologic cycle. Water input to the basin, primarily the precipitation on the basin, equals the algebraic sum of water output and change in storage. Water output includes surface runoff, ground-water underflow, evapotranspiration (sum of evaporation and transpiration), and consumptive use by man. Changes in storage occur in ground and surface water, as well as in soil moisture. The quantities of these budget items fluctuate from year to year, but major fluctuations occur only in precipitation, runoff, and evapotranspiration. Man's effect on these quantities is almost negligible in the St. Croix basin. A very small part of the ground and surface water withdrawn by man is consumed, and part of the water stored on the surface is evaporated.

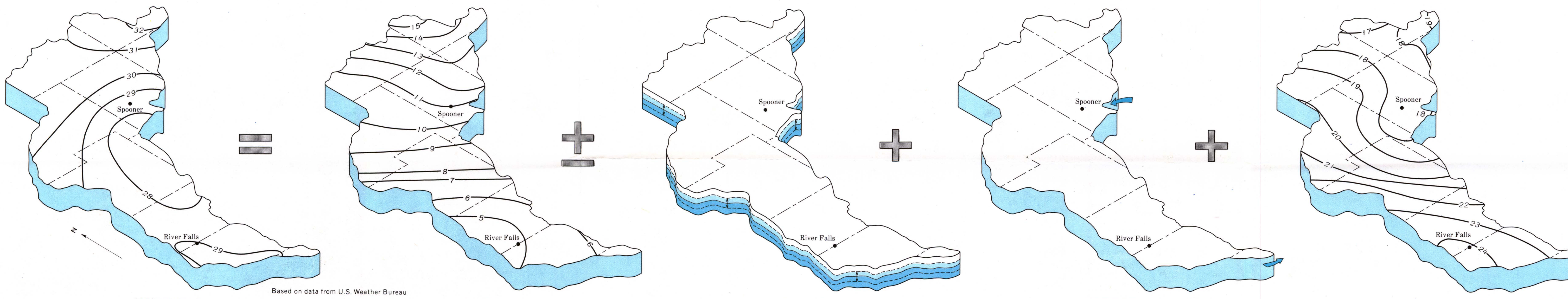
Average conditions for 1931-60 are illustrated on the budget diagrams. Average budget quantities are presented for that period, and extremes are given for a very dry year (1948) and for a very wet year (1938).



MONTHLY WATER BALANCE

The relation of soil moisture to evapotranspiration and precipitation varies throughout the year, as shown for two areas of the basin. Estimates of monthly "actual" and "potential" evapotranspiration, determined by an empirical method (Thornthwaite and Mather, 1957), illustrate the monthly water balance in the northern and southern parts of the basin at Spooner and at River Falls. Winter snow accumulation and spring rainfall maintain a soil-moisture surplus through spring. The monthly surplus decreases as evapotranspiration increases during the spring, until evapotranspiration exceeds precipitation in early summer and soil moisture is withdrawn from storage. A moisture deficit exists when soil moisture in storage is depleted and potential evapotranspiration exceeds actual evapotranspiration. In the fall, as air temperature declines and transpiration by vegetation ceases, precipitation recharges soil moisture until the winter phase of surplus moisture resumes.

Soil-moisture deficit and utilization from storage are less in the northern part of the basin because the air temperature is lower and the growing season is shorter than in the southern part.



PRECIPITATION
(INCHES)

Dry year (1948)	23.2
Average (1931-60)	29.3
Wet year (1938)	37.9

Average annual precipitation is greater than 32 inches in the northeast and less than 28 inches in the east-central part of the basin. Annual precipitation on the basin ranged from 6.1 inches below normal in 1948 to 8.6 inches above normal in 1938. About two-thirds of the annual precipitation falls during the growing season. Snowfall comprises about 15 percent of the annual precipitation.

RUNOFF
(INCHES)

7.1
9.0
10.4

An average of about 3,200 cfs (cubic feet per second), or 9 inches of water per year, runs off the basin. Average discharge of the St. Croix River at Prescott is about 5,400 cfs, of which about 3,000 cfs is from Wisconsin. The area of small streams that drain directly to the Mississippi River has an average runoff of about 200 cfs.

Average runoff increases from less than 5 inches per year in the southwest to more than 15 inches in the northeast. Runoff varied 1 to 2 inches from average in the extremely wet and extremely dry years. The map of average annual runoff is based on streamflow records of 25 U.S. Geological Survey gaging stations in and near the basin.

CHANGE IN STORAGE
(INCHES)

−1.4
0.0
+0.8

The long-term net change in ground- and surface-water storage in the basin is negligible. Annual gains and losses of water, as shown by lake-stage and ground-water hydrographs, are nearly equal over a long-term period. The amount of stored ground water is greater than the amount of stored surface water and soil moisture; therefore, net change in the water table indicates net change in basin storage.

A study of water-level records for the wet and dry years shows that the water table generally, but not everywhere, responded to extremes in precipitation. The resulting net annual rise or fall of the water table in these years is estimated to be about 0.45 foot and 0.78 foot, respectively. Assuming a storage coefficient of 0.15, these changes in water level equal about 0.8 and 1.4 inches of water, respectively.

UNDERFLOW
(INCHES)

0.0
0.0
0.0

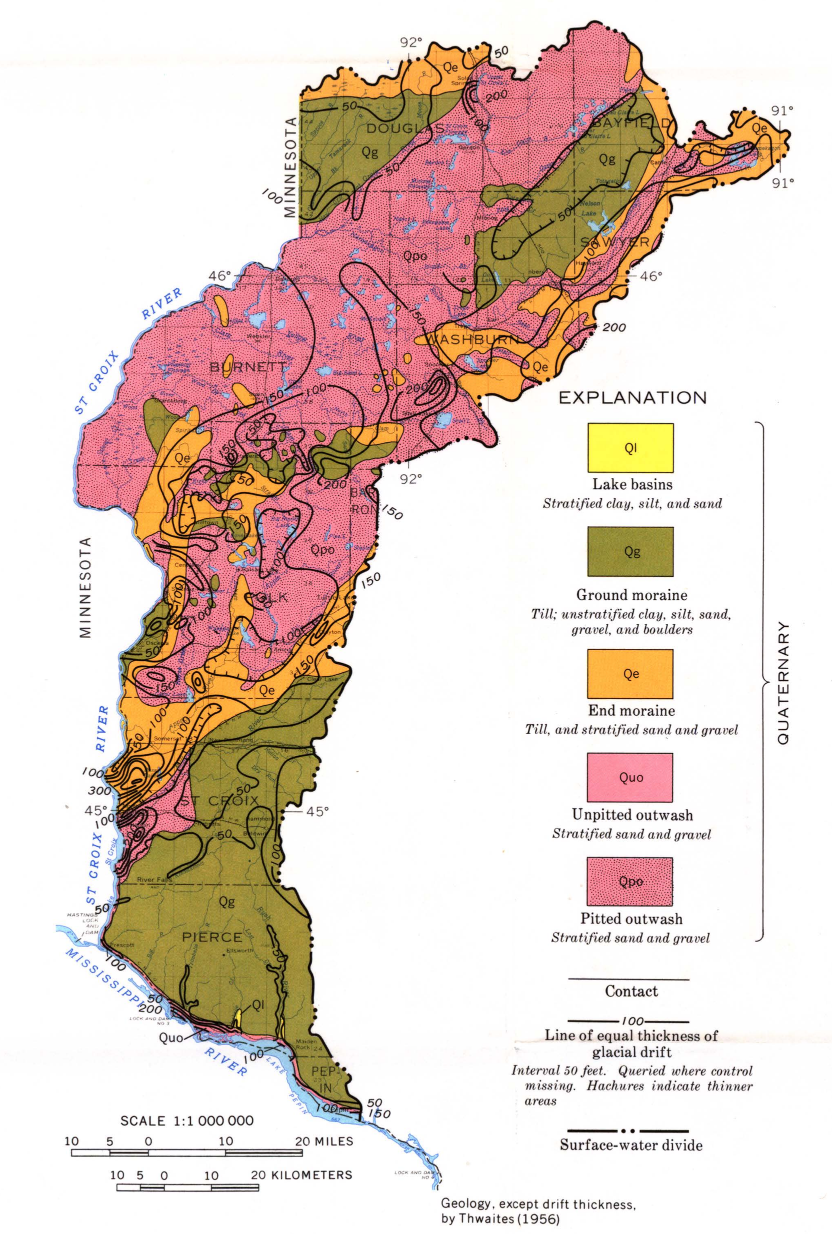
Subsurface underflow to or from the basin is very small. A net gain from underflow of about 0.04 inch per year takes place along the east edge of the basin where the ground-water divide lies outside the surface-water divide (see water-table map, sheet 2). Elsewhere along the basin boundary the ground-water divide is almost coincident with the surface-water divide, and small areas of ground-water inflow are balanced by areas of ground-water outflow. Underflow in the valley fill of the Mississippi River and the mouth of the St. Croix River is negligible due to the extremely flat hydraulic gradient in the pools behind Lock and Dam Nos. 3 and 4. Therefore, net underflow, as well as change in underflow during years of precipitation extremes, is negligible.

EVAPOTRANSPIRATION
(INCHES)

17.5
20.3
26.7

Evapotranspiration annually returns an average of 20.3 inches of water to the atmosphere by evaporation and plant transpiration. It is computed here as the difference between precipitation and the sum of runoff, changes in storage, and underflow. Evaporation from open-water surfaces in the basin accounts for about 1 inch. Man's consumptive use of water is less than 0.5 percent of evapotranspiration.

Evapotranspiration is greatest in the south and west, where air temperatures are highest, and least in the northeast, where air temperatures are lowest. In the very dry year evapotranspiration was 2.8 inches below average, but in the very wet year it was 6.4 inches above average.

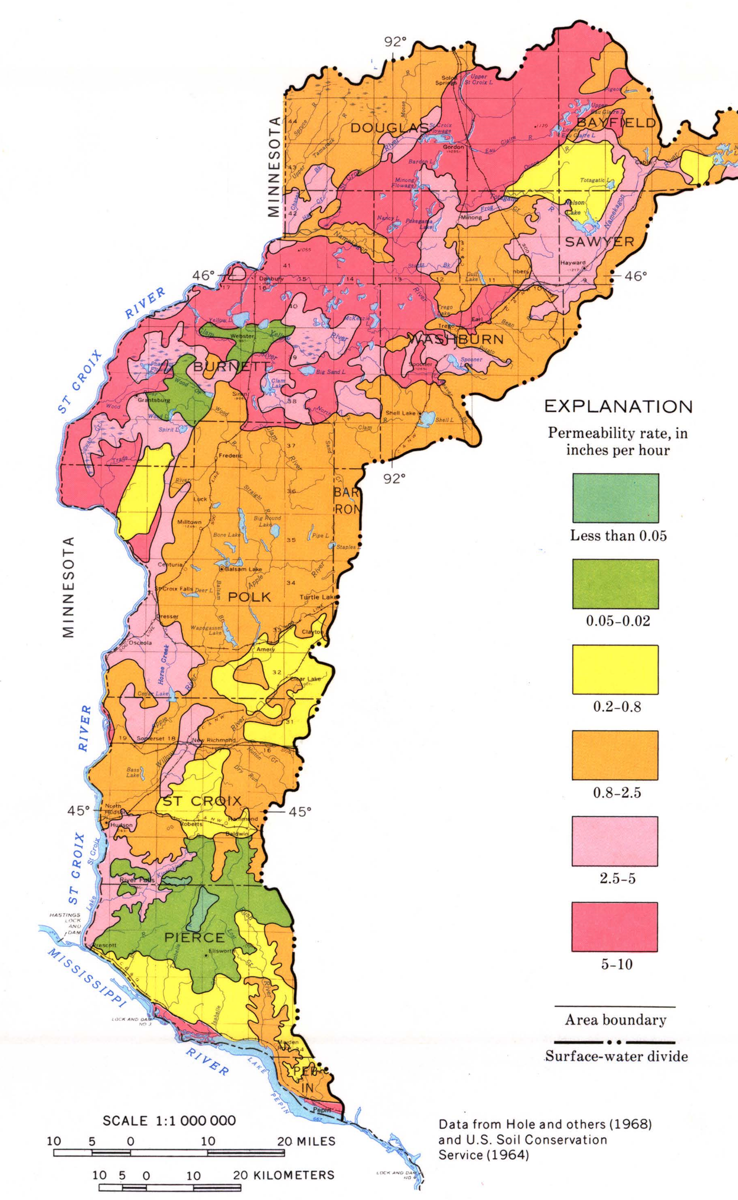


GLACIAL GEOLOGY

Glacial drift forms an almost continuous mantle as much as 350 feet thick over the bedrock. It is thickest in areas of end moraine and outwash and in preglacial bedrock valleys. Drift is thin to absent over lava flows in some northern and central areas and over sandstone and dolomite in the southern part of the basin.

Drift in the basin is composed of ground moraine, end moraine, outwash, and lake deposits. Ground moraine, laid down by advancing glaciers, overlies most of the southern one-fourth of the basin and part of the northern one-fourth. It is the least permeable type of drift, especially where it is clayey and silty. End moraines form broad belts across the center of the basin and along the northern and northeastern basin divide. Permeable outwash, which was deposited by melt-water streams from stagnating glaciers, occurs in most of the northern two-thirds of the basin and in the valleys of the Mississippi and St. Croix Rivers. Lake deposits fill the mouths of two valleys tributary to the Mississippi River.

A thin blanket of windblown silt or loess covers the basin. Silt thickness increases from 0.5 foot in the north to about 8 feet near the Mississippi River (Hole, 1950), but the thickness is 0.5 to 2 feet over most of the basin. The loess is the parent material for topsoil in most soil profiles.



SOIL PERMEABILITY

Soil permeability is an important factor in the rate of infiltration of precipitation into the soil, and hence in ground-water recharge. The soil permeability map shows areas of estimated permeability rates of the least permeable horizon. The areas are generalized, and each area includes several soil types and soil associations. These rates are indicative of the recharge potential to the ground-water reservoir. Soil-moisture content, vegetative cover, land slope, depth to the water table, and frequency and duration of precipitation are additional factors that affect infiltration. Soils with high permeability, greater than 2.5 inches per hour, cover 40 percent of the basin. These soils, loamy sands, sands, sandy loams, or alluvium, are formed largely on pitted outwash. Soils with permeability rates of 0.8 to 2.5 inches per hour cover 44 percent of the basin and consist of silt loams and sandy loams. The silty loams, mainly in St. Croix and Pierce Counties, are developed on thin ground moraine over Ordovician rocks. Sandy loams with these permeability rates generally are on end moraines and outwash. Soils with permeability rates of 0.2 to 0.8 inch per hour cover 8 percent of the basin and are mainly silt loams on ground moraine. The remaining 8 percent of the basin has silt loams with low permeability, less than 0.2 inch per hour, which are largely on ground moraine.

Base from U.S. Geological Survey, 1968

WATER RESOURCES OF WISCONSIN—ST. CROIX RIVER BASIN

By
H. L. Young and S. M. Hindall

1973

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973

For sale by U.S. Geological Survey, price $1.75 per set